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DETECTION AND ANTIBIOGRAM OF *Salmonella* FROM FRESH TOMATOES SOLD AT SELECTED MARKETS IN F.C.T. ABUJA

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Abstract. Fresh produce such as tomatoes is a major component of the Nigerian diet but can serve as vehicles for food-borne pathogens, particularly when consumed raw. This study aimed to detect and characterize *Salmonella* spp. from fresh tomatoes sold at four major area councils of the Federal Capital Territory (FCT), Abuja Kuje, Gwagwalada, Kwali and Bwari and to determine their antimicrobial resistance (AMR) profiles. A total of 201 tomato samples were processed using standard culture techniques and biochemical identification. Presumptive *Salmonella* spp. were detected in 24.3% (49/201) of samples, with the highest prevalence recorded in Kwali (30.7%) and the lowest in Bwari (16.0%). Antibiotic susceptibility testing (Kirby-Bauer disk diffusion) revealed high resistance to streptomycin (65.3%) and co-trimoxazole (36.7%), with gentamicin showing the highest susceptibility (98.0%). Multidrug resistance (MDR) was common, with multiple antibiotic resistance index (MARI) values as high as 0.9, indicating a high-risk contamination source. Molecular confirmation using PCR targeting the *invA* gene did not yield positive results for any isolate. The presence of multidrug-resistant presumptive Salmonella spp. in fresh tomatoes poses a significant public health risk, especially in regions where these products are frequently consumed raw. The study emphasizes the need for improved hygiene practices during cultivation, handling and marketing of fresh produce and calls for public awareness campaigns and policy-driven interventions in food safety and antibiotic stewardship.

Keywords: *Salmonella spp., fresh tomatoes, antimicrobial resistance, multidrug resistance, public health risk.*

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1. Introduction

Tomatoes (*Solanum lycopersicum*) are a vital component of human diets globally due to their nutritional, economic and culinary significance. They are consumed in both raw and processed forms and are often integrated into diverse dishes in many cultures, including Nigeria (Osemwegie *et al*., 2010). However, tomatoes, especially when consumed raw, have been implicated in the transmission of several foodborne pathogens, with *Salmonella* species being a major concern (Gupta *et al*., 2007; Centers for Disease Control and Prevention, 2005). This is largely attributed to contamination during pre and

post-harvest handling, including exposure to contaminated irrigation water, soil, animal manure and unhygienic market conditions (Beuchat, 2002; Guo *et al*., 2002). Foodborne illnesses caused by pathogens such as *Salmonella* constitute a significant global health burden. The World Health Organization (WHO) (2015) estimates that contaminated food leads to approximately 600 million cases of foodborne illness and 420,000 deaths annually. In developing countries like Nigeria, the impact is more profound due to limited food safety surveillance and regulatory enforcement (Odeyemi, 2016). Several studies have identified *Salmonella* in raw vegetables and fruits sold in open markets, posing a high risk for enteric infections and outbreaks (Wogu & Ofuase, 2014; Abakpa *et al*., 2015). Beyond fresh produce, *Salmonella* has also been detected in other widely consumed Nigerian foods such as nono (fermented milk), where poor handling practices by vendors and consumers in Abuja contributed to contamination (Godwin *et al*., 2025). These findings highlight the pervasive nature of *Salmonella* in the food chain and reinforce the need for robust food safety interventions.

Salmonella is a Gram-negative, rod-shaped, facultative intracellular bacterium belonging to the family *Enterobacteriaceae*. It comprises over 2,600 known serovars, with *Salmonella enterica* subspecies *enterica* being the most commonly implicated in human disease (Brenner *et al*., 2000; Grimont & Weill, 2007). These pathogens are responsible for both typhoidal and non-typhoidal salmonellosis, manifesting in symptoms ranging from gastroenteritis to systemic infections such as typhoid fever (Hohmann, 2001). The increasing concern is the emergence of antimicrobial resistance (AMR) among *Salmonella* strains, which complicates treatment and increases morbidity and mortality (Akinyemi *et al*., 2007; Fashae & Ogunsola, 2014). The indiscriminate use of antibiotics in agriculture and clinical settings has been linked to the development and spread of multidrug-resistant (MDR) *Salmonella* strains (Threlfall, 2002). As such, surveillance of antimicrobial susceptibility patterns is crucial to informing treatment protocols and public health interventions. In Nigeria, there is a dearth of data on the prevalence of *Salmonella* in fresh produce, particularly tomatoes sold in local markets in the Federal Capital Territory (FCT) Abuja. This study aims to fill that gap by detecting the presence of *Salmonella* spp. in fresh tomatoes and evaluating their antibiogram profiles. The findings are expected to contribute to food safety awareness, guide antimicrobial stewardship and inform public health policy.

