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Assessment of *Salmonella* species in Food Samples from Food Vendors in Wukari, North-East Nigeria

[1]Usman, I. M.*, [1]Brown, S. T. C., [2]Habibu, B., [2]Idris, H. A., & [3]Oladosu, J. I.

[1]Department of Microbiology, Faculty of Biosciences, Federal University, PMB 1020, Wukari, Nigeria

[2]Department of Biochemistry, Faculty of Biosciences, Federal University, PMB 1020, Wukari, Nigeria

[3]Department of Biological Sciences, Federal Polytechnic Bali, Taraba State

***Corresponding author: ikrimah25@gmail.com**

ABSTRACT
Street-vended foods serve as an essential source of nutrition and economic livelihood, particularly in urban and developing regions. However, the unhygienic conditions under which these foods are prepared and sold make them highly susceptible to microbial contamination. This study assessed *Salmonella* species in street-vended foods in Wukari Metropolis, Nigeria, with a specific focus on coliform counts and the presence of *Salmonella* species. A total of ten different food samples were collected from various vendor locations and analyzed using standard microbiological techniques. The results revealed high levels of coliform contamination, with the highest count recorded at MG2 (9.4×10^5 cfu/g) and the lowest at MC2 (3.2×10^5 cfu/g). Notably, NM1 showed no detectable coliform contamination, suggesting better hygiene practices or environmental conditions. *Salmonella* was detected in most food samples, with the highest prevalence at FL2 and MG2 (21.2%), and the lowest at NM1 (3.0%). These findings indicate widespread *Salmonella* species contamination, raising concerns about food safety and public health risks. The study concludes that poor food handling practices, inadequate sanitation, and environmental factors contribute significantly to microbial contamination in street-vended foods. To mitigate these risks, strict hygiene regulations, vendor training programs, and routine microbial surveillance should be implemented. Further research should focus on molecular characterization of pathogens and antibiotic resistance profiling to enhance food safety management strategies.

Keywords: Microorganism, *Salmonella*, Food, Vendors, Coliform, Wukari

INTRODUCTION
Foodborne diseases remain a significant public health challenge globally, with developing countries bearing a substantial burden due to inadequate food safety practices and infrastructure. Among the various pathogens responsible, *Salmonella* species are prominent culprits, causing illnesses ranging from mild gastroenteritis to severe systemic infections. The World Health Organization (WHO) emphasizes that unsafe food containing harmful bacteria, such as *Salmonella*, leads to more than 200 diseases, affecting millions annually (WHO, 2024). The *Salmonella* species, which

causes typhoidal *Salmonella* (TS) and non-typhoid *Salmonella* infection (NTS), is one of the most frequently reported foodborne pathogens currently causing illnesses in humans worldwide (Edobor *et al*., 2022; Abhadionmhen *et al*., 2024). *Salmonella* species are significant pathogens responsible for numerous foodborne illnesses worldwide. The transmission of these bacteria through food handlers poses a considerable public health challenge, especially in regions where food vending is prevalent. Food handling techniques and practices are significant in the transmission of *Salmonella* (Edobor *et al*., 2022).

Salmonella is a genus of Gram-negative, rod-shaped, motile bacterium whose reservoir is the intestines of various animals including humans (Abhadionmhen *et al*., 2024) and other warm and cold-blooded animals as their natural habitats (Imarenezor *et al*., 2022) and facultative anaerobic bacteria belonging to the family Enterobacteriaceae (Imarenezor *et al*., 2022; Abhadionmhen *et al*., 2024). These pathogens are commonly associated with foodborne diseases, leading to conditions such as gastroenteritis and typhoid fever. The primary reservoirs of *Salmonella* include poultry, livestock, and reptiles, but human carriers, particularly food handlers, can also serve as significant sources of contamination.

According to the United States Food Drug Administration (USFDA), poor hygienic practices of food handlers have contributed to the spread of *Salmonella* in foods (Lofstrom *et al*., 2015; USFDA, 2021). Several foodborne outbreaks are associated with restaurants (Ehuwa *et al*., 2021). In Nigeria, street food vending is an integral part of urban life, providing accessible and affordable meals to a large segment of the population and also they plays a crucial role in urban food supply (Ehuwa *et al*., 2021). However, this sector often operates with minimal regulatory oversight, leading to potential health risks. In other word, the sanitary conditions under which these foods are prepared and sold often raise concerns about microbial contamination, including *Salmonella* species.

