Food Safety and Risk

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Prevalence of Antibiotic-Resistant *Salmonella enterica* Isolates from Ready-to-Eat Meat (Suya) and its Contact Surfaces in Minna Metropolis, Nigeria

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Abstract

This study evaluated microbial contamination, antibiotic resistance of *Salmonella enterica* and hygienic practices associated with ready-to-eat (RTE) meat (suya) in Minna Metropolis, Niger State, Nigeria. Three hundred and eighty-four (384) samples (suya meat, spices, knives, and vendor hands) were analyzed for microbial contamination and the presence of *Salmonella enterica* according to Bacteriological Analytical Manual of the U.S. Food and Drug Administration. Antibiotic resistance for *Salmonella* isolates was determined using the disk diffusion method. Vendor hygiene practices were assessed via questionnaires. The results revealed that microbial load ranged from 8.5×10^7 to 2.35×10^8 cfu/g or cfu/cm^2 across all study locations, with the lowest from knives sampled at Tunga and highest from hand samples in Maikunkele. The overall prevalence of *Salmonella enterica* was 13%, with the lowest in spices and hand samples (9% each) and highest in suya meat (26%). The *Salmonella enterica* were highly resistant to amoxicillin (65%) and susceptible to trimethoprim-sulfamethoxazole (95%). Multidrug resistance was 43.1%. Resistant to amoxicillin was the commonest and was exhibited by 9 *Salmonella enterica* isolate. There was limited formal education (56.0%) and occupational training (51.3%) among suya vendors with poor adherence to hygienic practices. Training of suya vendors on hygienic handling of RTE meats is recommended.

Keywords Antibiotic resistance, Hygiene practices, Microbial load, RTE suya meat, *Salmonella enterica* and vendors

Introduction

Salmonella enterica is particularly known for causing severe gastrointestinal diseases in humans Centers for Disease Control and Prevention (CDC, 2022). According to Ngogo et al. (2020) and WHO (2023), the risk of *Salmonella* infection is keen in environments where food preparation and handling practices are informal, and where there is frequent reliance on untreated water sources, such as wells or rivers.

Vendors across different African countries often prepare and sell RTE meats under informal conditions, which raise concerns about their hygiene and safety standards. For instance, Abdullahi et al. (2020) noted the

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lack of comprehensive studies on food safety and handling practices in Nigerian food service establishments. Shiningeni et al. (2019) reported that RTE meats sold in Windhoek, Namibia, were contaminated with various pathogenic bacteria (*Salmonella*, *Shigella*, *Listeria monocytogenes*, *Staphylococcus aureus*, and *Escherichia coli*) at levels that were deemed unsatisfactory for human consumption. Aduah et al. (2021) found *Salmonella enterica* in some RTE meats sold in Bolgatanga Municipality, Ghana. Abey et al. (2024) reported the isolation of *Salmonella* strains from a variety of sources, including the slaughterhouse environment, slaughtered animals, critical control points throughout the processing line, slaughter equipment, and even on slaughterhouse workers. The authors further indicated some of these isolates exhibiting resistance to multiple antimicrobials commonly used in treatment.

In Nigeria, *Salmonella* species has significant public health implications due to its association with foodborne diseases and typhoid fever. Between 1999 and 2018, *Salmonella* bloodstream infections and gastroenteritis in Nigeria had prevalence rates of 1.9% and 16.3%, respectively, based on culture-confirmed data and over 60% of *Salmonella* isolates exhibited multidrug resistance (Akinyemi et al. 2021).

In 2020, *Salmonella* infections in Nigeria was reported to be 325,731 cases and 1,043 human deaths, amounting to a total of 37,321 disability-adjusted life years (Sanni et al. 2023).

Foodborne illnesses, particularly those caused by bacterial agents like *Salmonella enterica*, continue to be a significant public health issue, especially in countries with low and middle incomes. Improper handling of foods has been responsible for the outbreak of foodborne infections. Therefore, the knowledge, observance of hygiene and practice of food safety among food handlers are critical for foodborne diseases outbreaks and infections. Although various studies throughout Nigeria have documented the presence of microbial contamination in ready-to-eat (RTE) foods, there is a scarcity of research that specifically examines the occurrence of *Salmonella enterica* in RTE meat products such as suya, as well as the hygiene practices of suya vendors in Niger State. This research aims to fill this gap by investigating both the prevalence and antibiotic resistance patterns of *Salmonella enterica* in suya, and by assessing the food safety knowledge and handling practices of suya vendors in the Minna Metropolis.

Materials and Methods

Study location and design

The study was conducted in Minna Metropolis, Niger State, the largest state in Nigeria. Minna Metropolis consist of two major local government areas. The first is Chanchaga Local Government Area, from which Tunga and Maitumbi were selected for the study. The second is Bosso Local Government Area, from which Bosso, Maikunkele, and Tunga Goro were selected for the study. These five areas from the different Local Government were randomly selected based on the previous study conducted by (Mohammed et al. 2017). Minna is geographically located between longitudes 6° 34'E and 6° 42'E of the Greenwich Meridian and latitudes 9° 33'N and 9° 45'N of the equator (Bissala et al. 2021). Descriptive cross-sectional design was used in this study.

Sample size and collection of samples for microbial analysis

A total of 384 samples were selected for the study, with this figure determined by referencing earlier research from Nigeria that reported *Salmonella enterica* prevalence between 5 and 30% (Adio et al. 2014). The minimum required sample size was calculated using Cochran's formula:

$$n = \frac{Z^2 * p(1-p)}{e^2}$$

Where:

Z = 1.96 (95% confidence level); $p = 0.5$ (assumed half of the population will be *Salmonella* positive); e = 0.05 (margin of error).

$$n = \frac{(1.96)^2 * 0.5(1-0.5)}{(0.05)^2} = 384$$

Ninety-six (96) samples each of street vended RTE meats (suya), spices (yaji), swabs from vendors hand and cutting or slicing knives were obtained from five-selected locations in Minna Metropolis which made up total samples to be 384. Samples were collected aseptically, properly labelled, placed in an ice-box with ice blocks and transported immediately to the laboratory of Africa Centre of Excellence for Mycotoxin and Food Safety, Federal University of Technology Minna, Gidan Kwano Campus Nigeria for microbial analysis.

Determination of Microbial Load

Microbial load was determined according to the Bacteriological Analytical Manual (BAM) of the USA-FDA with slight modifications (Maturin and Peeler 2001; Adzitey et al. 2020a, b). One (1) grams of suya and yaji and each swabbed were thoroughly agitated in 9 ml Buffered Peptone Water (BPW) (Oxoid, Basingstoke, UK). One (1) ml of each diluent was used for serial dilutions from 10^1 to 10^5 in BPW. Hundred microliter (100 µl) of

each diluent was evenly spread on duplicate nutrient agar plates (Oxoid, Basingstoke, UK) using bent glass rod. The plates were incubated aerobically at 37 °C for 24 h. Total microbial load was expressed in cfu/g or cfu/cm^2 using the formula: $N = \Sigma C/[(1*n1) + (0.1* n2)]* (d)$; Where: N= Number of colonies per cm^2, $\sum C$ = Sum of all colonies on all plates counted, n1 = Number of plates in first dilution counted, n2 = Number of plates in second dilution counted and d = Dilution from which the first counts were obtained.

