Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

# Prevalence and Multiplex PCR-Based Molecular Detection of Campylobacter jejuni and Campylobacter coli in Chickens and Hand Swabs of Handlers at Live Bird Markets in Maiduguri Metropolis, Nigeria

**Moses Luke**

moseslukeofficial@gmail.com

University of Port Harcourt, Nigeria https://orcid.org/0000-0002-0600-6660

**Bashir Usman Malgwi**

University of Maiduguri

**Research Article**

**Keywords:** Campylobacter coli, Campylobacter jejuni, live bird market, molecular detection, multiplex PCR, prevalence, zoonosis, Nigeria

**Posted Date:** September 4th, 2026

**DOI:** https://doi.org/10.21203/rs.3.rs-10910729/v1

**License:** This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

**Additional Declarations:** The authors declare no competing interests.

# Prevalence and Multiplex PCR-Based Molecular Detection of Campylobacter jejuni and Campylobacter coli in Chickens and Hand Swabs of Handlers at Live Bird Markets in Maiduguri Metropolis, Nigeria

**Bashir Usman Malgwi[1,3,*], Abdulrahman Mohammed[1], Naphtali Nocholas Atsanda[1], Shuaibu Gidado Adamu[1], Adamu Saleh Saidu[1], Francis Ejeh Oche[1], Iliya Dauda Kwoji1[1], Barja John[1], Moses Luke[2,3]**

[1]Department of Veterinary Public Health and Preventive Medicine, Faculty of Veterinary Medicine, University of Maiduguri, Maiduguri, Borno State, Nigeria

[2]School of Public Health, University of Port Harcourt, Nigeria

[3]FHI 360, Abuja, Nigeria

***Correspondence: Bashir Malgwi; bashirusmanmalgwi@gmail.com**

## Abstract

**Background:** *Campylobacter jejuni* and *Campylobacter coli* are the leading bacterial causes of foodborne zoonotic gastroenteritis globally, with poultry as the principal reservoir. Despite the recognised risk posed by live bird markets (LBMs) in Nigeria, molecular surveillance of these pathogens at the human-poultry interface in Maiduguri, Borno State, remains limited. This study determined the prevalence and performed multiplex PCR-based species identification of *C. jejuni* and *C. coli* in chickens and chicken handlers across six LBMs in Maiduguri Metropolis.

**Methods:** A cross-sectional study was conducted between June and August 2020. A total of 212 samples were collected: 135 broiler cloacal swabs, 60 local chicken cloacal swabs, and 17 hand swabs from chicken handlers. All samples were cultured on Campylobacter-selective agar under microaerobic conditions (42°C, 48 h). Confirmed isolates were subjected to conventional PCR (16S rRNA, 566 bp) for genus confirmation and multiplex PCR targeting *HipO* (323 bp) for *C. jejuni* and *CeuE* (126 bp) for *C. coli*. Exact binomial 95% confidence intervals (CIs) were calculated using the Clopper-Pearson method. Binary logistic regression assessed species-specific infection risk by chicken type.

**Results:** Overall *Campylobacter* prevalence was 23.1% (95% CI: 17.5%–29.6%). Cloacal swabs yielded 22.6% (95% CI: 17.0%–29.2%) positive samples; hand swabs yielded 29.4% (95% CI: 10.8%–56.4%). Local chickens had significantly higher prevalence (35.0%; 95% CI: 22.3%–49.2%) than broilers (17.0%; 95% CI: 11.3%–24.3%; $\chi^2$=8.80, p=0.003). Multiplex PCR confirmed *C. jejuni* in 19 (38.8%; 95% CI: 25.0%–54.3%) and *C. coli* in 3 (6.1%; 95% CI: 1.3%–16.7%) of 49 isolates. Local chickens were 2.82 times more likely to harbour *Campylobacter* than broilers (OR=2.82; 95% CI: 1.39–5.69; p=0.004).

**Conclusions:** *C. jejuni* and *C. coli* are prevalent in chickens and on the hands of chicken handlers at Maiduguri LBMs. The significantly higher infection odds among local chickens and the documented occupational exposure among handlers underscore the need for targeted biosecurity measures, food safety interventions, and routine molecular surveillance at the human–poultry interface in northeastern Nigeria.

**Keywords:** Campylobacter coli; Campylobacter jejuni; live bird market; molecular detection; multiplex PCR; prevalence; zoonosis; Nigeria

## Background

*Campylobacter* species are the most frequently identified bacterial cause of acute gastroenteritis in humans globally, exceeding *Salmonella* and *Escherichia coli* in many surveillance systems (Skarp et al., 2016). The two thermophilic species *Campylobacter jejuni* and *Campylobacter coli* together account for approximately 95% of all human campylobacteriosis cases worldwide (Coker et al., 2002). In the European Union, more than 214,268 confirmed human cases were recorded in 2013 (European Food Safety Authority [EFSA], 2015), and approximately 1.3 million infections occur annually in the United States (Scallan et al.,

2011). In Nigeria, documented prevalences range from 10.5% to 81.9% depending on sample type and region (Abubakar, 2019; Salihu et al., 2009), though systematic data remain sparse in northeastern states.

