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Assessment of Antimicrobial Resistance Trends in *Listeria monocytogenes* in Borno State: Implications for Food Safety and Public Health

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Abstract

Listeria monocytogenes is a critical food-borne pathogen responsible for listeriosis, a severe infection that has significant repercussions on global public health. Considering the dearth of relevant researches on the prevalence and antibiogram of this pathogen in Northeastern Nigeria, this research was carried out to highlight the resilience of the pathogen against the backdrop of the rise of antimicrobial resistance. The bacteria were isolated from 258 food samples collected from diverse locations and various food types within Maiduguri, Borno State. Isolation was conducted using modified Public Health England protocols, followed by biochemical confirmation tests, including Gram staining and carbohydrate fermentation tests. Antimicrobial susceptibility testing was carried out using the Kirby-Bauer disk diffusion method. The results indicated that 8(3.1%) of the samples were positive for Listeria monocytogenes. The isolates demonstrated 100% sensitivity to Ciprofloxacin and Erythromycin, indicating their efficacy. However, the highest resistance was observed against Norfloxacin (2, 23.0%), followed by the β-lactams (Amoxacillin and Ampiclox), as well as Streptomycin, with resistance rates reaching up to 12.5%. The study recommends implementing antibiotic stewardship programs, enhancing food safety measures, and conducting regular surveillance of L. monocytogenes in food and environmental samples. The study provides a foundational database for monitoring resistance trends in the study region, and can aid the design of epidemiological and intervention strategies in the future.

INTRODUCTION

Listeria monocytogenes is a Gram-positive, facultative anaerobic bacterium that is a major food-borne pathogen, causing listeriosis —a serious zoonotic illness affecting both humans and animals (Quereda *et al.*, 2020). As of 2024, there are 28 species classified under the genus *Listeria,* separated into two categories: sensu stricto and sensu lato (Orsi *et al.*, 2016). The sensu stricto category contains *Listeria monocytogenes* along with nine closely related species*: L. cossartiae, L. farberi, L. immobilis, L. innocua, L. ivanovii, L. marthii, L. seeligeri, L. swaminathanii,* and *L. welshimeri* (Seeliger and Rocourt, 1984; Graves *et al.*, 2010). The other 18 species are part of the sensulato group, which includes *L. aquatica, L. booriae, L. cornellensis, L. costaricensis, L. fleischmannii, L. floridensis, L. goaensis, L. grandensis, L. grayi, L. ilorinensis, L. newyorkensis, L. portnoyi, L. riparia, L. rocourtiae, L. rustica, L. thailandensis, L. valentina,* and *L. weihenstephanensis* (Bertsch *et al.*, 2013; Leclercq *et al.*, 2010). Importantly, *Listeria dinitrificans*, which was initially categorized under *Listeria*, has been moved to a different genus, Jonesia (Rocourt *et al.*, 1987).

This bacterium demonstrates exceptional resilience, enabling it to survive harsh environmental conditions, such as low temperatures, high salt levels, and fluctuating pH levels, which aids its persistence in food processing areas and reduces the risk of food product contamination (Bucur *et al.*, 2018). While human listeriosis is infrequent, it has a high hospitalization rate, exceeding 95%, and mortality rates ranging from 20% to 30%, primarily affecting immunocompromised individuals, pregnant women, newborns, and the elderly (European Food Safety Agency and European Center for Disease Control, 2021). Symptoms can vary from febrile gastroenteritis to serious infections like septicemia and meningitis, with particularly severe consequences during pregnancy, including miscarriage or neonatal death (Rogalla and Bomar, 2022). The capacity of *L. monocytogenes* to invade host cells and breach

critical barriers—such as the intestinal epithelium, placenta, and blood-brain barrier—highlights its pathogenic nature (Koopmans *et al.*, 2023).

Recent outbreaks have highlighted the global threat posed by *L. monocytogenes*. For instance, the outbreak in South Africa from 2017 to 2018, linked to tainted meat products, led to over 1,060 confirmed cases and more than 200 deaths, making it the largest recorded listeriosis epidemic globally (WHO, 2018). Such events highlight the bacterium's adaptability and underscore the urgent need for stringent food safety regulations and effective public health monitoring to mitigate risks associated with *L. monocytogenes* contamination.

Listeria monocytogenes poses a considerable risk to food safety and public health, with patterns of antimicrobial susceptibility varying based on geographical and environmental influences. In Nigeria, including Borno State, there is limited data regarding its resistance profile; however, available studies highlight the need for extensive surveillance to address the rise of multidrug-resistant strains.

Research in Nigeria has shown that *L. monocytogenes* is frequently isolated from contaminated food sources, particularly meat and dairy products, highlighting its potential for foodborne transmission (Adetunji *et al.*, 2017). Documented resistance has been noted against antibiotics such as tetracycline, cephalosporins, and ampicillin, with some strains showing multidrug resistance (MDR) (Adebayo-Tayo and Odu, 2012). Notably, Adetunji and Akanbi (2017) identified resistance to chloramphenicol and amoxicillin-clavulanate, although gentamicin and vancomycin remained effective against the bacteria. This resistance trend raises concerns about the available therapeutic options in areas with limited resources.