Determination of *Salmonella enterica*

The isolation of *Salmonella* species was done using the method of Andrews et al. (2023) with some modifications. The samples (suya, yaji, knife swab, and hand swab) were pre-enriched in 9 ml of Buffered Peptone Water (Oxoid, Basingstoke, UK) and incubated at 37 °C for 24 h. After which 1 ml was transferred to 10 ml sterilized Rappaport–Vassiliadis (RV) broth (Oxoid, Basingstoke, UK) and Selenite Cystine (SC) broths (Oxoid, Basingstoke, UK). Samples in RV broths were incubated at 41.5 °C for 24 h while samples in SC broths were incubated at 37 °C for 24 h for enrichment. The enriched aliquots (≈10 µl loopful) were streaked on Xylose Lysine Desoxycholate (XLD) agar (Oxoid, Basingstoke, UK) and Salmonella-Shigella agar (Oxoid, Basingstoke, UK), and incubated at 37 °C for 24 h. After 24 h, the plates were observed for colonies morphology and presumptive *Salmonella* colonies were picked, purified and confirmed. Presumptive *Salmonella* colonies were confirmed using Grain stain, growth in triple sugar iron agar, lysine iron agar and *Salmonella* latex agglutination test kit (Adzitey et al. 2020a, b). All incubations were done under aerobic conditions.

Antibiotic Resistance Test of *Salmonella enterica*

This was done using the Kirby Bauer disc diffusion method. The *Salmonella enterica* isolates were subjected to the following nine antibiotics; 25 µg Amoxicillin (AML), 15 µg Azithromycin (AZM), 30 µg Cefotaxime (CTX), 30 µg Cefuroxime (CXM), 5 µg Ciprofloxacin (CIP), 30 µg Chloramphenicol (C), 10 µg Gentamicin (CN), 30 µg Tetracycline (TE), and 25 µg Trimethoprim-sulfamethoxazole (SXT). All the antibiotic discs used were purchased from Oxoid, Basingstoke, UK. Pure overnight grown cultures of *Salmonella* isolates were suspended in 10 ml nutrient broth (Oxoid, Basingstoke, UK), incubated aerobically at 37 °C for 16 h and the concentration adjusted to 0.5 McFarland solution. The surface of Mueller–Hinton agar (Oxoid, Basingstoke, UK) plate was evenly inoculated with the adjusted culture using a sterile glass spreader. Five and four antibiotic discs were placed on the surface of the inoculated Mueller–Hinton agar (Oxoid, Basingstoke, UK) plates some distance from each other to avoid overlap of the inhibition zone. After 24 h incubation at 37 °C, the inhibition zones were measured in triplicates for each antibiotic disc and the average results interpreted as sensitive, intermediate, or resistant according to Clinical and Laboratory Standards Institute Guidelines (CLSI, 2023). The multiple antibiotic resistance index (MAR) was calculated as number of antibiotics to which each isolate was resistant (X) divided by the total number of antibiotics the isolate was tested against (Y). MAR index = X/Y (Krumperman, 1983).

Survey Question Design, Pre-Test and Application

A well-structured questionnaire was developed based on previously published studies (Odonkor and Odonkor 2020; Boakye et al. 2023) with some adjustments to align with this study's objectives. The questionnaire was divided into three main sections. The first section was on the socio-demographic details of suya vendors. The second section assessed vendors'knowledge in relation to meat safety and the third section was an observational checklist which recorded vendors'actual meat safety practices. Pre-test of the survey questions was carried out and adjustment made before actual administration of the questionnaire. Feedback from the pre-test was used to improve the clarity, relevance, and suitability of the survey for the intended audience. Supplementary 1 shows the questionnaire used to collect data from the suya vendors while Supplementary 2 shows the informed consent form signed by the vendors. After the pre-test, the final questions were administered to 150 suya vendors using snowball sampling. The vendors were promised confidentiality with regards to their responses.

Statistical analysis

Data from survey was analyzed using IBM SPSS software 2012, version 21, and relationships between variables such as knowledge, practices, education, experience, and medical screening were investigated using correlation analysis at 5% significant level.

Results

Total Microbial Load of RTE Meat (Suya) and its Contact Surfaces in Minna

Table 1 shows the total microbial load of suya and its contact surfaces from the various locations (Maikunkele, Tunga-Goro Chanchaga, Bosso, Maitumbi, and Tunga) in Minna. The total microbial load was relatively high and ranged from 8.5×10^7 to 2.35×10^8 cfu/g or cfu/cm^2. The lowest total microbial load was obtained from knife samples collected from Tunga, while the highest total microbial load was obtained from hand samples of suya vendors in Maikunkele.

Table 1 Total microbial load of RTE meat (suya) and its contact surfaces in Minna

Samples	Microbial load (cfu/g or cm^2)	*(Center for Food Safety, 2014)
Maikunkele		
Suya	2.05×10^8	Unsatisfactory
Spice	1.91×10^8	Unsatisfactory
Knife	1.55×10^8	Unsatisfactory
Hand	2.35×10^8	Unsatisfactory
Tunga-Goro Chanchaga		
Suya	1.68×10^8	Unsatisfactory
Spice	1.43×10^8	Unsatisfactory
Knife	1.67×10^8	Unsatisfactory
Hand	1.18×10^8	Unsatisfactory
Bosso		
Suya	1.10×10^8	Unsatisfactory
Spice	1.14×10^8	Unsatisfactory
Knife	1.22×10^8	Unsatisfactory
Hand	1.54×10^8	Unsatisfactory
Maitumbi		
Suya	1.22×10^8	Unsatisfactory
Spice	1.68×10^8	Unsatisfactory
Knife	1.19×10^8	Unsatisfactory
Hand	9.5×10^7	Unsatisfactory
Tunga		
Suya	1.12×10^8	Unsatisfactory
Spice	1.03×10^8	Unsatisfactory
Knife	8.5×10^7	Unsatisfactory
Hand	1.09×10^8	Unsatisfactory

cfu Colony forming unit, *Centre for food safety standards (< 10^6, satisfactory; 10^6- < 10^7, borderline; ≥ 10^7, unsatisfactory).

Prevalence of *Salmonella enterica* in RTE Meat (Suya) and its Contact Surfaces in Minna

The prevalence of *Salmonella enterica* in the various samples examined was presented in Fig. 1. *Salmonella enterica* was detected in 13% of the 384 samples and suya meat showed the highest prevalence (26%), while yaji and hand samples showed the least (9% each).

The prevalence of *Salmonella enterica* in suya and its contact surfaces from the various locations in Minna Metropolis is showed in Fig. 2. The prevalence of *Salmonella enterica* was highest in samples collected from Bosso (17.0%), followed by those collected from Tunga and Maitumbi each (14.0%), and samples collected from Mekunkele and Tunga Goro-Chanchaga showed the least prevalence of 12.0% for *Salmonella enterica*.

Antibiotic Resistance of *Salmonella enterica* Isolates from RTE Meat (Suya) and its Contact Surfaces in Minna Metropolis

Results for the antibiotic resistance of *Salmonella enterica* isolates from RTE meat (suya) and its contact surfaces in Minna Metropolis is presented in Fig. 3. Overall, the isolates exhibited 24% resistant, 20% intermediate resistant and 56% susceptible to the antibiotics examined. The highest resistance was observed in amoxicillin (65%) and lowest in chloramphenicol (19%). Trimethoprim/sulfamethoxazole (95%), azithromycin (86%), gentamicin (74%), chloramphenicol (69%) and cefuroxime (54%) were susceptible.