Poultry are the principal zoonotic reservoir of thermophilic *Campylobacter*. The high body temperature of chickens (41–42°C) provides an ideal environment for colonisation (Hald et al., 2015), and the organisms are shed asymptomatically into the caecal environment. Transmission to humans occurs primarily through handling or consuming contaminated, undercooked poultry or via direct occupational contact with live birds (Stern & Robach, 2003). Live bird markets (LBMs), where poultry are traded, slaughtered, and processed under open-air, low-biosecurity conditions, represent critical amplification points for zoonotic spillover (Carron et al., 2018).

Molecular methods, particularly conventional and multiplex PCR, offer greater sensitivity and specificity than culture-based approaches for *Campylobacter* surveillance (Adzitey et al., 2013). The *HipO* gene is the established PCR target for *C. jejuni* speciation (Wang et al., 2002), while *CeuE* is the validated marker for *C. coli* (Nwankwo et al., 2017). Despite their complementary value and the combined culture, multiplex PCR studies at the LBM human–animal interface remain scarce in northeastern Nigeria.

Maiduguri Metropolis, capital of Borno State, hosts multiple active LBMs serving a population estimated at over one million (Jimme et al., 2016). A prior study documented *Campylobacter* prevalence of 31.3% in chickens and 10.5% in humans in this metropolis (Abubakar, 2019), but no subsequent study has applied multiplex PCR speciation concurrently with occupational exposure assessment among chicken handlers. The present study addressed that evidence gap by determining *Campylobacter* prevalence with exact confidence interval estimates, confirming genus and species identity by molecular methods, and assessing the odds of infection by chicken type.

## Methods

### Study Area and Design

A cross-sectional study was conducted from June to August 2020 in Maiduguri Metropolis, Borno State, northeastern Nigeria (coordinates: 11°04'N–11°44'N; 13°04'E–13°44'E; elevation 300 m above sea level). Six LBMs were purposively selected from 13 major markets across the metropolis: Monday Market, Baga Road, Milk Shop (Gidan Madara), Gamboru (Customs) Market, Damboa Road, and Bama Road. Ethical approval was obtained from the Borno State Ministry of Health; all chicken handlers provided written informed consent prior to enrolment.

### Sample Size and Sampling

The minimum sample size of 212 was calculated using the formula $N = Z^2P(1-P)/d^2$ (Thrusfield, 2010), with $Z = 1.96$, $P = 0.165$ (prior Nigerian prevalence from Coker & Adefeso, 1994), and $d = 0.05$. A total of 212 samples were aseptically collected: 135 cloacal swabs from broiler chickens, 60 from local (indigenous free-range) chickens, and 17 hand swabs from handlers. Cloacal swabs were inserted approximately 2 cm into the cloaca; hand swabs sampled the palmar surface and inter-digital spaces. All swabs were placed in Amies transport medium, stored on ice, and processed within six hours.

### Bacteriological Culture and Biochemical Confirmation

Swabs were enriched in buffered peptone water (Oxoid, UK) at 37°C for 18–24 h, then plated onto Campylobacter blood-free selective agar and incubated at 42°C for 48 h under microaerobic conditions (5% $O_2$, 10% $CO_2$, 85% $N_2$). Presumptive colonies were confirmed by Gram stain (curved or spiral Gram-negative rods) and a biochemical panel: oxidase-positive, catalase-positive, citrate-positive, and urease-negative (Leaper & Owen, 1981).

### DNA Extraction and Conventional PCR

Genomic DNA was extracted from confirmed colonies using the Promega Wizard Genomic DNA Purification Kit (Promega, France) following lysis at 100°C for 10 min, centrifugation at 13,000 × g, and resuspension in 100 µl Tris-EDTA buffer. Conventional PCR targeting the *Campylobacter* 16S rRNA gene

(566 bp) used primers described by Frasão et al. (2017): Forward 5'-GGTGTAGGATGAGACTATATA-3', Reverse 5'-TTCCATCTGCCTCTCCC-3'. Reactions (20 µl) comprised 4 µl Master Mix, 0.4 µl each primer (10 mM), 2.5 µl DNA, and 12.7 µl RNase-free water. Cycling: 95°C × 5 min; 35 cycles of 95°C × 5 min / 40°C × 5 min / 72°C × 5 min; final extension 72°C × 5 min.

