KENSINGTON BUSINESS SCHOOL
International Journal of Social Sciences and Management
(KBSIJSSM)
Home: kbsijssm.org/journal/ijssm | **E-ISSN: 2456-7890**

BACTERIOLOGICAL CONTAMINATION OF HAWKED SUYA MEATS IN UGBOKPO, APA LOCAL GOVERNMENT AREA OF BENUE STATE, NIGERIA: PREVALENCE, PATHOGENS, AND ANTIBIOTIC RESISTANCE PROFILES

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Abstract

Suya is a widely consumed street-grilled meat in Nigeria whose informal production chain creates multiple opportunities for bacteriological contamination. Despite growing documentation of microbial hazards associated with suya in other Nigerian cities, no systematic bacteriological assessment has been conducted for Ugbokpo, Apa Local Government Area of Benue State. Objective: This study evaluated the bacteriological contamination, pathogen prevalence, and antibiotic resistance profiles of bacteria isolated from hawked suya meats in Ugbokpo. Methods: Sixty suya samples were collected from six vendors across three locations in Ugbokpo over three months. Standard cultural and biochemical methods were used for enumeration and identification of bacteria. Antibiotic susceptibility testing was performed by the Kirby-Bauer disk diffusion method according to CLSI (2021) guidelines. Results: Total Aerobic Plate Counts (TAPC) ranged from 4.2×10^4 to 9.8×10^6 CFU/g, exceeding the ICMSF (2011) recommended threshold of 10^4 CFU/g. Pathogens isolated included Staphylococcus aureus (85%), Escherichia coli (72%), Salmonella species (58%), Klebsiella pneumoniae (48%), Bacillus cereus (43%), and Pseudomonas aeruginosa (38%). Multiple drug resistance (MDR) was detected in 64% of S. aureus, 71% of E. coli, and 68% of Salmonella isolates. Conclusion: Suya vended in Ugbokpo harbours dangerous levels of pathogenic and multidrug-resistant bacteria, constituting a significant public health hazard. Urgent regulatory and educational interventions are warranted.

Keywords: *bacteriological contamination, suya, street food, antibiotic resistance, Ugbokpo, Benue State, Nigeria, food safety*

Introduction

Street food vending constitutes an important component of Nigeria's informal food economy, providing affordable, accessible, and culturally acceptable meals to people across urban, semi-urban, and rural communities. Street foods also contribute to employment, household income, and the livelihoods of small-scale food vendors. However, the safety of these foods depends on the quality of raw materials, preparation methods, cooking temperatures, personal hygiene, storage conditions, and handling practices. Where adequate food-safety measures are lacking, ready-to-eat foods may become vehicles for transmitting foodborne bacterial infections. Suya is a popular Nigerian ready-to-eat meat product traditionally prepared from beef, although mutton, goat meat, and chicken may also be used. Its preparation involves cutting meat into thin slices, coating the slices with a mixture of spices commonly called yaji, and roasting them over charcoal. The seasoning typically contains ground pepper, ginger, salt, and groundnut-based ingredients, although recipes vary among vendors. Suya is widely associated with Hausa culinary traditions and has become popular among different ethnic groups throughout Nigeria. Its distinctive flavour, relatively affordable price, convenience, and availability during evening trading hours contribute to its widespread consumption. Despite the high temperatures generated during grilling, suya may become bacteriologically contaminated before, during, or after preparation. Potential sources include contaminated raw meat, inadequately cleaned knives, cutting boards, serving trays, water, spice mixtures, vendors' hands, and the surrounding environment. Furthermore, prolonged exposure to dust, flies, uncovered display surfaces, and repeated handling can introduce microorganisms into the finished product. When suya is stored at unsuitable temperatures, some bacteria may survive or multiply, depending on the organism, moisture content, and duration of storage.