Antibiotic Resistance Profile and Multiple Antibiotic Resistance (MAR) Index of *Salmonella enterica* Isolates from RTE meat (Suya) and its Contact Surfaces in Minna Metropolis

Tables 2a and 2b show the MAR index of the *Salmonella enterica* isolates. The MAR index ranged from

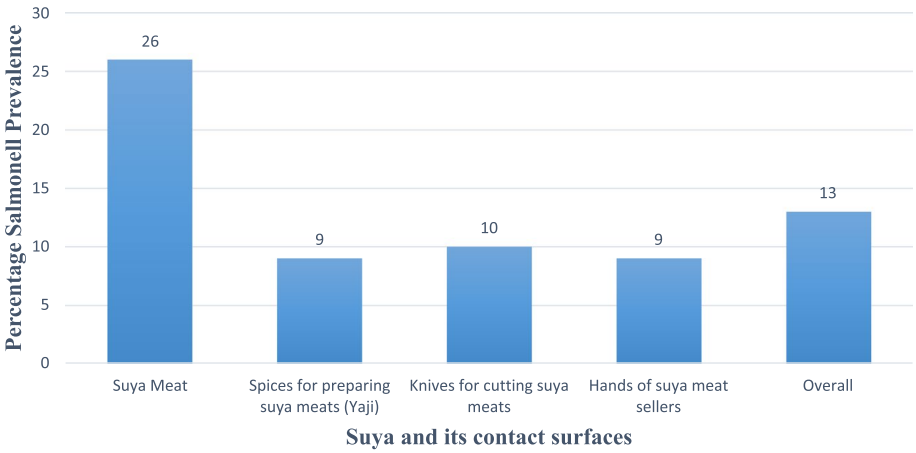

Fig. 1 Prevalence of Salmonella enterica in suya and its contact surfaces in Minna Metropolis

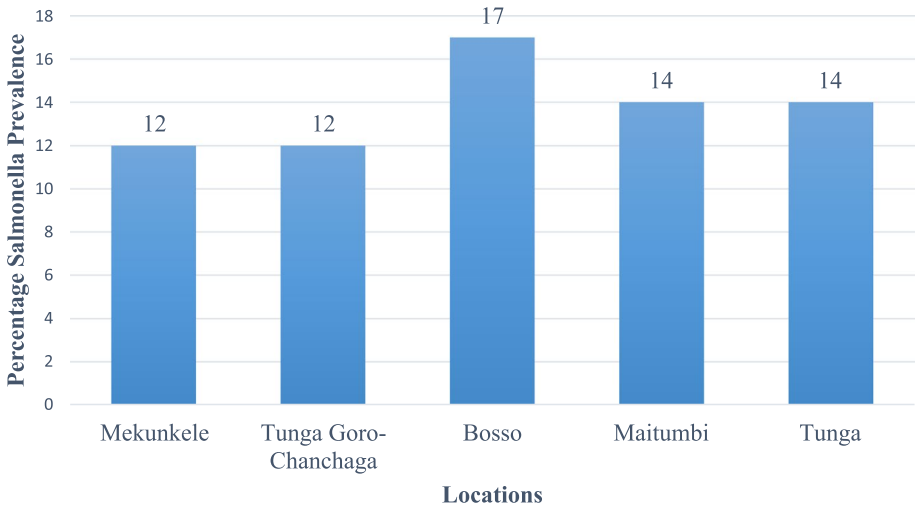

Fig. 2 Prevalence of Salmonella enterica in suya and its contact surfaces in various locations in Minna Metropolis

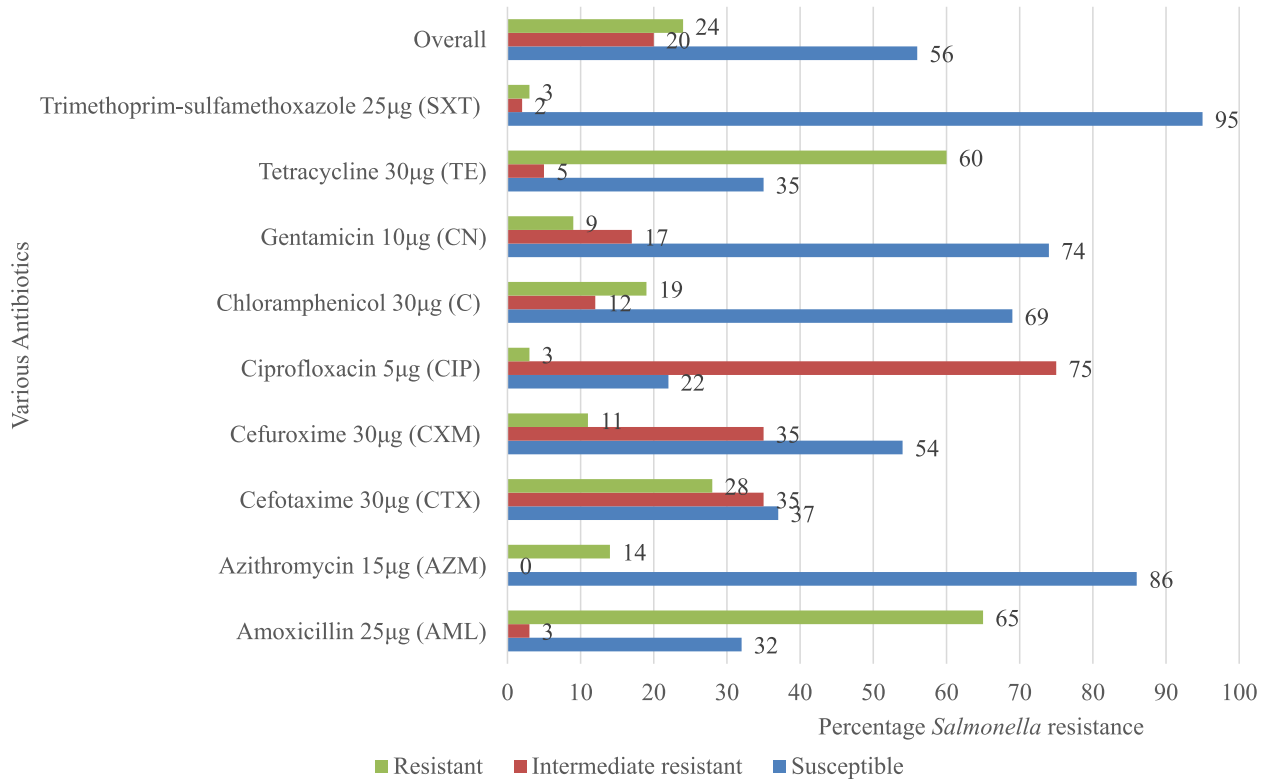

Fig. 3 Antibiotic resistance of Salmonella enterica isolates from RTE meat (suya) and its contact surfaces in Minna Metropolis

0.1 to 0.7 with an average MAR index of 0.2. Multidrug resistance (resistance to 3 or more different classes of antibiotics) was 43.1% (28/65). One *Salmonella enterica* isolate showed resistance to seven different antibiotics namely TE-AML-CXM-CTX-C-AZM-CN and three isolates were resistant to five antibiotics, that is, TE-AML-CXM-AZM-CN, TE-AML-CTX-CIP-C and TE-AML-CTX-AZM-CN. Resistant to only AML was the most common and was exhibited by 9 different *Salmonella enterica* isolates.