**Multiplex PCR for Species Identification**

Multiplex PCR simultaneously identified *C. jejuni* using the *HipO* gene (323 bp; Wang et al., 2002) and *C. coli* using the *CeuE* gene (126 bp; Nwankwo et al., 2017). Reactions (20 µl) contained 4 µl Master Mix, 0.8 µl of each primer pair (10 mM), 2 µl DNA, and 13.2 µl RNase-free water. Cycling: 95°C × 5 min; 25 cycles of 95°C × 3 min / 44°C × 30 s / 72°C × 40 s; final extension 72°C × 5 min. *Campylobacter jejuni* ATCC 33560 served as the quality control strain. Amplicons were resolved on 1.5% agarose gels.

**Statistical Analysis and Prevalence Estimation**

Data were analysed using SPSS version 20.0 (IBM Corp., Armonk, NY, USA). Prevalence was calculated as positive/total × 100. Exact binomial 95% CIs were calculated using the Clopper–Pearson method. Chi-square and Fisher's exact tests were used to compare prevalence across groups ($p<0.05$). Binary logistic regression estimated odds ratios (ORs) with 95% CIs for *Campylobacter* infection by chicken type, with broilers as the reference category. The positive predictive value (PPV) of biochemical confirmation relative to multiplex PCR speciation was also calculated.

## Results

**Overall Prevalence with Confidence Intervals**

Of the 212 samples analysed, 49 (23.1%) were positive for *Campylobacter* species. Table 1 presents the prevalence estimates with exact 95% CIs across all sample categories. Cloacal swabs yielded 44/195 (22.6%; 95% CI: 17.0%–29.2%) positives. Hand swabs yielded 5/17 (29.4%; 95% CI: 10.8%–56.4%). Within the chicken cohort, local chickens had a significantly higher prevalence (21/60; 35.0%; 95% CI: 22.3%–49.2%) compared to broilers (23/135; 17.0%; 95% CI: 11.3%–24.3%). The 95% CIs for local chicken and broiler prevalences do not overlap, consistent with the statistically significant difference confirmed by chi-square analysis ($\chi^2=8.80$, $p=0.003$).

**Table 1: Prevalence of Campylobacter species by sample type with exact 95% Clopper–Pearson confidence intervals, Maiduguri Metropolis**

| Sample Type | Tested (n) | Positive (n) | Prevalence (%) | 95% CI (%) |
|---|---|---|---|---|
| **Broilers (cloacal swabs)** | 135 | 23 | 17.0 | 11.3 – 24.3 |
| **Local chickens (cloacal swabs)** | 60 | 21 | 35.0 | 22.3 – 49.2 |
| **All cloacal swabs** | 195 | 44 | 22.6 | 17.0 – 29.2 |
| **Hand swabs (chicken handlers)** | 17 | 5 | 29.4 | 10.8 – 56.4 |
| **Overall** | 212 | 49 | 23.1 | 17.5 – 29.6 |

**Prevalence Across Live Bird Markets**

Table 2 presents the market-level distribution of *Campylobacter* positivity. The highest cloacal swab prevalence was at Bama Road (2/4; 50.0%) and Gamboru Market (19/42; 45.2%). Damboa Road had the lowest poultry prevalence (3/44; 6.8%). A statistically significant difference in prevalence was observed across market locations (Fisher's exact test, p=0.000). Among hand swabs, Damboa Road showed 100% positivity (4/4), while Baga Road, Gamboru Market, and Milk Shop yielded no positive hand swab samples.