In developing regions like Borno State, Nigeria, where food safety protocols and antimicrobial stewardship initiatives are often inadequate, the likelihood of outbreaks associated with antimicrobial-resistant *L. monocytogenes* is pertinent.

Borno State faces unique socio-economic and environmental challenges, including limited access to clean water, poor sanitation, and ongoing conflict with Boko Haram, which creates favorable conditions for the spread of food-borne pathogens (Legit.ng, 2020). Moreover, reliance on open markets and street food, combined with subpar cold chain systems, heightens the risk of contamination by *L. monocytogenes* (Adetunji *et al.*, 2017). These factors underline the need for localized studies to develop baseline antimicrobial susceptibility data, which is currently absent in the region.

Borno State represents a region with distinct epidemiological risks, making it essential to perform susceptibility testing to lessen the health and economic repercussions of listeriosis. The findings from such research can create a foundational database for antimicrobial resistance in the area, support the responsible use of antibiotics, and inform broader national and international monitoring initiatives. This work aims to assess the antimicrobial resistance trends of Listeria monocytogenes in Borno State, exploring the implications for food safety and public health.

MATERIALS AND METHODS

Sample Collection and Transportation

A total of 258 food samples were collected from various market locations in MaiduguriBorno state, Nigeria. The samples included ready-to-eat foods, raw and suya meat (n = 62), dairy products (n = 54), fruits (n = 125), and vegetables (n = 17), representing a broad spectrum of food sources. Sterile containers and polythene bags were used to ensure aseptic collection. Samples were transported under a cold chain (4°C) using insulated boxes with ice packs to preserve bacterial viability. Samples were transported to the Department of Medical Microbiology at the University of Maiduguri Teaching Hospital (UMTH) for analysis. Processing was completed within 24 hours of collection to minimize external contamination (Adetunji *et al.*, 2017).

Isolation of *Listeria monocytogenes*

Food samples were mashed into a semi-powdery paste using a sterile mortar and pestle, then diluted 1:10 in half Fraser broth and homogenized. After 24 hours of incubation at 30°C, 0.1 mL of the culture was transferred to Fraser broth and incubated aerobically for 48 hours at 37°C. Enriched samples were streaked onto Oxford agar and PALCAM agar and incubated at 37°C for 48 hours. Plates were examined at 24-hour intervals, and at least five presumptive colonies were subcultured onto blood agar and incubated at 37°C for 24 hours. Typical *Listeria* colonies were identified through biochemical confirmation tests following Public Health England protocols (2018).

Modification:

The secondary broth cultures (Fraser broths) were serially diluted tenfold using Brain Heart Infusion (BHI) as the diluent. Two loopfulls from 10^{-3} and 10^{-4} dilutions were inoculated into the PALCAM medium and incubated for 48 to 72 hours at 37ºC. Plates were examined for dark grayish or dark colonies with sunken centers,

surrounded by black halos, which are typical of *Listeria*. Each suspected colony was picked up using a wire loop and inoculated into BHI, then incubated at 37 °C for 24 hours. The BHIs were subcultured onto PALCAM agar and typical pure colonies were picked for biochemical tests.

MacConkey Inoculation

A loopful of samples from the half Fraser broth was also inoculated onto MacConkey and incubated at 37 °C for 18 hours. Lactose fermenting colonies suspected as coliform (pink one) were picked and subjected to biochemical tests (Cheesbrough, 2006).

Biochemical Identification

Presumptive colonies were screened as *Listeria monocytogenes* using the following biochemical tests such as Gram staining, catalase, carbohydrate fermentation test (mannitol, xylose and rhamnose, glucose and lactose), motility test, Christie Atkins Munch Peterson test (CAMP test), hemolysis, citrate, urea hydrolysis, indole and kligler's iron agar (KIA) tests (Cheesbrough, 2006).

Biochemical Identification Using VITEK 2 Compact

The isolated colonies were examined for species confirmation using the VITEK 2 Compact (bioMérieux, France) in the manner described below: A McFarland standard of 0.50 was prepared by suspending one purified colony in 3.0 mL of sterile 0.45% saline. This was followed by biochemical identification using the VITEK 2 GP (Gram-Positive) ID card. The card was automatically filled, sealed, and incubated at 37°C once the bacterial suspension was moved into the VITEK 2 Compact system. Over the course of eight hours, the system examined metabolic activity based on biochemical processes. The Advanced Expert System (AES) program was used to create and examine the identification findings and data (BioMerieux, 2021).

Antimicrobial Susceptibility Testing

The Kirby-Bauer disk diffusion method, based on Clinical and Laboratory Standards Institute (CLSI) guidelines, was employed for antimicrobial susceptibility testing. Pure colonies were suspended in sterile saline to achieve a turbidity equivalent to that of a 0.5 McFarland standard. Bacterial suspensions were evenly spread on Mueller-Hinton agar supplemented with 5% sheep blood using sterile cotton swabs. Antibiotic disks, including Ciprofloxacin (5 µg), Erythromycin (15 µg), Amoxicillin (25 µg), Ampiclox (25 µg), Norfloxacin (10 µg), Rifampicin (5µg), Chloramphenicol (10µg), and Streptomycin (10 µg), were aseptically placed on the agar surface. Plates were incubated at 37°C for 18 hours. Inhibition zones were measured in millimeters, and susceptibility was interpreted according to CLSI guidelines (Adetunji and Akanbi, 2017).