Table 2 Antibiotic resistance profiles and MAR index of *Salmonella* isolates from RTE meat (Suya) and its contact surfaces in Minna Metropolis

Location	Source	Isolate code	No. of Antibiotics	Antibiotic resistant profile
A				
Mekunkele	Suya	MLM1	3	TE-AML-CTX
Mekunkele	Suya	MLM2	4	TE-AML-CTX-AZM
Mekunkele	Suya	MLM6	2	TE-AML
Mekunkele	Spice	MLS1	1	TE
Mekunkele	Spice	MLS5	2	TE-AML
Mekunkele	Spice	MLS6	5	TE-AML-CXM-AZM-CN
Mekunkele	Knife	MLK7	3	TE-CTX-AZM
Mekunkele	Hand	MLH6	3	TE-AML-C
TC	Suya	TCM2	0	-
TC	Suya	TCM9	7	TE-AML-CXM-CTX-C-AZM-CN
TC	Suya	TCM11	3	AML-CTX-AZM
TC	Suya	TCM18.1	3	TE-AML-CTX
TC	Suya	TCM18.2	4	TE-AML-CXM-CTX
TC	Spice	TCS4	1	AML
TC	Spice	TCS5	5	TE-AML-CTX-CIP-C
TC	Knife	TCK7	0	-
TC	Knife	TCK8	1	AML
Bosso	Suya	BSM1	4	TE-AML-CTX-C
Bosso	Suya	BSM2	3	TE-AML-CTX
Bosso	Suya	BSM12	4	TE-AML-CTX-C
Bosso	Suya	BSM14	2	TE-AZM
Bosso	Suya	BSM17.1	3	SXT-TE-AML
Bosso	Suya	BSM17.2	2	TE-AML
Bosso	Suya	BSM18	0	-
Bosso	Knife	BSK7	2	TE-AML
Bosso	Knife	BSK12	3	TE-AML-AZM
Bosso	Knife	BSK17	3	TE-AML-C
Bosso	Hand	BSH4	2	TE-AML
Bosso	Hand	BSH6	3	TE-AML-C
Bosso	Hand	BSH10.1	3	TE-AML-C
Bosso	Hand	BSH10.2	3	TE-AML-CTX
B				
Maitumbi	Suya	MBM6.1	1	TE
Maitumbi	Suya	MBM6.2	3	CIP-C-AZM
Maitumbi	Suya	MBM13.1	3	TE-AML-CXM
Maitumbi	Suya	MBM13.2	3	AML-CTX-CN
Maitumbi	Suya	MBM15	2	TE-CTX
Maitumbi	Suya	MBM16.1	1	CXM
Maitumbi	Suya	MBM16.2	5	TE-AML-CTX-AZM-CN
Maitumbi	Suya	MBM16.3	1	TE
Maitumbi	Suya	MBM17.1	2	TE-AML
Maitumbi	Suya	MBM17.2	0	-
Maitumbi	Suya	MBM18.1	0	-
Maitumbi	Suya	MBM18.2	1	TE
Maitumbi	Spice	MBS2	3	AML-CTX-CN
Maitumbi	Spice	MBS5	2	TE-AML
Maitumbi	Spice	MBS18	3	SXT-CXM-CTX

Table 2 (continued)

Location	Source	Isolate code	No. of Antibiotics	Antibiotic resistant profile
Maitumbi	Knife	MBK3	1	TE
Tunga	Suya	TGM5.1	3	TE-AML-C
Tunga	Suya	TGM5.2	1	AML
Tunga	Suya	TGM5.3	1	AML
Tunga	Suya	TGM5.4	4	TE-AML-CTX-C
Tunga	Suya	TGM6.1	1	AML
Tunga	Suya	TGM6.2	0	-
Tunga	Suya	TGM12.1	1	AML
Tunga	Suya	TGM12.2	1	AML
Tunga	Suya	TGM16	1	TE
Tunga	Knife	TGK15.1	1	AML
Tunga	Knife	TGK15.2	1	AML
Tunga	Knife	TGK16.1	1	CXM
Tunga	Knife	TGK16.2	0	-
Tunga	Knife	TGK16.3	0	-
Tunga	Hand	TGH2	2	TE-AML
Tunga	Hand	TGH6	1	TE
Tunga	Hand	TGH8	3	AML-C–CN
Tunga	Hand	TGH18	0	-

TC Tunga-Goro Chanchaga, *AML* Amoxicillin, *AZM* Azithromycin, *CTX* Cefotaxime, *CXM* Cefuroxime, *CIP* Ciprofloxacin, *C* Chloramphenicol, *CN* Gentamicin, *TE* Tetracycline and *SXT* Trimethoprim-sulfamethoxazole.

Demographic characteristics of RTE Suya Meat Vendors in Minna Metropolis

The demographic information of RTE meat (suya) vendors in Minna Metropolis is shown in Table 3. All respondents were males with majority aged from 30–39 (44.0%). Majority were Muslims (96.7%) and over half of them had non-formal education (56.0%). Majority of the respondents (66.0%) have also been in the suya vending business for above 10 years. Beef was the most used meat type (36.7%), due to consumer preference (82.7%). Most respondents purchased raw meat from other sources (96.7%) rather than abattoir (3.3%) and have not undergone any medical examination within the past one year (60.7%).

Food Safety Knowledge of RTE Meat (suya) Vendors in Minna

Table 4 shows the knowledge of hygienic practices among RTE meat (suya) vendors in Minna. Most of the respondents knew food vendors are required to cover their hair (66.0%), wear apron (46.0%) and cannot use the same hand to collect money and handle meat without sanitizing (70.7%) while working. Majority of the respondents also knew that it is not permissible for food vendors to continue working in soiled clothing (89.3%), hands should be washed with soap and warm water to help reduce contamination (98.7%), keeping of long fingernails for vending is not allowed (54.0%) and medical check-up is mandatory for food vendors (81.3%). However, the majority thought it was optional to wear sterilized gloves (89.3%) and food vendors can scratch their body parts and continue working without sanitizing their hands (86.7%).

Furthermore, larger number of the respondents knew that the location of food preparation and sale should be free from pests and rodents (96.7%), far from drains (100.0%), as well as grilling and selling should be done on a table covered with glass or a net (79.3%), dirty clothes or hands can spread microorganisms to food (92.0%) and smoking while preparing or selling food is considered unacceptable (98.7%). Conversely, majority of the respondents did not know that it is unacceptable for food vendors to eat, drink or talk while selling food (92.0%), and coughing or sneezing on food have negative effects on consumers (78.7%).

Most of the respondents did not know whether grilled meat and spices should be covered (46.0%), knives should be washed under running water (56.0%), grilled meat should contain lower water content (54.0%) and grilled meat should be very hot before serving (96.7%). However, the respondents knew that it is unacceptable to store fresh and grilled meat together (64.0%), it is important to sanitize dishes used during food preparation (58.7%), left-over grilled meat should not be kept at room temperature

Table 3 Demographic characteristics of RTE meat (suya) vendors in Minna

Variables	Frequency	Percentage (%)
Gender		
Male	150	100.0
Female	0	0.0
Age		
18–29	21	14.0
30–39	66	44.0
40–49	23	15.3
50–60	40	26.7
Religion		
Christianity	5	3.3
Islam	145	96.7
Education		
None	84	56.0
Primary School	10	6.7
Junior Secondary School	14	9.3
Senior Secondary School	42	28.0
Work experience		
1–5 years	12	8.0
6–10 years	39	26.0
Above 10 years	99	66.0
Meat type used		
Beef	55	36.7
Chevon	8	5.3
Beef and chicken	32	21.3
Beef and chevon	21	14.0
Mutton and chevon	2	1.3
Above two different meat type	32	21.3
Rational		
Cheaper	14	9.3
Consumer preference	124	82.7
Others	12	8.0
Place of purchase raw meat		
Abattoir	5	3.3
Others	145	96.7
Medical check-up		
None	91	60.7
Once	32	21.3
More than one	27	18.0
Occupational training		
Yes	77	51.3
No	73	48.7

(50.0%) and separate cutting tables should be used for fresh and grilled meat (66.0%).

Food Safety Practices of RTE Meat (Suya) Vendors in Minna

The food safety practices of suya vendors are shown in Table 5. It was observed that majority of the respondents did not keep their hair tied or covered (87.3%), wear ring while working (62.0%), did not wear apron (76.0%), did not wear gloves during food handling (100.0%), handles both money and meat with the same hand without sanitizing (100.0%), did not wash hands with soap and warm water (100.0%) and talks while serving customers (100.0%). Contrarily, it was observed that majority of suya vendors wore clean and tidy clothing (71.3%) and maintains trimmed fingernails (72.7%).