Bacteriological contamination refers to the presence of bacteria in food, including organisms capable of causing disease and organisms that indicate inadequate hygiene. Important bacteria to investigate in suya include Staphylococcus aureus, Escherichia coli, Salmonella species, Bacillus cereus, and other relevant foodborne organisms. Their detection does not necessarily mean that every contaminated sample will cause illness, because the risk depends on the species, strain, bacterial concentration, amount consumed, and susceptibility of the consumer. Nevertheless, the presence of particular pathogens in ready-to-eat meat represents a public-health concern. Antibiotic resistance further complicates foodborne disease control. Resistant bacteria associated with food may potentially reach humans through contaminated food, direct contact, or environmental pathways. The detection of antibiotic-resistant isolates in suya would therefore be relevant to food safety, clinical treatment, and antimicrobial stewardship. However, resistance must be established through laboratory susceptibility testing rather than inferred from the presence of bacteria alone. Ugbokpo, the administrative headquarters of Apa Local Government Area in Benue State, provides an important setting for investigating the bacteriological quality of

hawked suya. Local evidence is needed to establish which bacteria occur in the product, how frequently contamination is detected, and whether the recovered isolates exhibit resistance to selected antibiotics. National or international findings cannot automatically establish the contamination status of suya sold in Ugbokpo because vending practices, environmental conditions, meat sources, and handling procedures may differ between locations. Suya is a ready-to-eat meat product whose microbiological safety depends on proper preparation, adequate grilling, hygienic handling, and appropriate storage. Although grilling reduces many vegetative bacteria when sufficient temperatures are achieved throughout the meat, contamination may occur through spices, utensils, hands, serving surfaces, packaging materials, and exposure to the surrounding environment. Consequently, the bacteriological quality of finished suya cannot be established from its appearance, smell, or taste alone. Bacteriological contamination can be assessed through the isolation and identification of microorganisms, enumeration of viable bacterial populations, and detection of specific pathogens. Bacterial counts provide information about the overall microbial burden, while pathogen identification helps establish the potential presence of organisms associated with foodborne illness. Antibiotic susceptibility testing provides additional information about whether recovered bacterial isolates are susceptible or resistant to selected antimicrobial agents. Datok, Ishaleku, Tsaku, Agya, and Adoga (2021), researchers affiliated with Nasarawa State University, Keffi, investigated multidrug resistance in Escherichia coli isolated from suya sold in Karu Local Government Area, Nasarawa State, Nigeria. Their findings demonstrated that contaminated suya could carry bacteria resistant to several antibiotics. This study is particularly relevant because it establishes that antibiotic resistance associated with suya is not merely a theoretical concern but a problem investigated within the Nigerian food environment. The public-health implications extend beyond individual food vendors. Consumers who ingest contaminated meat may develop gastrointestinal illness, while resistant organisms may complicate treatment when infections occur. However, the detection of antibiotic-resistant bacteria in food does not by itself prove that a consumer has acquired an infection from that food. Establishing transmission requires additional epidemiological or molecular evidence.

The independent variables comprise food preparation and handling practices, the hygiene of vendors, the cleanliness of utensils, the microbiological quality of spices, environmental exposure, packaging materials, and storage conditions. These factors may influence the likelihood and extent of bacterial contamination. For instance, inadequate handwashing and the use of contaminated knives may introduce bacteria into cooked meat, while prolonged storage at unsuitable temperatures may allow some organisms to multiply. The dependent variables are the prevalence of bacteriological contamination, the identity and distribution of bacterial pathogens, bacterial counts, and antibiotic susceptibility patterns. Prevalence may be expressed as the proportion of sampled suya portions from which the target organism is detected. Bacterial counts may be reported as colony-forming units per