RESULTS

The highest isolate was seen in the group of species other than bacterial growth 123 (47.3%), followed by Coliform species (49, 18.8%). The least isolated was *Listeria monocytogenes*, with 8 (3.1%) out of the total 258 samples collected, as shown below (Table 1).

Table 1: The distribution of the bacterial isolates within the different food samples

Isolates	Fruits (n, %)	Meat (Raw/Suya) (n, %)	Milk(n, %)	Vegetables (n, %)	Total(n, %)	P-Value
Coliform species	21 (8.1%)	14 (4.6%)	10 (3.8%)	4 (1.5%)	49 (18.8%)	0.01
Listeria monocytogenes	1 (0.8%)	3 (1.2%)	2 (0.8%)	2 (0.8%)	8 (3.1%)	
Other *Listeria* species	13 (5.0%)	5 (1.9%)	10 (3.8%)	3 (1.2%)	31 (11.9%)	
NBG (No Bacterial Growth)	33 (12.7%)	10 (3.8%)	4 (1.5%)	0 (0.0%)	47 (18.1%)	
Unid. Bacterial Growth	57 (21.9%)	30 (11.5%)	28 (10.8%)	8 (3.1%)	123 (47.3%)	
Total	125 (48.1%)	62 (23.8%)	54 (20.8%)	17 (6.5%)	258 (100.0%)	

Note: NBG = No Bacterial Growth; Unid. = Unidentified. A statistically significant relationship exists between the distribution of bacterial isolates and the types of food samples ($P \leq 0.05$).

The prevalence of *Listeria monocytogenes* in the food samples studied was 8 (3.1%) in this study. The Monday market had the highest number of *Coliform species* and *Listeria monocytogenes*, with 15 (5.8%) and 5 (1.9%) respectively, while the least *Listeria monocytogenes* was observed in Bulumkutu, with 0 (0.0%). The highest *Listeria species* count was observed in Bulumkutu and Custom, with 11 (4.2%) each, while the lowest count was 3 (1.2%) in Baga Road, as shown in Table 2. As for the prevalence within the *Listeria* species, *L. welshimeri* has the highest prevalence, at 17 (40.5%), followed by Listeria monocytogenes, at 8 (19.5%), while the least seen is L. grayi, with 1 (2.4%) out of the 39 total, as shown in Table 3.

Table 2: The prevalence of other *Listeria* species, *Listeria monocytogenes* and other bacterial isolates from the various locations within the state.

Isolates	Baga Road (n, %)	Bulumkutu (n, %)	Custom Market (n, %)	Monday (n, %)	Total (n, %)	P-Value
Coliform species	12 (4.6%)	13 (5.0%)	9 (3.5%)	15 (5.8%)	49 (18.8%)	0.03
Listeria monocytogenes	1 (0.4%)	0 (0.0%)	2 (0.8%)	5 (1.9%)	8 (3.1%)	
Other *Listeria* species	3 (1.2%)	11 (4.2%)	11 (4.2%)	6 (2.3%)	31 (11.9%)	
NBG (No Bacterial Growth)	6 (2.3%)	20 (7.7%)	13 (5.0%)	8 (3.1%)	47 (18.1%)	
Other Bacterial Growth	17 (6.5%)	42 (16.2%)	36 (13.8%)	28 (10.8%)	123 (47.3%)	
Total	39 (15.0%)	86 (33.1%)	71 (27.3%)	62 (23.8%)	258 (100.0%)	

Note: NBG = No Bacterial Growth. A statistically significant relationship exists between the occurrence of *Listeria monocytogenes*, other *Listeria species*, and other bacterial isolates across various locations (P < 0.05).

Table 3: The prevalence of*Listeria monocytogenes* and other *Listeria species from* the various locations within the state.

Location	L. grayi (n, %)	L. innocua (n, %)	L. ivanovii (n, %)	L. monocytogenes (n, %)	L. welshimeri (n, %)	Total (n, %)	P-Value
Baga Road	1 (2.4%)	0 (0.0%)	1 (2.4%)	1 (2.4%)	1 (2.4%)	5 (11.9%)	0.251
Bulumkutu	0 (0.0%)	4 (9.5%)	0 (0.0%)	0 (0.0%)	7 (16.7%)	11 (26.2%)	
Custom	0 (0.0%)	1 (2.4%)	3 (7.1%)	2 (4.8%)	7 (16.7%)	13 (31.0%)	
Monday Market	0 (0.0%)	3 (7.1%)	1 (2.4%)	5 (11.9%)	2 (4.8%)	11 (26.2%)	
Total	1 (2.4%)	8 (19.0%)	5 (11.9%)	8 (19.5%)	17 (40.5%)	39 (100.0%)	

Note: No statistically significant association was observed between Listeria monocytogenes, other *Listeria* species, and sample locations (P > 0.05).