Salmonella infections, or salmonellosis, are among the most common foodborne illnesses worldwide (Galanis *et al*., 2006). The Centers for Disease Control and Prevention (CDC) estimates that *Salmonella* causes approximately 1.35 million infections, 26,500 hospitalizations, and 420 deaths annually in the United States alone (CDC, 2023). Symptoms typically include diarrhea, fever, and abdominal cramps, appearing 6 hours to 6 days after infection and lasting 4 to 7 days. The severity of salmonellosis can vary, with vulnerable populations such as infants, the elderly, and immunocompromised individuals at higher risk for severe outcomes. The economic burden is also notable, considering medical costs, lost productivity, and implementation of control measures.

Foodborne diseases remain a major public health concern globally, with *Salmonella* species being one of the leading causes of foodborne infections. In developing countries like Nigeria, the risk of *Salmonella* contamination is exacerbated by inadequate food safety regulations, poor hygiene practices, and limited awareness among food vendors (Edobor *et al*., 2022). Street food vending is a vital component of the informal economy in Wukari Metropolis, providing affordable meals to a large portion of the population. However, the unhygienic conditions under which food is prepared, stored, and served

increase the likelihood of microbial contamination, including the presence of *Salmonella* species (Yu *et al*., 2018). Despite the growing concerns regarding food safety, there is limited empirical data on the prevalence and distribution of *Salmonella* among food vendors in Wukari Metropolis. The absence of routine microbial screening of food handlers further complicates the situation, as asymptomatic carriers of *Salmonella* can unknowingly contribute to widespread infections. The problem is further aggravated by the lack of proper infrastructure, such as clean water supply, waste disposal systems, and adherence to sanitary regulations, which are critical for preventing bacterial contamination.

Wukari Metropolis, like many urban centers in Nigeria, relies heavily on street food vendors for daily sustenance. While these vendors provide accessible and affordable meals, the potential for foodborne disease transmission is a pressing concern. Previous studies have documented the prevalence of *Salmonella* among food handlers in various Nigerian regions, but data specific to Wukari are scarce. Understanding the local prevalence and factors contributing to *Salmonella* contamination is essential for developing targeted interventions and policies to safeguard public health. Given these concerns, this study aimed to investigate the isolation and identification of *Salmonella* species from food vendors in Wukari Metropolis, providing insights into potential health risks and informing strategies for improved food safety practices.

MATERIALS AND METHODS

Study area

Wukari Metropolis, located in Taraba State, Nigeria, serves as a significant commercial and educational hub in the region. The town lies between latitude 7°51′0″N and longitude 9°47′0″E, characterized by a tropical climate with distinct wet and dry seasons (Adamu *et al*., 2021; Ikrimah *et al*., 2025). The economic activities in Wukari are diverse, with agriculture, trading, and food vending being prominent (Mohammed, 2024). The presence of the Federal University Wukari and a vibrant market system contribute to the high demand for street-vended food, making the study of foodborne pathogens, such as *Salmonella*, essential for public health surveillance (Ibrahim *et al*., 2020). The selection of Wukari Metropolis for this study is based on its high concentration of food vendors and reported cases of foodborne illnesses (Adebayo *et al*., 2023).

Study Population (Food vendors)

The study population comprises food vendors operating within Wukari Metropolis. These vendors include individuals selling cooked meals, snacks, and raw food items at various locations, including markets, schools, and roadside stalls. Food vendors in the region operate under informal settings with minimal regulatory oversight, increasing the risk of microbial contamination (Aliyu *et al*., 2019). Participants in the study was selected using a stratified random sampling method to ensure representation across different categories of food vendors. The study was taken into consideration factors such as hygiene practices, food handling methods, and knowledge of food safety principles among vendors, which have been reported to influence bacterial contamination levels (Eze *et al*., 2021).

Collection of Samples

To assess the presence of *Salmonella* species among food vendors, various sample types was collected. The sampling strategy targeted critical locations or points. Various ready-to-eat food items, including rice, beans, meat, and salads, was collected for microbial analysis (Ekundayo *et al*., 2022). All collected samples were placed in sterile sample bags and transported under cold-chain conditions (4°C) to the laboratory for analysis within 24 hours to ensure bacterial viability (WHO, 2021).

Laboratory Analysis

The laboratory analysis was followed standard microbiological techniques for the isolation, identification, and confirmation of *Salmonella* species.

Isolation Techniques

The isolation of *Salmonella* was carried out using culture-based methods involving selective and differential media. Initially, samples were pre-enriched in Buffered Peptone Water and incubated at 37 °C for 24 hours to allow the resuscitation and recovery of stressed bacterial cells (ISO, 2020). Following pre-enrichment, selective enrichment was performed by transferring the cultures into Rappaport–Vassiliadis (RV) broth and incubating them at 42 °C for 24 hours to promote the growth of *Salmonella* while suppressing competing microorganisms (Tadesse *et al*., 2021). Subsequently, the enriched cultures were streaked onto selective media, namely Xylose Lysine Deoxycholate (XLD) agar and *Salmonella*–Shigella (SS) agar, and incubated at 37 °C for 24 hours. Presumptive *Salmonella* colonies were identified based on their characteristic appearance as red colonies with black centers on XLD agar due to hydrogen sulfide production (Yousuf *et al*., 2022).