gram (CFU/g), while antibiotic resistance may be expressed as the proportion of tested isolates classified as resistant to particular antibiotics. Datok et al. (2021), in a study conducted in Karu Local Government Area, Nasarawa State, Nigeria, collected 300 suya samples to investigate the occurrence of E. coli and its antibiotic resistance profile. The researchers reported an overall E. coli occurrence of 13.3%. They also found that 97.5% of the isolates were classified as multidrug-resistant. In their published report, the authors highlighted the "potential danger of multidrug resistant organisms in circulation." This finding demonstrates the importance of including antibiotic susceptibility testing in studies of ready-to-eat meat. However, the resistance levels observed in Karu should not be assumed to represent those in Ugbokpo, because the bacterial populations, sampling methods, and local vending conditions may differ. Eruteya and Nmehielle (2021), in research conducted in Rivers State, Nigeria, assessed the safety of suya condiments sold in Choba, Rumuepirikom, and Aluu. Their study identified Staphylococcus species, Salmonella species, Bacillus species, Shigella species, Enterobacter species, and Streptococcus species in the sampled condiments. This finding is important because spices are often added to grilled meat after cooking, potentially introducing microorganisms into the final product. The study indicates that contamination investigations should consider the seasoning mixture as well as the meat itself. Nevertheless, findings from suya condiments cannot be treated as direct estimates of pathogen prevalence in finished suya portions.

Omotoso, Adebesin, and Olubode (2023), researchers affiliated with Nigerian universities, published a review of bacterial and fungal contamination in suya. Their review reported frequent identification of Staphylococcus species, E. coli, Bacillus species, Salmonella, and Klebsiella across the studies examined. They also identified unhygienic processing, bare-hand contact, environmental exposure, and unsuitable packaging as relevant concerns. Because this was a review of existing studies, its percentages represent the literature reviewed rather than a single survey of suya in one Nigerian community. The review supports the need to investigate contamination pathways and improve hygiene throughout preparation, display, and sale. Bassey, Mbah, and Agbiji (2024), in a study of ready-to-eat suya sold in Calabar, Cross River State, Nigeria, investigated bacterial contamination and antimicrobial susceptibility. They reported six bacterial genera, including Bacillus, Staphylococcus, Klebsiella, E. coli, Enterobacter, and Proteus. Their findings also showed differences in susceptibility to the antibiotics tested, with some agents demonstrating greater activity against the recovered isolates than others. This evidence reinforces the need to determine resistance profiles locally instead of assuming that all bacteria recovered from suya share the same susceptibility pattern. Researchers in Katsina State also investigated hawked suya in a study published in 2024. The study, Isolation and Identification of Bacteria from Hawked Suya Meat Sold within Katsina Metropolis, examined 25 samples obtained from five vendors. The investigators identified Salmonella, Bacillus, Staphylococcus,

and E. coli. They reported that E. coli was the most frequently occurring isolate, while Salmonella and Staphylococcus were the least frequent among the organisms reported. Resistance to several tested antibiotics was also observed. Although the sample was relatively small, the study provides geographically relevant evidence that hawked suya can harbour organisms of public-health importance. Osunde, Isoah, Obasuyi, Akpoghelie, and Oshoma (2024) examined ready-to-eat suya sold in Adolor and Oluku, Benin City, Edo State. Their findings included E. coli, Listeria monocytogenes, Bacillus cereus, Clostridium species, and Staphylococcus aureus, among other organisms. The researchers also reported concerns about bacterial counts, antibiotic resistance, and packaging materials. This study is relevant to the present research because it illustrates how both the handling environment and the materials used to wrap finished meat may influence microbiological quality. A 2024 study of suya sold in the Federal Capital Territory, Abuja, specifically examined Salmonella prevalence and antimicrobial susceptibility. The researchers analysed 200 suya samples collected between August and November 2022 and reported Salmonella in 3.5% of the samples. Their results indicated resistance to several antibiotics tested, including ampicillin and gentamicin. These findings demonstrate the importance of testing for specific pathogens even where they occur less frequently than other bacterial groups. The results also suggest that prevalence and resistance estimates can differ substantially according to the organism under investigation and the geographical setting. Adoh and Olisaka (2025), in a study of street-vended suya meat in Benin City, Nigeria, examined 50 samples and reported E. coli in 46% of samples, Staphylococcus aureus in 38%, and Pseudomonas species in 30%. They also reported resistance among isolates to selected antibiotics. The authors concluded that the findings highlighted the public-health risks associated with contaminated street-vended suya. Their work provides recent Nigerian evidence supporting the simultaneous investigation of bacterial occurrence and antimicrobial susceptibility. Ekli et al. (2025), in a study conducted in Minna, Niger State, investigated 384 samples comprising suya meat, spices, knives, and vendors' hands. They reported an overall Salmonella enterica prevalence of 13%, with the highest prevalence, 26%, occurring in suya meat. The isolates showed 65% resistance to amoxicillin, while multidrug resistance was reported in 43.1% of isolates. The authors recommended training suya vendors in hygienic handling practices. By sampling both food and contact surfaces, the study demonstrated the value of investigating possible contamination pathways rather than examining meat in isolation. .