Results from all the *Listeria species* isolated in the food presented pineapple and raw meat have the highest species total of 7(17.9%), with 1(2.6%) and 3(7.7%) *Listeria monocytogenes*, while kindirmu and pawpaw have 5(12.8%) each with *Listeria monocytogenes* 0(0.0%). The least species was seen in suya meat 1(2.6%) with 0(0.0%) *Listeria monocytogenes*, out of the total 39(100%) *Listeria species* isolated as presented in Table 4. Sliced fruits have the highest number of *Listeria species* consisting of 6(14.3%) *Listeria welshimeri* followed by 5(11.9%) each of *Listeria welshimeri* and *Listeria innocua* in sliced fruits and milk respectively. Least *Listeria species* was seen in vegetable 5(11.9%) from 39(100%) total as presented in Table 5.

The most active antibiotics were Ciprofloxacin, Levofloxacin, Erythromycin, and Rifampicin, with 8 (100%) each, while most of the isolates were resistant to Norfloxacin, with 2 (23.0%), as presented in Table 6.

Table 4: The relationship between *Listeria* species in the different food samples (types) collected.

Food Sample	*L. grayi* (n, %)	*L. innocua* (n, %)	*L. ivanovii* (n, %)	*L. monocytogenes* (n, %)	*L. welshimeri* (n, %)	Total(n, %)	P-Value
Cabbage	0 (0.0%)	1 (2.6%)	0 (0.0%)	0 (0.0%)	1 (2.6%)	2 (5.1%)	0.01
Kindirmu	1 (2.6%)	2 (5.1%)	1 (2.6%)	0 (0.0%)	1 (2.6%)	5 (12.8%)	
Pawpaw	0 (0.0%)	3 (7.7%)	0 (0.0%)	0 (0.0%)	2 (5.1%)	5 (12.8%)	
Pineapple	0 (0.0%)	1 (2.6%)	2 (5.1%)	1 (2.6%)	3 (7.7%)	7 (17.9%)	
Raw Meat	0 (0.0%)	0 (0.0%)	1 (2.6%)	3 (7.7%)	3 (7.7%)	7 (17.9%)	
Rufaida	0 (0.0%)	0 (0.0%)	1 (2.6%)	0 (0.0%)	3 (7.7%)	4 (10.4%)	
Sala (sour milk)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (5.1%)	1 (2.6%)	3 (7.7%)	
Salad	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (5.1%)	1 (2.6%)	3 (7.7%)	
Suya Meat	0 (0.0%)	0 (0.0%)	1 (2.6%)	0 (0.0%)	1 (2.6%)	2 (5.1%)	
Watermelon	0 (0.0%)	0 (0.0%)	5 (12.8%)	0 (0.0%)	0 (0.0%)	5 (12.8%)	
Total	1 (2.6%)	8 (20.5%)	8 (20.5%)	8 (20.5%)	14 (35.9%)	39 (100.0%)	

Note: L=*Listeria*. There is a significant relationship between *Listeria* species and the different food types as P≤0.05 statistically in this study.

Table 5: The relationship between *Listeria species* in the different food samples (categories) collected.

Food Category	*L. grayi* (n, %)	*L. innocua* (n, %)	*L. ivanovii* (n, %)	*L. monocytogenes* (n, %)	*L. welshimeri* (n, %)	Total (n, %)	P-Value
Fruits (sliced)	0 (0.0%)	5 (11.9%)	2 (4.8%)	1 (2.4%)	6 (14.3%)	14 (34.1%)	0.01
Meat	0 (0.0%)	0 (0.0%)	1 (2.4%)	3 (7.1%)	4 (9.5%)	8 (19.0%)	
Milk	1 (2.4%)	2 (4.8%)	2 (4.8%)	2 (4.8%)	5 (11.9%)	12 (28.6%)	
Vegetables	0 (0.0%)	1 (2.4%)	1 (2.4%)	2 (4.8%)	2 (4.8%)	6 (14.3%)	
Total	1 (2.4%)	8 (19.0%)	6 (14.3%)	8 (20.5%)	17 (40.5%)	39 (100.0%)	

Note*: L=Listeria and mono=monocytogenes.*There is a significant relationship between *Listeria* species and the different food categories, P<0.05 in this study.

Table 6: The antibiogram susceptibility testing of *Listeria monocytogenes* isolated from the various food samples.

Antimicrobial Group	Antibiotic	Susceptible (n, %)	Resistant (n, %)
Fluoroquinolones	Ciprofloxacin	8 (100.0%)	0 (0.0%)
	Levofloxacin	8 (100.0%)	0 (0.0%)
	Norfloxacin	6 (75.0%)	2 (25.0%)
Penicillins (ß-lactam)	Amoxicillin	7 (87.5%)	1 (12.5%)
	Ampiclox	7 (87.5%)	1 (12.5%)
Aminoglycosides	Streptomycin	7 (87.5%)	1 (12.5%)
Macrolides	Erythromycin	8 (100.0%)	0 (0.0%)
Synthetics	Chloramphenicol	7 (87.5%)	1 (12.5%)
	Rifampicin	8 (100.0%)	0 (0.0%)

DISCUSSION

The prevalence of Coliform species in this study was found to be 18.8%, which is higher than the 12.7% reported by Kia *et al.* (2018) in Kaduna but aligns closely with 17.1% reported by Olatoye *et al.* (2012) in Southwest Nigeria. Despite enhanced sanitation measures from 2019 to 2025, the presence of fecal contamination in food remains a public health concern. This finding highlights the need for stricter hygiene regulations, as fecal contamination is a significant pathway for foodborne illnesses, including diarrhea and other gastrointestinal infections.