2. Materials and methods

2.1. Study area and design

A cross-sectional study was conducted in the Federal Capital Territory (FCT), Abuja, Nigeria. The territory lies between latitude 8.25° and 9.20° North and longitude 6.45° and 7.39° East. It covers approximately 7,315 km^2 and is situated within the savannah ecological zone with moderate climatic conditions. Tomato samples were collected between February and March 2024 from four Area Councils: Gwagwalada, Kuje, Kwali and Bwari.

2.2. Sample size and sampling technique

Sample size was determined using Thrusfield's formula (1997) based on a 5% expected prevalence and 95% confidence level, yielding a total of 201 fresh tomato

samples. Samples were randomly collected from tomato vendors 16 to 20 samples per seller across selected markets in the four Area Councils.

2.3. Sample collection and transportation

Tomato samples were collected aseptically in sterile polythene bags, labeled appropriately and transported under cold chain conditions to the Laboratory of Public health and preventive medicine, University of Abuja, for microbiological analysis.

2.4. Isolation and identification of Salmonella *spp.*

Isolation of *Salmonella* spp. was carried out using a standard method described by Andrews et al. (2011) and Cheesbrough (2006). Briefly, the outer surface of each tomato was swabbed, cut and pre-enriched in 9 ml of selenite F broth (Oxoid, UK) at 35°C for 18-24 hours. Tubes showing turbidity were subcultured onto *Salmonella-Shigella a*gar (SSA) and bismuth sulfite agar (BSA), followed by incubation at 37°C for 24 hours. Colonies showing black centers or metallic sheen were selected for further biochemical confirmation.

2.5. Biochemical characterization

Presumptive isolates were purified and subjected to a series of biochemical tests, including: triple sugar iron (TSI) agar, methyl red-voges proskauer (MR-VP), indole test, urease test, motility test, citrate utilization test, catalase test, lysine decarboxylase test, carbohydrate fermentation tests, hydrogen sulfide production in SIM medium.

All tests followed the procedures described by Cheesbrough (2006). *Salmonella* spp. were identified based on standard reactions: Gram-negative rods, MR-positive, citrate-positive, urease-negative and motile.

2.6. Antibiotic susceptibility testing

Antimicrobial susceptibility testing was conducted using the Kirby-Bauer disk diffusion method as described by Bauer et al. (1966) and interpreted according to Clinical and laboratory standards institute (CLSI, 2020) guidelines. The following antibiotic discs were used: ampicillin (10 µg), amoxicillin-clavulanic Acid (30 µg), cefotaxime (30 µg), ceftazidime (30 µg), ciprofloxacin (5 µg), co-trimoxazole (25 µg), gentamicin (10 µg), streptomycin (10 µg), nalidixic Acid (30 µg) and cefoxitin (30 µg).

Inocula were standardized to 0.5 McFarland turbidity. Mueller-Hinton agar plates were inoculated and incubated at 37°C for 24 hours. Zones of inhibition were measured in millimeters and categorized as Susceptible, Intermediate or Resistant based on CLSI 2020 breakpoints.

2.7. Molecular detection of Salmonella *spp through Polymerase Chain Reaction*

Molecular confirmation of *Salmonella* spp. was performed using Polymerase Chain Reaction (PCR) targeting the *invA* gene, a highly conserved virulence gene in *Salmonella* spp. (Malorny e*t al*., 2003).

DNA extraction: Genomic DNA was extracted using the AccuPrep Genomic DNA Extraction Kit (Bioneer, Korea) according to the manufacturer's instructions and purity was assessed spectrophotometrically.