The study is anchored on the Germ Theory of Disease and the One Health approach. These perspectives provide a scientific explanation of how microorganisms can contaminate food, cause illness, and contribute to wider public-health concerns, including antimicrobial resistance. The Germ Theory of Disease, historically associated with the work of Louis Pasteur and Robert Koch during the nineteenth century, explains that specific microorganisms can cause particular diseases. Pasteur's experiments during the 1860s helped establish the role of microorganisms in

fermentation and contamination, while Koch's investigations, particularly his work on anthrax in 1876 and subsequent research, contributed to establishing the relationship between specific microorganisms and infectious diseases. Although these foundational contributions predate the 2021–2026 literature period, the theory remains relevant to contemporary food microbiology. Applied to hawked suya in Ugbokpo, the theory explains that foodborne bacteria may enter the product through contaminated raw meat, spices, utensils, water, vendors' hands, or environmental exposure. Organisms such as Salmonella species, pathogenic E. coli, and Staphylococcus aureus can pose health risks when present under conditions that permit infection or toxin production. Adequate cooking, hygienic handling, safe packaging, and appropriate storage are therefore essential preventive measures. Laboratory isolation and identification provide evidence for determining whether specific bacteria are present in the sampled suya. The second perspective is the One Health approach, which recognises the interconnectedness of human, animal, and environmental health. This approach is particularly appropriate for investigating antibiotic resistance in food products because resistant bacteria may circulate among livestock, humans, food-processing environments, and other ecological settings. In suya production, the potential chain of transmission includes the animals from which meat is obtained, slaughter and processing facilities, spices, food handlers, vending equipment, and the environment in which the product is sold. Datok et al. (2021) demonstrated the relevance of antimicrobial resistance surveillance by reporting multidrug-resistant E. coli among isolates obtained from suya in Nasarawa State. Similarly, Ekli et al. (2025) investigated Salmonella enterica in suya and associated contact surfaces in Minna, highlighting the importance of examining food, handling practices, and environmental sources together. These Nigerian studies support applying a One Health perspective to understanding bacterial contamination and resistance in ready-to-eat meat. The two perspectives complement each other. Germ Theory explains the relationship between pathogenic microorganisms and disease, while One Health provides a broader framework for examining the movement of bacteria and resistance across interconnected human, animal, food, and environmental systems. Together, they support investigating bacterial prevalence, identifying pathogens, determining antibiotic susceptibility profiles, and examining the hygiene conditions associated with hawked suya in Ugbokpo.

MATERIALS AND METHODS

Study Area and Sample Collection

The study was conducted in Ugbokpo, Apa Local Government Area, Benue State, Nigeria (approximately 80 km south of Makurdi). Sixty suya samples (~100 g each) were collected from six vendors at three locations the main market, the motor park, and the central road axis (2 vendors per site) weekly for three months (10 samples per vendor; 20 per location). Samples were obtained between 18:00 and 21:00 hours (peak vending hours) in sterile polythene bags, transported in ice-packed coolers, and analysed within 24 hours of collection.