From a socio-economic perspective, differences in prevalence rates across regions could be attributed to income levels, accessibility to clean water, and food handling practices. In lower-income areas, poor sanitation infrastructure, reliance on street food, and lack of consumer awareness contribute to higher contamination levels. A global comparison shows that in developed countries like the U.S. and Germany, stringent food safety laws and regular inspections have significantly reduced Coliform prevalence to below 5% (European Food Safety Agency, 2023).

The overall prevalence of *Listeria monocytogenes* in this study was 3.1%, with positive results found in fruit (0.8%), meat (1.2%), milk (0.8%), and vegetables (0.8%). This aligns with the 2.6% reported in Benue State by Hemen et al. (2013), but contrasts sharply with the 28% reported in New Zealand (Stonsaovapak *et al.*, 2010). The higher prevalence in New Zealand may be attributed to climatic conditions that favor bacterial persistence, advanced surveillance mechanisms, and extensive dairy and meat production systems, which increase exposure risks.

Public health implications include an increased risk of listeriosis, a serious food-borne disease with high mortality in vulnerable populations (pregnant women, newborns, and immunocompromised individuals). Socio-economically, developing countries may have higher *Listeria* contamination due to inadequate cold chain storage, making perishable food more susceptible. In comparison, the European Union closely monitors Listeria prevalence in ready-to-eat foods, with contamination rates averaging less than 2% due to improved handling and effective regulatory enforcement (EFSA, 2018).

The occurrence of non-monocytogenes *Listeria* species was 11.9%, with the highest prevalence in fruits (5.0%), meat (1.9%), milk (3.8%), and vegetables (1.2%). This contradicts findings from Maiduguri (60.9%, Onyilokwu et al., 2016) and Ethiopia (26.1%, Gebretsadik et al., 2011), which are likely due to improved sanitation in the study areas.

From a food safety perspective, non-monocytogenes *Listeria* species are generally less pathogenic but can still cause illness, especially in immunocompromised individuals. Socioeconomic factors, such as informal food markets with weak regulatory oversight, contribute to higher rates of contamination. In contrast, developed nations report significantly lower Listeria prevalence due to the enforcement of Hazard Analysis and Critical Control Points (HACCP) in the food industry. Global trends indicate that while *Listeria* outbreaks have declined in high-income countries, they remain a significant problem in regions with weak food safety infrastructure.

The highest *Listeria monocytogenes* prevalence was observed at Monday Market (1.9%), while Bulumkutu Market had a prevalence of 0.0%. This aligns with Musa *et al.* (2023) in Sokoto, who found that smaller, less crowded markets had lower contamination rates due to reduced handling and shorter food exposure times.

Public health implications include higher risk of cross-contamination in densely populated markets. Socio-economically, larger markets tend to have poorer hygiene due to high foot traffic, insufficient waste disposal, and informal food vending. Comparatively, in China and the UK, wet markets and open-air food stalls have been identified as critical points for microbial contamination (Zhao *et al.*, 2022). The trend in developed nations is shifting towards supermarket-based food distribution, which offers better temperature control and hygiene protocols, thereby reducing microbial contamination.

The highest percentage of NBG was found in Bulumkutu Market (7.7%), while Baga Road Market had the least (2.3%). This supports findings from Kasua Central Market in Kaduna (Awopetu *et al.*, 2024), where smaller markets had fewer bacterial isolates due to lower environmental contamination.

This highlights the importance of sanitation training for food vendors and the enforcement of food safety laws. In global food safety trends, high-income countries implement strict hygiene measures, such as mandatory vendor licensing, periodic food inspections, and the use of sanitized food packaging, to maintain low bacterial loads.

The highest *Listeria* occurrence was in sliced fruits (34.1%), suggesting contamination during food handling. This aligns with findings from Benue State (Hemen *et al.*, 2013), where whole

fruits had zero *Listeria* detection. Public health concerns include the risk of listeriosis from contaminated fresh-cut produce, often consumed without further cooking. Socioeconomic factors include inadequate vendor education and a lack of refrigeration in informal markets, which increase microbial growth. In comparison, in Germany, pre-cut fruit contamination has been effectively controlled through strict packaging and cold chain monitoring (Friesema *et al.*, 2023). Global trends emphasize the increased regulation of ready-to-eat foods, particularly in developing nations, where street food culture remains a key source of food.

All *Listeria monocytogenes* isolates in this study (100%) were sensitive to Ciprofloxacin, Ofloxacin, Erythromycin, and Rifampicin, aligning with Ebakota *et al.* (2018) in Ondo, Edo, Delta, and Bayelsa, where Ciprofloxacin sensitivity was 86.66%. However, resistance to Amoxicillin, Ampiclox, and Streptomycin (12.5%) was noted, which contrasts with 100% resistance in Ebakota *et al.* (2018) but aligns with Christy *et al.* (2023) in Egypt (32.65%). The increasing antibiotic resistance among *Listeria* species is a major global food safety challenge. Public health implications include potential treatment failures in listeriosis cases. Resistance mechanisms such as efflux pumps, horizontal gene transfer, and biofilm formation are key contributors (Abdeen *et al.*, 2021). Socioeconomically, the misuse of antibiotics in animal farming and self-medication in humans accelerates resistance. A global comparison reveals that in Europe and the U.S., strict antibiotic stewardship programs have reduced *Listeria* resistance, while Africa and parts of Asia continue to struggle with rising antimicrobial resistance. The global trend is shifting towards alternative treatments such as bacteriophage