Biochemical Test for *Salmonella* Identification

Biochemical tests are important for the confirmation and identification of *Salmonella* species after their initial isolation on selective culture media. Although colony morphology on selective and differential media may suggest the presence of *Salmonella*, accurate identification requires further biochemical characterization. These tests assess the metabolic and enzymatic activities of the organism, such as carbohydrate fermentation patterns, hydrogen sulfide production, and the ability to utilize specific substrates. The biochemical reactions obtained from these tests help differentiate *Salmonella* from other closely related members of the family *Enterobacteriaceae*. Therefore, a combination of standard biochemical tests are commonly used for the reliable confirmation of *Salmonella* isolates (Cheesbrough, 2006; Tortora *et al*., 2017; Madigan *et al*., 2021).

Triple sugar iron (TSI) test

A sterile needle was used to pick a bacterial colony, stabbed it into the butt of the TSI agar, and streak the slant. The tube is then incubated at 35-37°C for 18-24 hours. Results are interpreted based on color changes: red slant/red butt (no fermentation), red slant/yellow butt (glucose fermentation), yellow slant/yellow butt (glucose + lactose/sucrose fermentation), black precipitate (H_2S production), and bubbles/cracks (gas production) (Brown *et al*., 2025).

Urease test
A urea broth or urea agar slant was prepared by dissolving the base media in distilled water, sterilizing it, and then adding filter-sterilized urea to prevent thermal degradation. The medium was then dispensed into test tubes and stored until use. A sterile inoculating loop was used to transferred a pure bacterial colony into the urea broth or streak it across the slant. The inoculated tube was incubated at 35-37°C for 24-48 hours. After incubation, a bright pink color indicates a positive test, confirming the presence of urease activity due to ammonia production. If there is no color change or a yellow color, the test is negative, indicating that the bacterium does not produce urease (Brown *et al*., 2025).

Indole test
The colony of the 24 hours culture of the test organism (after been checked by Gram staining) was inoculated in a bijou bottle containing 3 mL of sterile tryptone water. It was incubated at 35-37°C for up to 48 hours, then it was tested for production of indole by dispensing 0.5 mL of Kovac's reagent. After gently shaking it, red colour in the surface layer within ten (10) minutes indicated positive result (Cheesbrough, 2006; Brown *et al*., 2025).

Citrate test
A slant of Simmons Citrate Agar was prepared in bijou bottles, one of the sets was used to identify organism. Then with the aid of sterile wire loop, normal saline suspension of the test organisms was streaked on the slants and was incubated at 37°C for 48 hours. A bright blue colour on the agar slants indicated positive result (Cheesbrough, 2006; Brown *et al*., 2025).

RESULTS
The zone of inhibition of the methanol leaf extract of *Chromolaena odorata* shown in Table 1 indicates that the zones of inhibition recorded following exposure of *S. aureus*, *E. coli*, *P. aeruginosa*, *Salmonella spp*., and *Bacillus spp*. to 400 mg/mL methanol leaf extract of *C. odorata* were not significantly ($p>0.05$) different from those recorded following exposure to gentamicin (80 mg/mL), but were significantly ($p<0.05$) higher than those recorded following exposure of isolates to 200 mg/ml, which were not significantly ($p>0.05$) different from those observed following exposure to 100 mg/mL. The zones of inhibition at 100 mg/ml were significantly ($p<0.05$) higher than those reported after exposing isolates to 50 mg/mL, which were also significantly ($p<0.05$) higher than those reported for 25 mg/mL.

Table 1: Zone of inhibition of Methanol Leaf extract of *Chromolaena odorata* (Christmas bush)

	Zone of inhibition (mm)				
Treatment (mg/mL)	*S. aureus*	*E.coli*	*P. aeruginosa*	*Salmonella Sp*	*Bacillus Sp*
400 mg/mL COMLE	26.49 ± 0.01^{d}	26.98 ± 0.29^{c}	26.67 ± 0.28^{c}	26.90 ± 0.37^{c}	26.80 ± 0.27^{c}
200 mg/ mL COMLE	25.60 ± 0.29^{c}	25.60 ± 0.30^{b}	25.40 ± 0.31^{b}	25.00 ± 0.36^{b}	25.60 ± 0.36^{b}