Fig. 2.1: Map of Nigeria showing Benue State

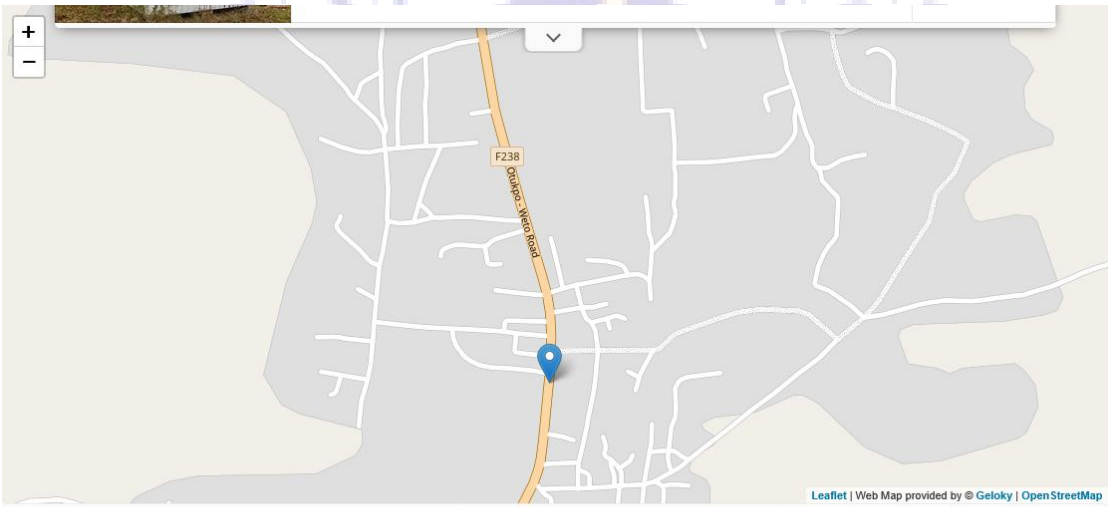


Fig. 2.2: GPRS Coordinates of Ugbokpo, Benue State.

Bacteriological Analysis

Ten grams of each sample were homogenised in 90 mL sterile normal saline (0.85% NaCl). Serial 10-fold dilutions (10^{-1} to 10^{-6}) were prepared and appropriate dilutions pour-plated on Nutrient Agar (NA), MacConkey Agar (MCA), Mannitol Salt Agar (MSA), Salmonella-Shigella Agar (SSA), and Cetrimide Agar. Plates were incubated aerobically at 37°C for 24–48 hours. Total Aerobic Plate Count (TAPC) and Total Coliform Count (TCC) were determined per gram (CFU/g). Bacterial isolates were identified by Gram staining and standard biochemical tests including catalase, coagulase, oxidase, indole, methyl red, Voges-Proskauer, citrate, urease, and triple sugar iron (TSI) reactions, following Cheesbrough (2006) and Holt et al. (2000).

Antibiotic Susceptibility Testing

Antibiotic susceptibility was determined by the Kirby-Bauer disk diffusion method on Mueller-Hinton Agar following CLSI (2021) guidelines. Bacterial suspensions were adjusted to 0.5 McFarland turbidity standard. Ten antibiotic discs (Oxoid, UK) were tested: ampicillin (10 µg), amoxicillin/clavulanate (30 µg), ciprofloxacin (5 µg), erythromycin (15 µg), gentamicin (10 µg), tetracycline (30 µg), chloramphenicol (30 µg), trimethoprim/sulfamethoxazole (25 µg), ceftriaxone (30 µg), and oxacillin (1 µg). Isolates resistant to three or more antibiotic classes were classified as multidrug-resistant (MDR).