This study also revealed that the vending areas showed signs of the presence of pests and rodents (57.3%), were near or directly on drainage systems (78.7%), vending was done in an unclean area (64.7%) and grilling and selling were conducted on tables without glass or net coverings (100.0%), however, wrappers for suya were clean (93.3%)..

This study found that majority of the respondents reheat leftover or previously cold foods (63.3%), separate raw meats from grilled meats (84.7%), do not serve grilled suya meats at cold temperature (82.0%) and do not thaw frozen meats under sun (62.0%). Nonetheless, the respondents use the same chopping table for raw and grilled meat (97.3%), do not use calibrated food thermometers (100.0%), and knives are not sanitized or heated before use (100.0%).

Table 6 shows the relationships between RTE meat (suya) vendors' practices, knowledge, education and others, based on their correlation coefficients and significance levels. Perfect positive correlations (1.000, 1.000, 1.000) occur among practices, medical check-up, and job training, while strong negative correlations (− 1.000, −1.000, − 1.000) were evident between medical checkup and age, as well as work experience with practices, medical checkup, and job training.

Discussion

This study reveals the microbial contamination and prevalence of antibiotic-resistant *Salmonella enterica* in RTE meat (suya) and its contact surfaces as well as the knowledge and practices of food safety among suya vendors in Minna Metropolis, Niger State, Nigeria. The total microbial load of RTE meat (suya) and its contact surfaces was relatively high, with counts (8.5×10^7 to 2.35×10^8 cfu/g or cm^2) exceeding acceptable levels set by food safety standards and categorized as unsatisfactory (Center for Food Safety, 2014). Notably, the highest total microbial load was enumerated from hand samples of suya vendors in Maikunkele, while the lowest was on knife samples from Tunga. The unsatisfactory total microbial load levels in this study highlighted hygienic deficiencies in the handling and processing of meat into suya. This result agrees with the report by Adeleye et al. (2022) who indicated unsatisfactory total microbial load ranging from 9.20 $\times 10^6$ to 1.30 $\times 10^7$ cfu/g in RTE hawked suya samples

Table 4 Knowledge of hygienic practices among RTE meat (suya) vendors in Minna

Variables	True (%)	False (%)	Don't know (%)
Personal hygiene			
Food vendors are required to cover their hair while working	66.0	4.7	29.3
Is it essential for food vendors to wear an apron or overcoat	46.0	27.3	26.7
Is it optional for food vendors to wear sterilized gloves	89.3	2.0	8.7
Food vendors can use the same hand to collect money and handle meat without sanitizing	20.0	70.7	9.3
Is it permissible for food vendors to continue working in soiled clothing	3.3	89.3	7.3
Washing hands with soap and warm water help reduce contamination	98.7	1.3	0.0
Food vendors can scratch their body parts and continue working without sanitizing their hands	86.7	8.7	4.7
Food vendors are allowed to have long fingernails while working	34.0	54.0	12
Medical examination is mandatory for food vendors	81.3	18.7	0.0
Environmental hygiene			
It is acceptable for food vendors to eat, drink, or talk while selling food	92.0	3.3	4.7
Location of food preparation and sale should be free from pests and rodents	96.7	0.0	3.3
Location of food preparation must be far from drains	100.0	0.0	0.0
Grilling and selling should be done on a table covered with glass or a net	79.3	5.3	15.3
Dirty clothes or hands can spread microorganisms to food	92.0	4.7	3.3
Coughing or sneezing on food have negative effects on consumers	12.0	78.7	9.3
Smoking while preparing or selling food is considered acceptable	1.3.0	98.7	0.0
Food hygiene			
Both grilled meat and spices should remain uncovered	12.0	42.0	46.0
Is it acceptable to store fresh and grilled meat together	19.3	64.0	16.7
Equipment like knives should be washed under running water	8.7	35.3	56.0
It is unimportant to sanitize dishes used during food preparation	19.3	58.7	22.0
Leftover grilled meat should be kept at room temperature	12.0	50.0	38.0
It is appropriate to thaw frozen food under the sun	39.3	31.3	29.3
Separate cutting tables should be used for fresh and grilled meat	66.0	17.3	16.7
Grilled meat should contain higher water content	28.7	17.3	54.0
Grilled meat should be very hot before serving	3.3	0.0	96.7

obtained from Dutse Urban, Northwest Nigeria. Osunde et al. (2024) also reported high levels of total microbial load (4.00×10^9) contamination in RTE suya collected from Adolor, Benin City Nigeria, which also agrees with this study. However, the results of this study was generally higher than that of Adio et al. (2014) who found the total microbial load of RTE meat (suya) sold in Lagos to be 9.4×10^6 cfu/g borderline according to Centre for Food Safety (2014). Total microbial load of 9.10×10^6 to 2.68×10^7 cfu/g was recorded for khebab (suya) obtained from Kumasi, Ghana (Ayamah et al. 2021), which was a bit lower than the findings of the current study. The differences in total microbial load may be due to the differences in the level of hygienic practices observed by vendors in the various geographical areas.

The presence of *Salmonella enterica* in RTE meat (suya) emphasizes the public health threat associated with the consumption of suya. *Salmonella enterica* was detected in 13% of the 384 samples, of which suya (26%) was the most contaminated source. The presence of *Salmonella* contamination in suya could be due to cross contamination from the fresh meat during and after processing. The prevalence varied across locations, with Bosso exhibiting the highest rate (17%), followed by Tunga and Maitumbi (14%). The presence of *Salmonella enterica* in contact surfaces.

such as knives, spices and hands was lower than suya, but these contact surfaces can increase cross contamination rate. The results of this study was higher than 3.5% reported by Dagah et al. (2024) from Abuja and 4.9% reported by Oludairo et al. (2022) from Ilorin. The differences in prevalence of these studies could be due to variations in hygienic practices, number of samples examined, sampling procedures and methodologies employed. The current result found for spice agreed with the findings of D'Oca et al. (2021) who reported 8.3% *Salmonella* spp. in sesame samples, used as spices in Nigeria. However, the result was higher than that of Famewo et al. (2019); Korkmaz and İslamoğlu (2021) who did not isolate *Salmonella* spp. from spices used for barbecue in

Table 5 Food safety practices among RTE meat (suya) vendors in Minna

Dependent Variables	Yes (%)	No (%)
Personal hygiene		
Vendor keeps hair tied or covered	12.7	87.3
Vendor wears an apron or protective coat	24.0	76.0
Vendor wears clean and tidy clothing	71.3	28.7
Vendor uses gloves during food handling	0.0	100.0
Vendor handles both money and meat with the same hand without sanitizing	100.0	0.0
Vendor wears ring while working	62.0	38.0
Vendor maintains trimmed fingernails	72.7	27.3
Vendor washes hands with soap and warm water	0.0	100.0
Vendor talks while serving customers	100.0	0.0
Environmental hygiene and sanitation		
Grilled meat vendors work in a clean environment	35.3	64.7
The vending area shows signs of pests and rodents	57.3	42.7
The vending location is near or directly on drainage systems	78.7	21.3
Grilling and selling are conducted on tables with glass or net coverings	0.0	100.0
Wrappers for grilled meat are unclean	6.7	93.3
Food hygiene		
Vendor reheats leftover or previously cold food	63.3	36.7
Raw meat is kept separate from grilled meat	84.7	15.3
Grilled meats are served at a cold temperature	18.0	82.0
Vendor thaws frozen meat in direct sunlight	38.0	62.0
The same chopping board is used for raw and grilled meat	97.3	2.7
Vendor uses calibrated food thermometers	0.0	100.0
Knives are sanitized or heated before use	0.0	100.0

Table 6 Correlation among suya vendors and their knowledge and practices of food safety

Correlation (Multiple R-squared)						
Variables	**Practices**	**Knowledge**	**Education**	**Work experience**	**Medical checkup**	**Job Training**
Practices	1					
Knowledge	−0.08(1%)	1				
Education	0.60(36%)	0	1			
Work experience	−1.000**	−0.50(25%)	−0.50(25%)	1		
Medical checkup	1.000**	−1.000**	1.000**	−1.000**	1	
Job Training	1.000**	−1.000**	1.000**	−1.000**	1.000**	1
Age	0	0.60(36%)	−0.80 (64%)	0.50(25%)	−1.000**	−1.000**

**Correlation is significant at $P < 0.01$

Alice, South Africa and İstanbul, Turkey, respectively. The result of this study was lower than 31% of *Salmonella* spp. found in spices in India (Gulati and Das 2021).