PCR amplification: PCR reactions were prepared in 20 µL volumes using AccuPower® HotStart PCR Premix (Bioneer), containing 2 µL template DNA, 1 µL each of *invA* forward (5′-ACAGTGCTCGTTACGACCTGAAT-3′) and reverse (5′-AGACGACTGGTACTGATCGATAAT-3′) primers and nuclease-free water to final volume. Thermal cycling was performed following the protocol of Malorny et al. (2003): initial denaturation at 95 °C for 5 min, 35 cycles of denaturation (94 °C, 30 s), annealing (54 °C, 30 s) and extension (72 °C, 30 s), with a final extension at 72 °C for 5 min.

2.8. Gel electrophoresis

PCR products were analyzed by electrophoresis in 2% agarose gel stained with ethidium bromide. Bands were visualized under UV light using a gel documentation system. A 100 bp DNA ladder served as the molecular weight marker.

2.9. Statistical analysis

Data were summarized using descriptive statistics and presented in tables. Statistical analyses were performed using the Statistical package for the social sciences (SPSS), version 28.0.

3. Results

3.1. Occurrence of Salmonella *spp. in fresh tomatoes*

Out of 201 fresh tomato samples collected from four Area Councils within the Federal Capital Territory (FCT), Abuja, 49 samples (24.3%) tested positive for *Salmonella* spp. The prevalence varied by location, with Kwali showing the highest contamination rate (30.7%), followed by Bwari (28.0%), Kuje (22.9%) and Gwagwalada (17.6%) (Table 1).

Table 1. Occurrence of *Salmonella* spp. in fresh tomatoes by location

Location	No. of Samples	No. (%) of Isolates
Kuje (K)	48	11 (22.9)
Gwagwalada (G)	51	9 (17.6)
Kwali (KW)	52	16 (30.7)
Bwari (B)	50	13 (28.0)
Total	**201**	**49 (24.3%)**

3.2. Antibiotic susceptibility of Salmonella *isolates*

All 49 *Salmonella* isolates were tested for susceptibility against 10 antibiotics. Gentamicin exhibited the highest effectiveness (98.0% susceptible), while streptomycin had the highest resistance (65.3%). Ciprofloxacin showed no fully susceptible isolates but had 61.2% intermediate responses (Table 2).

Table 2. Antibiotic susceptibility profiles of *Salmonella spp* isolates

Antibiotics	Susceptible no. (%)	Intermediate no. (%)	Resistant no. (%)
Amoxicillin/clavulanic acid (AMC)	24 (49.0)	7 (14.3)	18 (36.7)
Ceftazidime (CAZ)	26 (53.1)	3 (6.1)	20 (40.8)
Cefuroxime (CXM)	7 (14.3)	24 (49.0)	18 (36.7)
Cefoxitin (FOX)	24 (49.0)	0 (0.00)	25 (51.0)
Ciprofloxacin (CIP)	0 (0.00)	30 (61.2)	19 (38.8)
Gentamicin (GEN)	48 (98.0)	1 (2.0)	0 (0.00)
Ampicillin (AMP)	21 (42.9)	12 (24.5)	16 (32.6)
Streptomycin (S)	17 (34.7)	0 (0.00)	32 (65.3)
Co-trimoxazole (SXT)	13 (26.5)	18 (36.7)	18 (36.7)
Nalidixic acid (NAL)	35 (71.4)	5 (10.2)	9 (18.4)

Note: AMC = Amoxicillin/clavulanic acid, CAZ = Ceftazidime, CXM = Cefuroxime, FOX = Cefoxitin, CIP = Ciprofloxacin, GEN = Gentamicin, AMP = Ampicillin, S = Streptomycin, SXT = Co-trimoxazole, NAL = Nalidixic acid

3.3. Location based resistance patterns

Antibiotic resistance patterns varied across the four locations. Resistance to streptomycin and co-trimoxazole was consistently high across all sites, with Bwari showing the highest resistance to both. Gentamicin resistance remained low in all areas (Table 3).