100 mg/ mL COMLE	25.01±0.05^{c}	25.00±0.43^{b}	25.02±0.33^{b}	25.03±0.38^{b}	25.00±0.38^{b}
50 mg/ mL COMLE	24.20±0.18^{b}	24.01±0.26^{a}	24.30±0.43^{a}	24.30±0.19^{a}	24.30±0.41^{a}
25 mg/ mL COMLE	23.08±0.27^{a}	23.70±0.75^{a}	23.09±0.39^{a}	23.90±0.26^{a}	23.09±0.43^{a}
80 mg/mL Gentamicin	26.03±0.31^{d}	27.01±0.21^{c}	26.31±0.33^{c}	26.40±0.33^{c}	26.90±0.51^{c}

Results are expressed as mean ± standard deviation. Values with the same superscript in a row are not significantly ($p<0.05$) different

COMLE = *Chromolaena odorata* Leaf Extract

Zone of inhibition of the aqueous leaf extract of *Chromolaena odorata* shown in Table 2 indicates that the zones of inhibition recorded following exposure of *S. aureus*, *E. coli*, *P. aeruginosa*, *Salmonella spp*., and *Bacillus spp*. to 400 and 200 mg/ml were not significantly different ($p<0.05$), but were significantly lower ($p>0.05$) than those recorded after exposing isolates to gentamicin (80 mg/ml). However, exposing isolates to 100, 50, and 25 mg/ml did not elicit inhibition.

Table 2: Zone of Inhibition of Aqueous Leaf extract of *Chromolaena odorata* (Christmas bush)

	Zone of inhibition (mm)				
Treatment (mg/mL)	*S. aureus*	*E.coli*	*P. aeruginosa*	*Salmonella Sp*	*Bacillus Sp*
400 mg/ mL COALE	15.50±0.01^{b}	15.00±0.31^{b}	15.27±0.23^{b}	16.00±0.37^{b}	15.80±0.21^{b}
200 mg/ mL COALE	14.98±0.92^{b}	15.30±0.32^{b}	14.81±0.38^{b}	15.01±0.37^{b}	15.10±0.37^{b}
100 mg/ mL COALE	0.01±0.05^{a}	0.00±0.43^{a}	0.02±0.33 ^{a}	0.03±0.38^{a}	0.00±0.38 ^{a}
50 mg/ mL COALE	0.00±0.12^{a}	0.00±0.01^{a}	0.00±0.13^{a}	0.00±0.11^{a}	0.00±0.41^{a}
25 mg/ mL COALE	0.00±0.17^{a}	0.00±0.75^{a}	0.00±0.02^{a}	0.00±0.06^{a}	0.00±0.03^{a}
80 mg/mL Gentamicin	22.03±0.31^{c}	22.60±0.21^{c}	22.31±0.33^{c}	22.40±0.33^{c}	22.90±0.51^{c}

Results are expressed as mean ± standard deviation. Values with the same superscript in a row are not significantly ($p<0.05$) different

COALE = *Chromolaena odorata* Aqueous Leaf Extract

DISCUSSION

The area on a culture medium where an antimicrobial agent suppresses bacterial growth is called a zone of inhibition. It is instrumental in determining the effectiveness of antimicrobial substances, aiding clinical treatment and drug discovery. It is an important measurement in laboratory pre-diagnosis, and the final output is instrumental in providing effective treatment against bacterial infections (Balouri *et al*., 2016). The methanol leaf extract of *Chronolaena odorata* was effective against the test bacteria (*S. aureus*, *E. coli*, *P. aeruginosa*, *Salmonella sp, Bacillus sp*) in a dose-dependent manner.

This was contrary to the observations made on the aqueous extract of the leaf of *Chronolaena odorata*. The reportedly impressive antibacterial activity of the methanol leaf extract of *C. odorata* could be attributed to flavonoids, which have been scientifically proven to exhibit antibacterial activity (Odutayo *et al*., 2017). This is consistent with the finding of Phetburom *et al* (2025), which demonstrated the antibacterial activity of ethanol leaf extract of *Chronolaena odorata* against some bacterial strains associated with the skin. The outcome of our study is in tandem with the findings made by Omeke *et al*. (2019), which showed that isolates of *P. aeruginosa* were susceptible to the methanol crude extract of *C. odorata* leaf at high concentrations. The same study also revealed that the antibacterial activity of *C. odorata* methanol leaf crude extract was potentiated with low concentrations of standard antibiotics. The poor antibacterial activity observed in the aqueous leaf extract of *C. odorata* could be attributed to the limited solubility of active non-polar compounds in water, while methanol has the potential to extract a broad spectrum of compounds owing to its ability to extract both polar and semi-polar compounds.

CONCLUSION

The study evaluated the antibacterial activity of the methanol leaf extract of *C. odorata* to assess potency relative to the conventionally used aqueous extract. The results revealed that the methanol leaf extract was more effective than its aqueous counterpart.

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CONFLICTS OF INTREST

The authors declare no conflicts of interest

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