Cross contamination has long been recognized as a significant contributing factor to the presence of pathogens on food contact surfaces, and this understanding is reinforced by numerous studies. Dantas et al. (2018) demonstrated that cutting boards made from various materials including plastic, wood and glass, can retain *Salmonella* after being used to cut poultry meat deliberately inoculated with the bacteria. This finding emphasized the risks associated with reusing contaminated utensils and surfaces without proper sanitization. Also, Kanko et al. (2023) reported that 38% of swab samples from butcher shops in Ethiopia were contaminated, with knives, workers' hands, and tables being frequently implicated as vectors for bacterial transmission. These findings indicated that multiple points

of contact in food handling environments can serve as reservoirs for pathogens. In contrast, lower contamination rates have been observed in some studies in Nigeria. For instance, Okafor et al. (2020) reported a 4.5% contamination rate on knives used in the slaughter and dressing of carcasses in abattoirs in Anambra State, Nigeria. Furthermore, a study conducted in Egypt by Fahim et al. (2022) found that only 1.56% of hand swabs from food handlers were contaminated.

In this study, the antibiotic susceptibility test revealed that 56% of the *Salmonella enterica* isolates were susceptible to the antibiotics examined and, 24% were resistant, with the highest resistant observed for amoxicillin (65%). Susceptibility was highest for trimethoprim-sulfamethoxazole (95%), azithromycin (86%), and gentamicin (74%). On average, MAR index was 0.2, suggesting a moderate level of resistance. However, some isolates demonstrated resistance to multiple antibiotics, including a concerning case of resistance to seven antibiotics. This finding reflected the pressing need for judicious antibiotic use in both healthcare and food production to mitigate the spread of resistant strains. The current result was similar to the following studies; Aduah et al. (2021) who found *Salmonella enterica* isolates from RTE meat to be resistant to more than one antibiotic drugs. Dagah et al. (2024) also reported that *Salmonella* isolates from suya in Abuja displayed multidrug resistance. In addition, Oludairo et al. (2022) found that all the *Salmonella* isolates from RTE meat (suya) in Ilorin, Kwara State, Nigeria, were resistant to multiple antibiotics, presenting an even more concerning scenario of resistance compared to the current study. These variations in resistance rates across different studies may reflect differences in geographical regions, and the extent of antibiotics usage.

The demographic data of suya (RTE meat) vendors in Minna indicated that all the respondents were men of which majority were aged 30–39 years and had limited formal education. Similar findings were reported by Aduah et al. (2021), Hassan et al. (2017) and Asati et al. (2024) that men, youth and people with limited educational background predominate the RTE meat selling. However, this contradicts the findings of Magqupu et al. (2023) who found that female dominate RTE street pork vending business. Majority have been in the suya vending business for 10 years and above and beef was the most used meat type as a result of consumer preference which is similar to findings by Aduah et al. (2021). Most respondents purchased raw meats from other sources like middlemen who provide them the meats on credit other than from the abattoir due to financial challenges of vendors which raises concerns about the quality and safety (health status of the animals, where and how they were slaughtered) of the meats used for suya processing.

Majority of the respondents knew food vendors are required to cover their hair, wear apron and cannot use the same hand to collect money and handle meat without sanitizing while working. Most of the respondents also knew that it is not permissible for food vendors to continue working in soiled clothing, hands should be washed with soap and warm water to help reduce contamination, keeping of long fingernails for vending is not allowed and medical examination is mandatory for food vendors. However, the majority thought it was optional to wear sterilized gloves and food vendors can scratch their body parts and continue working without sanitizing their hands. These aligned with the findings of Aduah et al. (2021), which highlighted the importance of hygiene in meat processing. Furthermore, most of the respondents knew that the location of food preparation and sale should be free from pests and rodents, far from drains, as well as grilling and selling should be done on a table covered with glass or a net, dirty clothes or hands can spread microorganisms to food and smoking while preparing or selling food is considered unacceptable. Conversely, majority of the respondents did not know that it is unacceptable for food vendors to eat, drink or talk while selling food and coughing or sneezing on food have negative effects on consumers. This is inconsistent with observations made by Aduah et al. (2021), who found that, 99% of RTE meat vendors were aware that eating and drinking while selling meat increases the risk of meat contamination. In addition, most of the respondents did not know whether grilled meat and spices should be covered, knives should be washed under running water, grilled meat should contain lower water content and grilled meat should be very hot before serving. However, the respondents knew that it is unacceptable to store fresh and grilled meat together, it is important to sanitize dishes used during food preparation, leftover grilled meat should not be kept at room temperature and separate cutting tables should be used for fresh and grilled meat.

Majority of the respondents did not tie or cover their hair, wear gloves during food handling, or sanitize their hands after handling both money and meat with the same hand. They used the same chopping board for raw and ready-to-eat (RTE) suya meats, did not use calibrated food thermometers, and failed to sanitize or heat knives before use. These practices align with findings by Ma et al. (2019), who reported that over half of street food handlers did not cover their hair while handling, preparing, or serving food, used bare hands, handled money while serving food, and used the same utensils for raw and cooked food. Additionally, many wore rings while working, did not wear aprons, failed to wash hands with soap and warm water, and talked while serving customers. Grilling and selling often occurred

on tables without glass or net coverings, and vending areas were frequently located near drainage systems or showed signs of pests and rodents. This contradicts findings by Asati et al. (2024) and Ma et al. (2019) who observed that vending areas were far from rubbish, wastewater, toilets, and open drains. Conversely, most suya vendors were observed wearing clean and tidy clothing, maintaining trimmed fingernails, reheating leftovers or previously cold foods before serving, avoiding serving RTE suya meat at cold temperatures, and refraining from thawing frozen meats under the sun. These findings align with Asati et al. (2024), Ma et al. (2019) and Siluma et al. (2023) who reported that food handlers often wore clean, presentable clothing and maintained clean, short fingernails.

Perfect positive correlations (1.000) were observed among practices, medical check-ups, and job training, while strong negative correlations (−1.000) were noted between medical check-ups and age, as well as work experience with practices, medical check-ups, and job training. These findings contrast with Hilmi (2020), who stated that street food vendors'practices were primarily influenced by their business experience. Education showed a moderate positive influence on practices (0.60), with job training and medical check-ups being the main drivers. This aligns with Fillol et al. (2024), who emphasized education's transformative potential in improving health and well-being. However, the findings differ from Hashanuzzaman et al. (2020) who reported a strong positive correlation (0.8415) between food handlers'knowledge and practices, and Boakye et al. (2023) who found that knowledgeable fruit and vegetable vendors exhibited positive food hygiene practices (0.45).