Table 3. Resistance (%) of *Salmonella spp* isolates by location

Antibiotic	Kuje (n=11)	Gwagwalada (n=9)	Kwali (n=16)	Bwari (n=13)
Amoxicillin/clavulanic acid (AMC)	4 (36.3%)	3 (33.3%)	8 (50.0%)	6 (46.1%)
Ceftazidime (CAZ)	5 (45.4%)	3 (33.3%)	6 (37.5%)	5 (38.4%)
Cefuroxime (CXM)	4 (36.3%)	4 (44.4%)	5 (31.2%)	6 (46.1%)
Cefoxitin (FOX)	3 (27.2%)	5 (55.5%)	5 (31.2%)	7 (53.8%)
Ciprofloxacin (CIP)	1 (9.0%)	2 (22.2%)	4 (21.4%)	3 (23.0%)
Gentamicin (GEN)	0 (0.0%)	0 (0.0%)	3 (18.7%)	1 (7.6%)
Ampicillin (AMP)	6 (54.5%)	3 (33.3%)	10 (62.5%)	8 (61.5%)
Streptomycin (S)	9 (81.8%)	7 (77.7%)	13 (81.2%)	11 (84.6%)
Co-trimoxazole (SXT)	8 (72.7%)	6 (66.6%)	12 (75.0%)	10 (76.9%)
Nalidixic acid (NAL)	3 (27.2%)	2 (22.2%)	3 (18.7%)	5 (38.4%)

3.4. Multiple antibiotic resistance index (MARI)

The MARI ranged from 0.0 to 0.9 among the isolates. A significant proportion of isolates had MARI ≥0.5, suggesting exposure to high-risk environments with heavy antibiotic use.

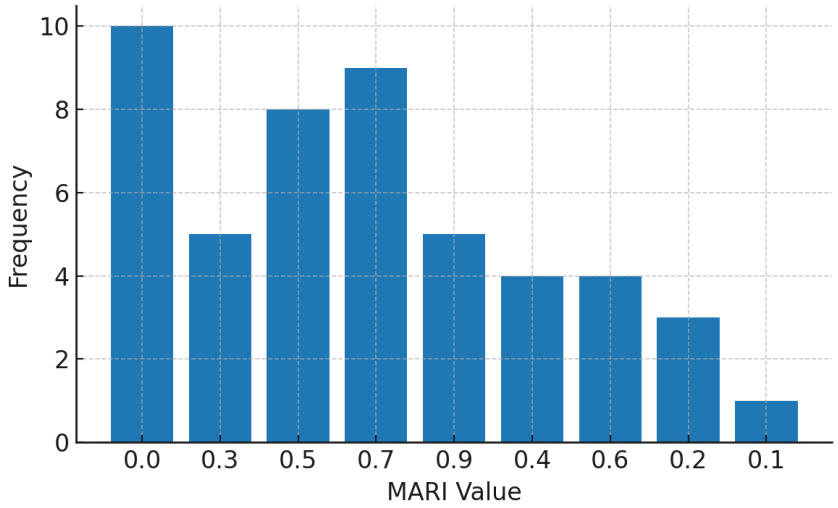

Figure 1. Distribution of MARI values among 49 *Salmonella* isolates

3.5. Molecular Confirmation Using PCR

Molecular detection using genus-specific *invA* gene primers were unsuccessful in the confirmation of all 49 isolates as *Salmonella* spp. The *invA* gene, a virulence marker associated with epithelial invasion, was not successfully amplified in each isolate.