5.1 Distribution of the Bacterial Isolates within the Different Food Samples

This study identified the prevalence of Coliform species at 18.8%, which is higher than the 12.7% reported by Kia *et al.* (2018) in Kaduna, but closely resembles the 17.1% found by Olatoye *et al.* (2012) in Southwest Nigeria. Despite the implementation of improved sanitation measures from 2019 to 2025, the presence of fecal contamination in food remains a significant public health concern. This finding underscores the urgent need for more robust hygiene regulations, as fecal contamination is a primary pathway for foodborne illnesses, including diarrhea and other gastrointestinal infections. From a socio-economic perspective, the differences in prevalence rates across regions can be attributed to factors such as income levels, access to clean water, and food handling practices. In lower-income areas, inadequate sanitation infrastructure, reliance on street food, and a lack of consumer awareness contribute to elevated contamination levels. A global comparison reveals that in developed countries such as the U.S. and Germany, stringent food safety laws and regular inspections have effectively reduced Coliform prevalence to below 5% (EFSA, 2021). Additionally, therapy and novel antimicrobials are being developed to combat multidrug-resistant *Listeria* strains.

CONCLUSION

This study demonstrates the presence of Listeria monocytogenes in the study area, albeit at low levels (3.1%), with fruits and raw meat having the highest rates. The isolates are completely susceptible to Ciprofloxacin, Erythromycin, Levofloxacin, and Rifampicin. However, moderate resistance to Norfloxacin, β-lactams, and Streptomycin was observed. These findings offer insights into specific patterns of antibiotic resistance and underscore food safety concerns in informal markets in the study area.

Recommendations

1. There is an urgent need for improved hygiene practices, continuous monitoring of antibiotic resistance, and robust public health education to effectively reduce the risk of listeriosis and protect vulnerable populations in resource-limited areas.
2. Regulatory agencies should enforce hygiene protocols in food processing and distribution chains to minimize bacterial contamination, particularly in ready-to-eat foods.
3. Continuous monitoring of antimicrobial resistance patterns in Listeria monocytogenes is crucial to inform treatment strategies and risk mitigation
4. Education campaigns targeting food handlers and vendors should focus on proper food handling and storage practices, as well as the risks associated with cross-contamination.
5. Markets and regions with higher contamination rates should be prioritized for targeted interventions, including infrastructure improvements and hygiene training programs.
6. To ensure rapid pathogen detection and the development of alternative antimicrobial strategies, multi-sectoral collaboration among governments, food industries, and public health organizations is necessary to ensure food safety and protect public health worldwide.

Competing Interests

The authors have declared that no competing interests exist.

Authors' contribution

Author A designed the study and carried out all the laboratory investigations. B and C- reviewed the protocols, procedures, and made the final corrections with Author A. Author D performed the statistical analyses of the study, Authors E, F and G manage literature searches during the analyses.

REFERENCES

Abdeen, E. E., Mousa, W. S., Harb, O. H., Fath-Elbab, G. A., Nooruzzaman, M., Gaber, A., Alsanie, W. F., & Abdeen, A. (2021). Prevalence, antibiogram and genetic characterization of *Listeria monocytogenes* from food products in Egypt. *Foods, 10*(13), 1–8. [Crossref]

Adebayo-Tayo, B. C., & Odu, N. N. (2012). Incidence and antibiotic susceptibility pattern of *Listeria monocytogenes* from retail smoked fish in Ibadan, Nigeria. *African Journal of Biotechnology, 11*(24), 6050–6058. [Crossref]

Adetunji, V. O., & Akanbi, B. O. (2017). Antimicrobial resistance of *Listeria monocytogenes* from milk and dairy products in Southwestern Nigeria. *Veterinary World, 10*(6), 556–563. [Crossref]

Adetunji, V. O., Olaoye, O. A., Obadina, A. O., et al. (2017). Microbial hazards and critical control points in street-vended foods in South-West Nigeria. *Food Control, 73*, 155–166. [Crossref]

Aisha, B. M., & Kawo, A. H. (2014). Isolation of *Listeria monocytogenes* recovered from some ready-to-eat foods sold in Kano, North-western Nigeria. *Bayero Journal of Pure and Applied Sciences, 7*(2), 8–12. [Crossref]

Alsheikh, A. D. I., Mohammed, G. E., & Abdalla, M. A. (2013). Isolation and identification of *Listeria monocytogenes* from retail broiler chicken ready-to-eat meat products in Sudan. *International Journal of Animal and Veterinary Advances, 5*(1), 9–14. [Crossref]

Awopetu, M. S. (2024). Determination of water quality in pipe distribution network within the Premier Air Force Base Kaduna, Nigeria. *International Journal of Environmental Research and Earth Science, 3*(4).