Limitation of the study

The study was confined to five areas within Minna Metropolis, which may limit how applicable the findings are to other parts of Nigeria. Although pre-tested questionnaires were used to improve the reliability of self-reported information, there is still a risk that the desire to give socially acceptable answers might have influenced the vendors' responses. The use of snowball sampling, which is non-random can lead to potential bias, limiting the generalization of the current findings. Lastly, while microbiological tests were performed in triplicate to ensure accuracy, the study did not carry out molecular analyses of the *Salmonella* isolates (e.g., serotyping, detection of antimicrobial and virulence genes, and assessment of genetic relatedness) which limits the depth of understanding regarding the pathogenic potential, transmission dynamics, and public health implications of the isolates identified.

Conclusion

The study identified microbiological contamination in suya samples sold within Minna Metropolis, including the presence of *Salmonella enterica*, suggesting lapses in hygiene and food safety practices among vendors. In addition, the study highlights moderate prevalence of antibiotic-resistant *Salmonella*, with concerning cases of multidrug resistance. Vendors'inconsistent adherence to food safety practices is a worry and necessitates actions to prevent foodborne diseases outbreaks from the consumption of suya and contact with suya associated sources.

Recommendations

Regular job training, mentorship programs, and continuous education on hygienic food handling by stakeholders are recommended to enhance vendors'practices and minimize contamination risks. Moreover, stricter monitoring and enforcement of food safety standards by the National Agency for Food and Drug Administration and Control are necessary to mitigate the public health threat posed by contaminated suya and its contact surfaces.

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

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Authors' contributions

Author Contributions Conceptualization: R.E., J.D.B, S.M. and F.A.; Methodology: R.E., J.D.B., S.M. and F.A.; Formal analysis: R.E. and F.A.; Investigation: R.E., J.D.B. and F.A.; Data curation: R.E.; Writing original draft preparation: R.E.; Review and editing: F.A., J.D.B. and R.E.; Supervision: J.D.B., S.M. and F.A.; Funding acquisition: H.S.A., H.L.M. and A.H.M.

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Data availability
Availability of data and materials The datasets used and/or analysed during the current study are in the manuscript and supplementary and any further information are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with ethical standards and guidelines outlined by Research Ethics Committee of the Federal University of Technology, Minna. Ethical approval for the research was obtained from Research Ethics Committee of the Federal University of Technology, Minna, with approval number 000088.

Informed consent
All participants involved in the study signed informed consent prior to participation, and their confidentiality and anonymity were strictly maintained.

Competing interests
The authors declare no competing interests.

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References

Abdullahi BS, Maiha SB, Lawal HK (2020) Hygiene, Food Safety Practices and Sanitation in Some Food Service Centres in Zaria, Kaduna State, NigeriaAmerican Journal of Food Science and Technology. American Journal of Food Science and Technology 8(5):206–210. https://doi.org/10.12691/ajfst-8-5-5

Abey SL, Gedefaw M, Molla W, Dagnaw GG, Mengistu BA, Kinde MZ, Nigatu S, Jemberu WT, Adugna T, Berju A, Dagnachew S, Birhanu K, Ejo M, Bitew AB (2024) Molecular detection and antimicrobial resistance profile of Salmonella isolated from humans, animals, abattoir equipment and environment. Applied Food Research 4(2):100437. https://doi.org/10.1016/j.afres.2024.100437

Adeleye A, Sim K, Yerima M (2022) Bacteriological Quality Assessment of Ready-To-Eat Hawked Suya in Dutse Urban. Northwest Nigeria Stamford Journal of Microbiology 12(1):25–30. https://doi.org/10.3329/sjm.v12i1.63340

Adio I, Ovuoraini H, Esther A (2014) Microbial Quality of Ready To Eat Barbecue Meat (Suya) Sold on the Streets of Lagos State. Int J Adv Pharm, Biol Chem 3(4):973–982. https://www.ijapbc.com

Aduah M, Adzitey F, Amoako DG, Abia ALK, Ekli R, Teye GA, Shariff AHM, Huda N (2021) Not All Street Food Is Bad: Low Prevalence of Antibiotic-Resistant Salmonella enterica in Ready-to-Eat (RTE) Meats in Ghana Is Associated with Good Vendors' Knowledge of Meat Safety. Foods 10(5):1011. https://doi.org/10.3390/foods10051011

Adzitey F, Assoah-Peprah P, Teye GA, Somboro AM, Kumalo HM, Amoako DG (2020a) Prevalence and Antimicrobial Resistance of Escherichia coli Isolated from Various Meat Types in the Tamale Metropolis of Ghana. Int J Food Sci 2020:1–7. https://doi.org/10.1155/2020/8877196

Adzitey F, Teye GA, Amoako DG (2020b) Prevalence, phylogenomic insights, and phenotypic characterization of *Salmonella enterica* isolated from meats in the Tamale metropolis of Ghana. Food Sci Nutr 8(7):3647–3655. https://doi.org/10.1002/fsn3.1647

Akinyemi KO, Ajoseh SO, Fakorede CO (2021) A systemic review of literatures on human Salmonella enterica serovars in Nigeria (1999–2018). The Journal of Infection in Developing Countries 15(09):1222–1235. https://doi.org/10.3855/jidc.12186

Andrews WH, Wang H, Jacobson A, Ge B, Zhang G, and Hammack T (2023) Bacteriological Analytical Manual (BAM) Chapter 5: Salmonella. https://www.Fda.Gov/Food/Laboratory-Methods-Food/Bacteriological-Analytical-Manual-Bam

Asati DA, Abdulai PM, Boateng KS, Appau AAA, Ofori LA, Agyekum TP (2024) Food safety knowledge and practices among raw meat handlers and the microbial content of raw meat sold at Kumasi Abattoir Butchery Shops in Kumasi. Ghana BMC Public Health 24(1):975. https://doi.org/10.1186/s12889-024-18514-w

Ayamah A, Sylverken AA, Andoh LA (2021) Assessment of microbiological quality of khebab sold on the campus of a tertiary education and its environs in Ghana. Journal of Microbiology and Antimicrobials 13(2):20–26. https://doi.org/10.5897/JMA2021.0444

Bissala AC, Owoicho C, Anwana SB, Abdusalam B, Duru TC (2021) Urban Expansion Land Use and Land Cover Changes Using Remote Sensing and GIS: The Case of Minna Metropolis, Niger State Nigeria. Journal of Research in Environmental and Earth Sciences 7(12):38–43. www.questjournals.org

Boakye MK, Tornyi JM, Dzubey I, Adzoyi P, Ayimah JC, Boakye DS, Wiafe ED (2023) Assessment of food hygiene and safety knowledge, attitude, and practices of fruit and vegetable vendors in the Ho central market. Ghana Heliyon 9(9):e19579. https://doi.org/10.1016/j.heliyon.2023.e19579

CDC, C. for D. C. and Prevention (2022) Antibiotic resistance threats in the United States. Available at: https://www.cdc.gov/drugresistance/biggest-threats.html

Center for Food Safety (2014) Microbiological Guidelines for Foods. For Ready-to-eat-Food in General and Specific Food Items, Food and Environmental Hygiene Department, Queensway Government Offices, Queensway, Hong Kong. Center for Food Safety. Available at https://www.cfs.gov.hk/english/food_leg/files/food_leg_Microbiologi cal_Guidelines_forFood_e.pdf

Centre for Food Safety C (2014) Microbiological guidelines for food: For ready-to-eat food in general and specific food items. Food Environ Hyg Dep, Gov Hong Kong Special Adm Reg 1–38. https://www.cfs.gov.hk

CLSI, C. and L. S. I. (2023) M100 Performance Standards for Antimicrobial Susceptibility Testing (Version 33rd Edition). www.clsi.org standard@clsi.org