Statistical Analysis

Data were analysed using IBM SPSS Statistics version 26.0. One-way ANOVA was used to compare mean microbial counts across vendor locations, with Tukey's HSD post-hoc test for multiple comparisons. Significance was set at $p < 0.05$.

RESULTS

Microbial Counts

The TAPC of suya samples ranged from 4.2×10^4 to 9.8×10^6 CFU/g (mean: 3.6×10^6 CFU/g), exceeding the ICMSF (2011) safety limit of 10^4 CFU/g in the majority of samples. Significantly higher counts ($p < 0.001$) were observed in motor park samples compared to other locations (Table 1). TCC ranged from 1.0×10^2 to 6.4×10^5 CFU/g (mean: 2.3×10^5 CFU/g).

Table 1. Mean microbial counts (CFU/g) of suya samples from different locations in Ugbokpo

Location	TAPC (CFU/g)	TCC (CFU/g)	F-value	p-value
Main Market	$5.4 \times 10^6 \pm 1.2 \times 10^6$	$3.1 \times 10^5 \pm 0.8 \times 10^5$		
Motor Park	$9.8 \times 10^6 \pm 2.1 \times 10^6$	$6.4 \times 10^5 \pm 1.3 \times 10^5$	12.46	<0.001
Central Road	$4.2 \times 10^4 \pm 0.9 \times 10^4$	$1.0 \times 10^2 \pm 0.3 \times 10^2$		
Overall Mean	$3.6 \times 10^6 \pm 1.5 \times 10^6$	$2.3 \times 10^5 \pm 0.9 \times 10^5$		

Values are mean ± SD of triplicate determinations

Bacterial Isolates

A total of 216 bacterial isolates were recovered. Staphylococcus aureus was the most prevalent, isolated from 85% of samples, followed by Escherichia coli (72%), Salmonella spp. (58%), Klebsiella pneumoniae (48%), Bacillus cereus (43%), and Pseudomonas aeruginosa (38%) (Table 2). All motor park samples yielded at least three species simultaneously.

Table 2. Frequency and percentage of bacterial species isolated from suya samples (n = 60)

Bacterial Species	Gram Reaction	No. Positive Samples	Prevalence (%)
Staphylococcus aureus	+ve cocci	51	85.0
Escherichia coli	-ve rods	43	71.7
Salmonella species	-ve rods	35	58.3
Klebsiella pneumoniae	-ve rods	29	48.3
Bacillus cereus	+ve rods	26	43.3
Pseudomonas aeruginosa	-ve rods	23	38.3

Antibiotic Susceptibility

Resistance to ampicillin was highest across all species tested (Table 3). Multidrug resistance (MDR) was detected in 64% of S. aureus, 71% of E. coli, and 68% of Salmonella isolates. Ciprofloxacin and gentamicin retained the highest activity across isolates. All Salmonella isolates were intermediate or resistant to trimethoprim/sulfamethoxazole.

Table 3. Antibiotic resistance (%) of key bacterial isolates from suya samples

Antibiotic	S. aureus %R	E. coli %R	Salmonella spp. %R	K. pneumoniae %R
Ampicillin (10 µg)	82	91	86	88
Ciprofloxacin (5 µg)	12	19	14	21
Erythromycin (15 µg)	76	68	55	62
Gentamicin (10 µg)	16	22	18	24
Tetracycline (30 µg)	67	79	72	75
Chloramphenicol (30 µg)	34	41	38	44
Ceftriaxone (30 µg)	23	23	27	31
Trimethoprim/SXT (25 µg)	59	67	71	74