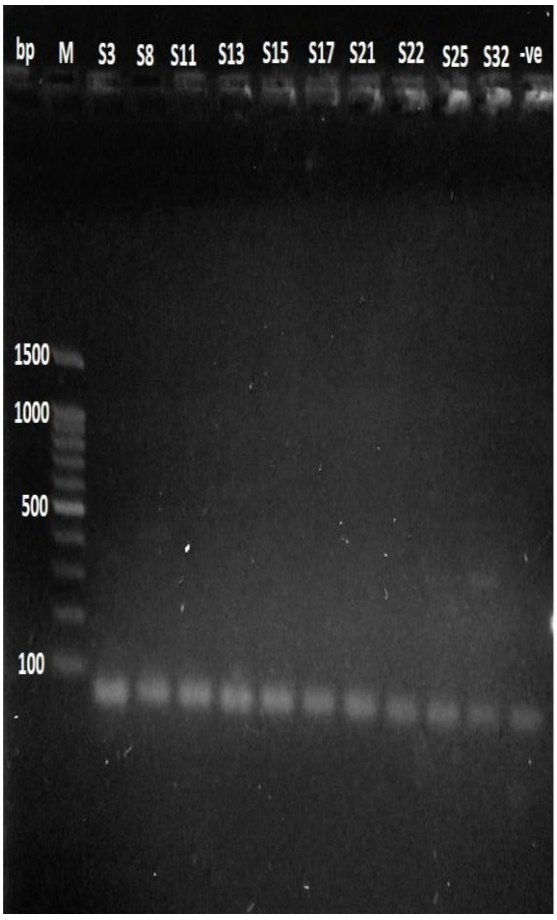

Figure 2. Showing absence of the expected amplicon, indicating unsuccessful amplification

4. Discussion

This study reports a 24.3% prevalence of presumptive *Salmonella* spp. in fresh tomatoes sold in selected markets across the Federal Capital Territory (FCT), Abuja, with Kwali recording the highest rate (30.7%) and Gwagwalada the lowest (17.6%). These values are comparable to the 22.8% prevalence reported by Ogbonna et al. (2011) in Zaria and the 26.3% recorded by Bagudo et al. (2014) in Sokoto. However, they are higher than the 12.5% reported by Abdu et al. (2020) in Kano but lower than the 36.4% prevalence documented by Eze et al. (2018) in Enugu. Such variation may reflect differences in irrigation water quality, hygiene practices and handling methods across regions, as previously observed in fresh produce studies within Nigeria (Afolabi *et al*., 2023).

Antibiotic susceptibility profiling revealed high resistance rates to streptomycin (65.3%) and cefoxitin (51.0%), while gentamicin remained highly effective (98.0% susceptibility). This pattern is comparable to findings from Ibadan (Fashae & Ogunsola, 2014) and Maiduguri (Iliyasu *et al*., 2017), which also documented widespread resistance to first-line antibiotics. The high multiple antibiotic resistance index (MARI) values (≥0.5 in 27 isolates) suggest that these organisms originated from environments with heavy antibiotic use, consistent with studies from Zaria (Tamba *et al*., 2016) and Benin City (Uzeh & Imafidon, 2022).

Although conventional culture and biochemical tests successfully isolated presumptive *Salmonella* spp., molecular confirmation using *invA*-targeted PCR did not yield amplification in any of the 49 isolates. Similar culture-positive but PCR-negative results have been reported in produce studies from Oyo State (Adesetan *et al*., 2019) and elsewhere, with possible causes including degraded DNA, inhibitory plant compounds, or primer inefficiency (Malorny *et al*., 2003; Rahn *et al*., 1992). These findings emphasize the value of combining culture-based methods with molecular diagnostics for more reliable detection.

The detection of *Salmonella spp* isolates in tomatoes is of significant public health concern, as tomatoes are commonly consumed raw in Nigeria. Contamination sources may include irrigation water, untreated animal manure and poor post-harvest handling, aligning with similar findings from open markets in Enugu (Eze *et al*., 2018) and Ogun State (Oni *et al*., 2015), which identified contaminated water and unhygienic handling practices as major contributors.

From a public health perspective, these results call for strengthened surveillance of *Salmonella* contamination in fresh produce, improved hygiene practices among tomato handlers and vendors and the enforcement of antimicrobial stewardship programs in both agriculture and healthcare (WHO, 2007; Masterton, 2008).

Recommendations

To mitigate the public health risks associated with *Salmonella* contamination of tomatoes, a multifaceted approach is required. Training and sensitization of farmers, distributors and vendors on safe irrigation, handling and storage practices should be prioritized, alongside routine monitoring of irrigation and wash water for microbial contamination. Strengthened surveillance incorporating both culture and molecular methods will enhance pathogen detection, while strict antimicrobial stewardship in agriculture and clinical practice is necessary to curb resistance. Consumer education campaigns should encourage proper washing and cooking of tomatoes to reduce infection risk. Finally, advanced research including serotyping and whole genome sequencing is

recommended to characterize virulence and resistance genes and to establish potential epidemiological links with human clinical cases.

Conflict of interest

The authors declare no conflict of interest.

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Data availability

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

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