Belias, A., Brassill, N., Roof, S., Rock, C., Wiedmann, M., & Weller, D. (2021). Cross-validation indicates predictive models may provide an alternative to indicator organism monitoring for evaluating pathogen presence in Southwestern US agricultural water. *Frontiers in Water, 3*(693631), 8–9. [Crossref]

Bertsch, D., Rau, J., Eugster, M. R., Haug, M. C., Lawson, P. A., Lacroix, C., & Meile, L. (2013). *Listeria fleischmannii* sp. nov., isolated from cheese. *International Journal of Systematic and Evolutionary Microbiology, 63*(Pt_2), 526–532. [Crossref]

BioMérieux. (2021). *VITEK 2 Compact: Automated microbial identification and antibiotic susceptibility testing system*. biomerieux.com

Bucur, F. I., Grigore-Gurgu, L., Crauwels, P., Riedel, C. U., & Nicolau, A. I. (2018). Resistance of *Listeria monocytogenes* to stress conditions encountered in food and food processing environments. *Frontiers in Microbiology, 9*, 2700. [Crossref]

Cheesebrough, M. (2006). *District laboratory practice in tropical countries, Part 2* (2nd ed.). Cambridge University Press. [Crossref]

Christy, M. T., Soliman, M., and El-Naggar, M. (2023). Prevalence and antibiotic resistance patterns of foodborne pathogens in Egypt: A systematic review. *Journal of Food Safety*, 43(2), e12967. [Crossref]

Daniel, O., Ebakota, O. A., & Obayagbona, O. N. (2018). Prevalence of antibiotics resistant *Listeria monocytogenes* strains in Nigerian ready-to-eat foods. *Food Safety, 6*(3), 118–125. [Crossref]

Dunka, H. I., Bello, M., & Lawan, M. K. (2021). Prevalence and antibiogram of *Listeria monocytogenes* contamination of liver, spleen, ruminal content and effluent in Jos, Nigeria. *Journal of Veterinary Medicine and Animal Sciences, 4*(1), 1072.

Ebakota, D. O., Abiodun, O. A., & Nosa, O. O. (2018). Prevalence of antibiotics resistant *Listeria monocytogenes* strains in Nigerian ready-to-eat foods. *Food Safety, 6*(3), 118–125. [Crossref]

Ebakota, O. S., Chah, K. F., and Iroha, I. R. (2018). Antibiotic resistance profiles of Escherichia coli isolates from ready-to-eat foods in Nigeria. *African Journal of Microbiology Research*, 12(14), 322-328. [Crossref]

European Food Safety Authority & European Centre for Disease Prevention and Control. (2021). The European Union

summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2020. *EFSA Journal, 19*(12), e06971.

European Food Safety Authority and European Centre for Disease Prevention and Control. (2023). *The European Union One Health 2022 Zoonoses Report*. EFSA Journal, 21(12), e08170. [Crossref]

European Food Safety Authority. (2018). *Listeria monocytogenes* contamination of ready-to-eat foods and the risk for human health in the EU. *EFSA Journal, 16*(1), 5134. [Crossref]

FAO & WHO. (2022). *Listeria monocytogenes in ready-to-eat (RTE) foods: Attribution, characterization, and monitoring (Microbiological Risk Assessment Series No. 38)*. FAO.

Friesema, I. H. M., Verbart, C. C., van der Voort, M., Stassen, J., & Lanzl, M. I. (2023). Combining whole genome sequencing data from human and non-human sources: Tackling *Listeria monocytogenes* outbreaks. *Microorganisms, 11*, 2617. [Crossref]

Gebretsadik, S., Kassa, T., Alemayehu, H., Huruy, K., & Kebede, N. (2011). Isolation and characterization of *Listeria monocytogenes* and other *Listeria* species in foods of animal origin in Addis Ababa, Ethiopia. *Journal of Infection and Public Health, 4*(1), 22–29. [Crossref]

Graves, L. M., Helsel, L. O., Steigerwalt, A. G., Morey, R. E., Daneshvar, M. I., Roof, S. E., Orsi, R. H., Fortes, E. D., Milillo, S. R., den Bakker, H. C., Wiedmann, M., Swaminathan, B., & Sauders, B. D. (2010). *Listeria marthii* sp. nov., isolated from the natural environment, Finger Lakes National Forest. *International Journal of Systematic and Evolutionary Microbiology, 60*(6), 1280-1288. [Crossref]

Hammuel, C., Abdullahi, I. O., Whong, C. M. Z., & Kadima, K. B. (2019). Occurrence of *Listeria* species in some food items sold in parts of Kaduna, Nigeria. *FUDMA Journal of Sciences, 3*(4), 544–552.

Hemen, J. T., Johnson, J. T., Ambo, E. E., Ekam, V. S., Odey, M. O., & Fila, W. A. (2013). Multi-antibiotic resistance of some Gram-negative bacterial isolates from poultry litters of selected farms in Benue State. *International Journal of Science and Technology, 2*(8), 543–547.

Hemen, J. T., Johnson, J. T., Fagbenro, O. M., & Bassey, S. E. (2013). An assessment of the presence of *Listeria monocytogenes* in ready-to-eat food and fruits sold in markets in Guinea Savanna Belt-Nigeria. *International Journal of Pharma and Bio Sciences, 4*(4), 286–292.

Ikeh, E. I., Obi, S. K. C., Ezeasor, D. N., et al. (2010). Incidence and virulence determinants of *Listeria monocytogenes* isolates from food and environmental samples in Nigeria. *African Journal of Biotechnology, 9*(30), 4776–4782.