Dagah H, Ameh JAS, Mailafia S, Dantong DD, Onigbanjo OH, Casmir IC, & Adeyemo BJ (2024) Prevalence and Antimicrobial Susceptibility of Salmonella from Roasted Meat ('Suya') Sold in Federal Capital Territory, Abuja, Nigeria. The Microbe 100179 https://doi.org/10.1016/j.microb.2024.100179

Dantas STA, Rossi BF, Bonsaglia ECR, Castilho IG, Hernandes RT, Fernandes A, Rall VLM (2018) Cross-Contamination and Biofilm Formation by *Salmonella enterica* Serovar Enteritidis on Various Cutting Boards. Foodborne Pathog Dis 15(2):81–85. https://doi.org/10.1089/fpd.2017.2341

D'Oca MC, Di Noto AM, Bartolotta A, Parlato A, Nicastro L, Sciortino S, Cardamone C (2021) Assessment of contamination of Salmonella spp. In imported black pepper and sesame seed and salmonella inactivation by gamma irradiation. Italian Journal ofFood Safety 10(1). https://doi.org/10.4081/ijfs.2021.8914

Fahim KM, Ahmed LI, Abdel-Salam AB (2022) Influence of The Hygienic Status of Food Contact Surfaces and Handler's Hands on The Microbial Safety of Ready to Eat Foods. International Journal of Veterinary Science 11(2):249–256. https://doi.org/10.47278/journal.ijvs/2021.102

Famewo EB, Otunola GA, Afolayan AJ (2019) The Microbial Safety Profile of Commercial Barbecue Spice Blends Sold in Alice, Eastern Cape Province, South Africa. *A*sian Journal of Microbiology Biotechnology and Environmental Sciences · November, 21, 109-S115

Fillol, A., Wallerich, L., Larose, M.-P., Ferron, C., Rivadeneyra-Sicilia, A., Vandentorren, S., Brandler-Weinreb, J., and Cambon, L. (2024). The Influence of Educational Determinants on Children's Health: A Scoping Review of Reviews. Public Health Reviews 45. https://doi.org/10.3389/phrs.2024.1606372

Gulati D, Das N (2021) Microbiological Quality of Spices Marketed in Uttarakhand, India. Journal of Bio Innovation 10(3):750–759. https://doi.org/10.46344/JBINO.2021.v10i03.04

Hashanuzzaman M, Bhowmik S, Rahman MdS, Zakaria MUMA, Voumik LC, Mamun A-A (2020) Assessment of food safety knowledge, attitudes and practices of fish farmers and restaurants food handlers in Bangladesh. Heliyon 6(11):e05485. https://doi.org/10.1016/j.heliyon.2020.e05485

Hassan MZ, Islam MS, Salauddin M, Zafr AHA, Alam S (2017) Food Safety Knowledge, Attitudes and Practices of Chotpoti Vendors in Dhaka. Bangladesh Journal of Enam Medical College 7(2):69–76. https://doi.org/10.3329/jemc.v7i2.32651

Hilmi M (2020) Street food vendors' entrepreneurial marketing characteristics and practices from12 countries: What lessons can be learnt for improving food marketing inBOP/Subsistence marketplaces. Middle East Journal of Agriculture Research 9(2):321–348. https://doi.org/10.36632/mejar/2020.9.2.27

Kanko T, Seid M, Alemu M (2023) Evaluation of bacteriological profile of meat contact surfaces, handling practices of raw meat and its associated

factors in butcher shops of Arba Minch town, southern Ethiopia-A facility based cross sectional study. Food Safety and Risk 10(1):1. https://doi.org/10.1186/s40550-023-00102-2
Korkmaz BIO, İslamoğlu AH (2021) Assessment of Salmonella Spp. And Mold-Yeast Contamination in Packaged and Unpackaged Spices. Acta Pharmaceutica Sciencia,59(2):207–215. https://doi.org/10.23893/1307-2080.APS.05912
Ma L, Chen H, Yan H, Wu L, Zhang W (2019) Food safety knowledge, attitudes, and behavior of street food vendors and consumers in Handan, a third tier city in China. BMC Public Health 19(1):1128. https://doi.org/10.1186/s12889-019-7475-9
Magqupu S, Katiyatiya CLF, Chikwanha OC, Strydom PE, Mapiye C (2023) Street pork vendors' hygiene and safety practices and their determinants in the Cape Metropole District, South Africa. Journal of Food Protection 100197. https://doi.org/10.1016/j.jfp.2023.100197
Maturin L, Peeler JT (2001) Bacteriological Analytical Manual Chapter 3 Aerobic Plate Count. Laboratory Methods > BAM: Aerobic Plate Count. https://www.fda.gov/Food/FoodScienceResearch/LaboratoryMethods/ucm063346.htm
Mohammed SSD, Adeniyi OD, Damisa D, Bala E (2017) Mycological assessment of Suya Sold in some parts of Minna, Niger State. Nigerian Journal of Biotechnology, 32, 33–40. https://www.ajol.info/index.php/njb/article/view/155264
Ngogo FA, Joachim A, Abade AM, Rumisha SF, Mizinduko MM, Majigo MV (2020) Factors associated with Salmonella infection in patients with gastrointestinal complaints seeking health care at Regional Hospital in Southern Highland of Tanzania. BMC Infect Dis 20(1):135. https://doi.org/10.1186/s12879-020-4849-7
Odonkor ST, Odonkor CJA (2020) An Assessment of Food Safety Knowledge and Practices in the Ghanaian Hospitality Industry. J Food Qual 2020:1–9. https://doi.org/10.1155/2020/5618492
Okafor UC, Okafor SC, Ogugua AJ (2020) Occurrence of multidrug-resistant Salmonella in cattle carcass and contact surfaces in Kwata slaughterhouse, Awka, Anambra State, Nigeria. International Journal of One Health, 6(1):49–55. https://doi.org/10.14202/IJOH.2020.49-55
Oludairo OO, Balogun AK, Daodu OB, Aiyedun JO (2022) Isolation and Antimicrobial Resistance Phenotype of Salmonella species from Ready-to-Eat Roasted Meat (Suya) in Ilorin, Kwara State, Nigeria. Journal of Applied Veterinary Sciences 7(4):67–73. https://doi.org/10.21608/javs.2022.154058.1166
Osunde DO, Isoah GO, Obasuyi C, Akpoghelie PO, Oshoma CE (2024) Bacteriological Analysis of Ready to Eat Suya Meat Sold In Adolor and Oluku Area of Benin City, Nigeria. J Appl Sci Environ Manag 28(5):1477–1483. https://doi.org/10.4314/jasem.v28i5.19
Sanni AO, Onyango J, Rota AF, Mikecz O, Usman A, PicaCiamarra U, Fasina FO (2023) Underestimated economic and social burdens of non-Typhoidal Salmonella infections: The One Health perspective from Nigeria. One Health 16:100546. https://doi.org/10.1016/j.onehlt.2023.100546
Shiningeni D, Chimwamurombe P, Shilangale R, Misihairabgwi J (2019) Prevalence of pathogenic bacteria in street vended ready-to-eat meats in Windhoek, Namibia. Meat Sci 148:223–228. https://doi.org/10.1016/j.meatsci.2018.05.014
Siluma BJ, Kgatla ET, Nethathe B, Ramashia SE (2023) Evaluation of Meat Safety Practices and Hygiene among Different Butcheries and Supermarkets in Vhembe District, Limpopo Province, South Africa. Int J Environ Res Public Health 20(3):2230. https://doi.org/10.3390/ijerph20032230
WHO, WHO (2023) Food Safety Incidents; INFOSAN Quarterly Summary. https://www.who.int

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