%R = percentage resistant; SXT = Sulfamethoxazole

DISCUSSION

The TAPC values recorded in this study (mean 3.6×10^6 CFU/g) indicate that suya vended in Ugbokpo is heavily contaminated with bacteria, surpassing the microbiological safety limit of 10^4 CFU/g for ready-to-eat meat products stipulated by ICMSF (2011). These findings align with reports from other Nigerian cities: Filli et al. (2013) recorded TAPC of up to 1.2×10^7 CFU/g in Maiduguri suya, Ihejirika et al. (2015) reported $3.4–8.7 \times 10^6$ CFU/g in Owerri, and Igwegbe et al. (2020) documented similar counts in Anambra State. The significantly higher counts at the motor park reflect the well-documented relationship between high-traffic, dusty environments and elevated microbial contamination of exposed food products (Aliyu et al., 2021). The predominance of Staphylococcus aureus (85%) among bacterial isolates is consistent with national and international literature on street meat contamination. S. aureus is the foremost food poisoning organism associated with street foods in Nigeria (Bello et al., 2021; Okonko et al., 2013). Its presence in suya at this prevalence confirms that direct hand contact during post-grilling serving observed in all vendors surveyed is the principal contamination route, as S. aureus is a normal commensal of human skin and mucous membranes (Hennekinne et al., 2012). Of particular concern is the high proportion of S. aureus isolates resistant to erythromycin (76%) and ampicillin (82%) and classified as MDR (64%). The production of heat-stable staphylococcal enterotoxins, which resist inactivation during cooking, means that contaminated suya can cause food poisoning even when reheated before consumption.

The isolation of E. coli from 72% of suya samples confirms fecal contamination, an unambiguous indicator of inadequate sanitary practices. This level of E. coli contamination exceeds that reported by Okonko et al. (2013) at 65% and Abubakar et al. (2019) at 68% in their respective study areas. Given that pathogenic serotypes such as enterohemorrhagic E. coli O157:H7 can cause severe haemolytic uremic syndrome and death, the public health implications of this finding are serious (Kaper et al., 2004). The high ampicillin resistance (91%) among E. coli isolates, combined with MDR prevalence of 71%, may reflect the widespread unregulated use of antibiotics in livestock production in Benue State, consistent with global trends in food animal antimicrobial resistance (WHO, 2022). The recovery of Salmonella species from 58% of suya samples is alarming, as Salmonella is a notifiable foodborne pathogen responsible for millions of cases of gastroenteritis globally each year (WHO, 2022). Salmonella contamination in suya likely reflects poor slaughter hygiene, inadequate evisceration practices, or recontamination by food handlers. The high resistance to trimethoprim/sulfamethoxazole (71%) and ampicillin (86%) among Salmonella isolates is clinically significant, as these drugs are first-line agents used for salmonellosis management in Nigerian hospitals. Similarly, Bacillus cereus (43%) poses a spoilage and toxicological risk due to its heat-resistant endospores and diarrheal toxin production (Bottone, 2010), while Pseudomonas aeruginosa (38%) signals environmental contamination and raises concerns about intrinsic antibiotic resistance and biofilm formation on

serving surfaces (Abubakar et al., 2019). The overall MDR profile documented in this study contributes to the growing body of evidence that street food environments serve as reservoirs and dissemination points for antibiotic-resistant bacteria in the community. This has implications not only for foodborne illness treatment but also for the broader antimicrobial resistance crisis in Nigeria and globally (WHO, 2022). A comprehensive response is needed, including enforcement of food safety regulations, vendor training, routine surveillance of food-associated bacterial resistance, and responsible antibiotic use in food animal production.

CONCLUSION

This study provides the first documented evidence of significant bacteriological contamination of hawked suya meats in Ugbokpo, Apa LGA, Benue State. The high prevalence of pathogenic species particularly S. aureus, E. coli, and Salmonella alongside elevated levels of multidrug resistance, constitutes a major public health risk to suya consumers in this community. The bacteriological quality of suya in Ugbokpo falls far below acceptable international food safety standards. Regulatory authorities, food safety agencies, and local government bodies are urged to prioritise vendor training, enforce food hygiene standards, and institute routine microbiological monitoring of street-vended meats in Ugbokpo and comparable communities in Benue State.

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