Jadhav, S. (2015). Detection and characterization of *Listeria monocytogenes* in food and environmental samples. *Food Control, 47*, 501–508. [Crossref]

John, G. E., Lennox, J. A., Johnson, J. T., Peters, H., & Umoafia, G. E. (2017). *Salmonella* and *Listeria* associated with street-vended watermelon and pawpaw sold in Calabar Metropolis. *Journal of Advances in Microbiology, 5*(4), 1–6. [Crossref]

Kia, G. S. N., Mshelia, W. P., Sackey, A. K. B., & Tekdek, L. B. (2018). Bacteriological quality of dried crayfish (*Procambarus clarkii*) sold in Samaru, Sabon-Gari and Central Market Kaduna, Kaduna State, Nigeria. *Nigerian Veterinary Journal, 41*(1), 33–40. [Crossref]

Koopmans, M. M., Bijlsma, M. W., Brouwer, M. C., & van de Beek, D. (2023). *Listeria monocytogenes* meningitis: A review of clinical presentation, diagnosis, and treatment. *Journal of Clinical Medicine, 12*(2), 471.

Lawan, M. K., Maitala, Y. S., Ojonuma, Y. R., Yusuf, Y., Yusuf, M. S., Muhammad, G. M., & Bashir, U. U. (2021). Occurrence of *Listeria monocytogenes* in camel milk cheese from two township markets of Borno and Kano States, Nigeria. *Savannah Veterinary Journal, 4*(20), 1-8. [Crossref]

Leclercq, A., Clermont, D., Bizet, C., Grimont, P. A. D., Le Flèche-Matéos, A., Roche, S. M., Buchrieser, C., Cadet-Daniel, V., Le Monnier, A., Lecuit, M., & Allerberger, F. (2010). *Listeria rocourtiae* sp. nov. *International Journal of Systematic and Evolutionary Microbiology, 60*(9), 2210-2214. [Crossref]

Legit. (2020). State of access to effective water, sanitation and hygiene in Nigeria's urban areas. legit.ng

Musa, K. A., Bello, A., & Usman, Y. M. (2023). *Listeria monocytogenes* contamination in milk and poultry products: A case study from Sokoto State, Nigeria.

African Journal of Microbiology, 19(4), 221–229.

Okonkwo, L. N., Chukwuezi, F. O., & Ozuogwu, N. E. O. (2014). Isolation of *Listeria monocytogenes* from raw vegetables and meat sold in open market in Onitsha metropolis, Anambra State, Nigeria. *Advances in Biological Research, 8*(2), 79–82.

Olatoye, I. O., Amosun, E. A., & Ogundipe, G. A. (2012). Multidrug resistant *Escherichia coli* 0157:H7 contamination of beef and chicken in municipal abattoirs of Southwest Nigeria. *Nature and Science, 10*(8), 3–4.

Onyilokwu, S. A., Lawan, F. A., Hambali, I. U., Mailafiya, S., Adamu, N. B., Atsanda, N. N., & Jauro, S. (2016). Phenotypic characterisation and distribution pattern of *Listeria* species isolated from food samples retailed in markets and central abattoir in Maiduguri, Nigeria. *Alexandria Journal of Veterinary Sciences, 51*(1), 122–126. [Crossref]

Orsi, R. H., Borowsky, M. L., Lauer, P., Young, S. K., Nusbaum, C., & Galagan, J. E. (2008). Short-term genome evolution of *Listeria monocytogenes* in a non-controlled environment. *BMC Genomics, 9*(2008), 1–17. [Crossref]

Public Health England. (2018). *Detection and enumeration of Listeria monocytogenes and other Listeria species* (National Infection Service, Food, Water & Environmental Microbiology Standard Method FNES22 (F19); Version 4).

Public Health England. (2018). *Listeria species: Identification and susceptibility testing*. gov.uk

Quereda, J. J., Morón-Gálvez, L., Ortega, A. D., & Pucciarelli, M. G. (2020). Pathogenicity and ecology of *Listeria monocytogenes*: An overview. *International Journal of Food Microbiology, 324*, 108640.

Rocourt, J., Wehmeyer, U., & Stackebrandt, E. (1987). Transfer of *Listeria dentrificans* to a new genus, *Jonesia* gen. nov., as *Jonesia denitrificans* comb. nov. *International Journal of Systematic Bacteriology, 37*(3), 266–270. [Crossref]

Rogalla, D., & Bomar, P. A. (2022). *Listeria monocytogenes*. In *StatPearls* [Internet]. StatPearls Publishing.

Seeliger, H. P. R., & Rocourt, J. (1984). Notes: *Listeria ivanovii* sp. nov. *International Journal of Systematic and Evolutionary Microbiology, 34*(3), 336–337. [Crossref]

Stonsaovapak, S., & Boonyaratanakornkit, M. (2010). Prevalence and antimicrobial resistance of *Listeria* species in food products in Bangkok, Thailand. *Food Safety, 30*(1), 153–161. [Crossref]

World Health Organization. (2018). *Listeriosis - South Africa*. who.int

Zhao, X., Lin, C. W., Wang, J., & Oh, D. H. (2022). Advances in rapid detection methods for food-borne pathogens. *Journal of Microbiology and Biotechnology, 24*, 297–312. [Crossref]