**Table 2: Campylobacter prevalence across Live Bird Markets in Maiduguri Metropolis**

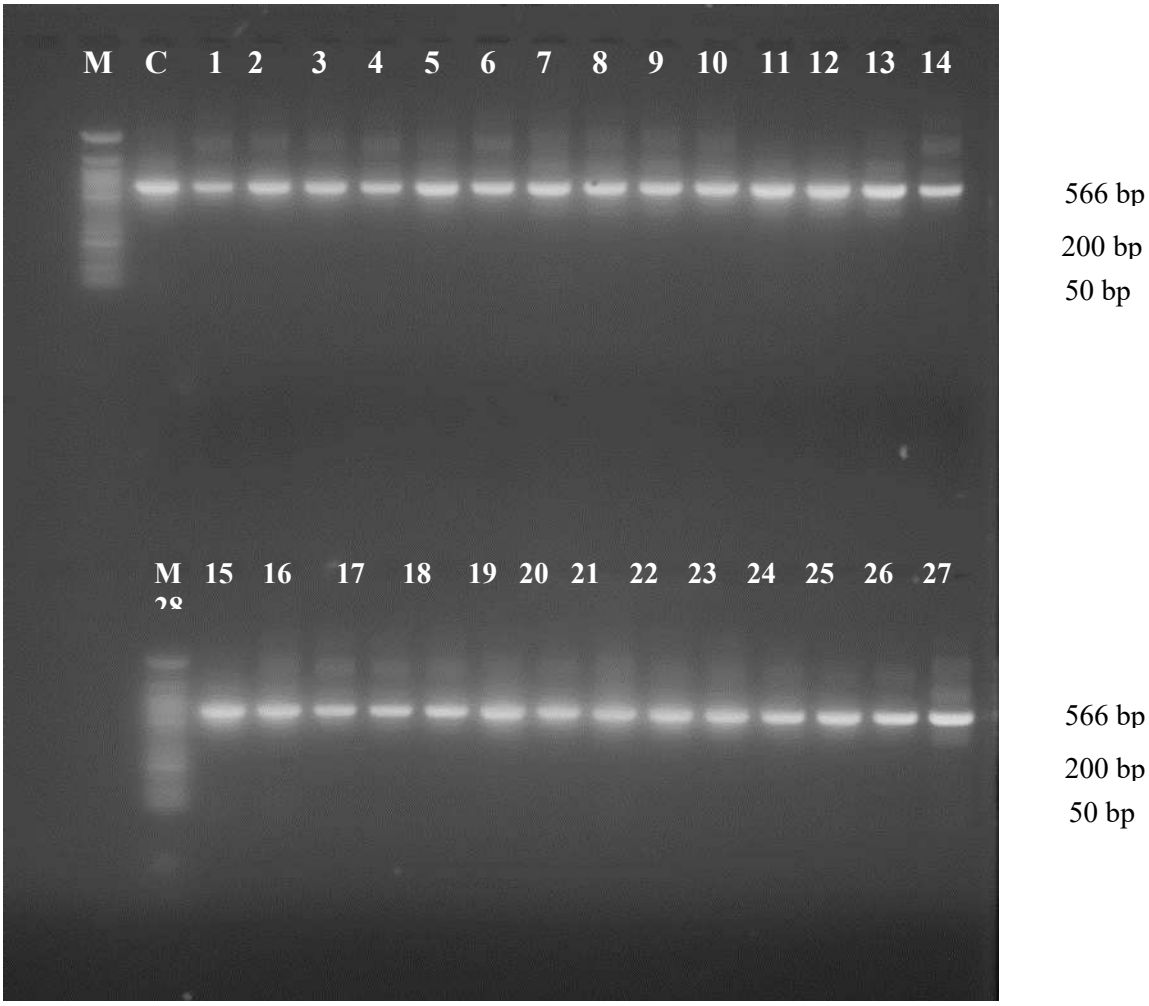
| LBM Location | Cloacal Swabs Tested | Positive n (%) | Hand Swabs Tested | Positive n (%) |
|---|---|---|---|---|
| **Baga Road** | 17 | 7 (41.2) | 3 | 0 (0.0) |
| **Bama Road** | 4 | 2 (50.0) | 2 | 1 (50.0) |
| **Gamboru Market** | 42 | 19 (45.2) | 3 | 0 (0.0) |
| **Damboa Road** | 44 | 3 (6.8) | 4 | 4 (100.0) |
| **Milk Shop** | 15 | 2 (13.3) | 5 | 0 (0.0) |
| **Monday Market** | 73 | 11 (14.5) | 0 | — |
| **Total** | 195 | 44 (22.6) | 17 | 5 (29.4) |

**Molecular Speciation by Multiplex PCR**

All 49 culture-confirmed isolates were positive by conventional PCR at 566 bp (16S rRNA), confirming the *Campylobacter* genus. Subsequent multiplex PCR (Table 3) identified *C. jejuni* in 19/49 isolates (38.8%; 95% CI: 25.0%–54.3%) and *C. coli* in 3/49 (6.1%; 95% CI: 1.3%–16.7%). The *C. jejuni*:*C.* The *coli* ratio was approximately 6.3:1. Species-level breakdown by source revealed that local chicken isolates accounted for the highest proportion of species identifications. The remaining 27 isolates (55.1%) were not speciated by the two-species multiplex, suggesting the presence of other thermophilic *Campylobacter* species or mixed colonisation patterns.

**Molecular Confirmation of *Campylobacter* Isolates by 16S rRNA Gene Amplification**

The molecular confirmation of *Campylobacter* isolates was performed using agarose gel electrophoresis following PCR amplification of the 16S rRNA gene. Figures 1 and 2 present representative gel images showing successful amplification of the expected 566 bp amplicon among isolates obtained from chickens and the hands of chicken handlers in Maiduguri Metropolis. Positive controls confirmed the validity of the assay, while the molecular marker was used to verify the expected fragment size.




Figures 1: Agarose Gel Electrophoresis for Amplification of 16S rRNA Gene of Genus *Campylobacter* Among Chickens and Hands of the Chicken Handlers in Maiduguri Metropolis. Lane M: Molecular marker (50 bp, Fermentas), Lane 1: positive control; Lane 2- 29: positive *Campylobacter* isolates.

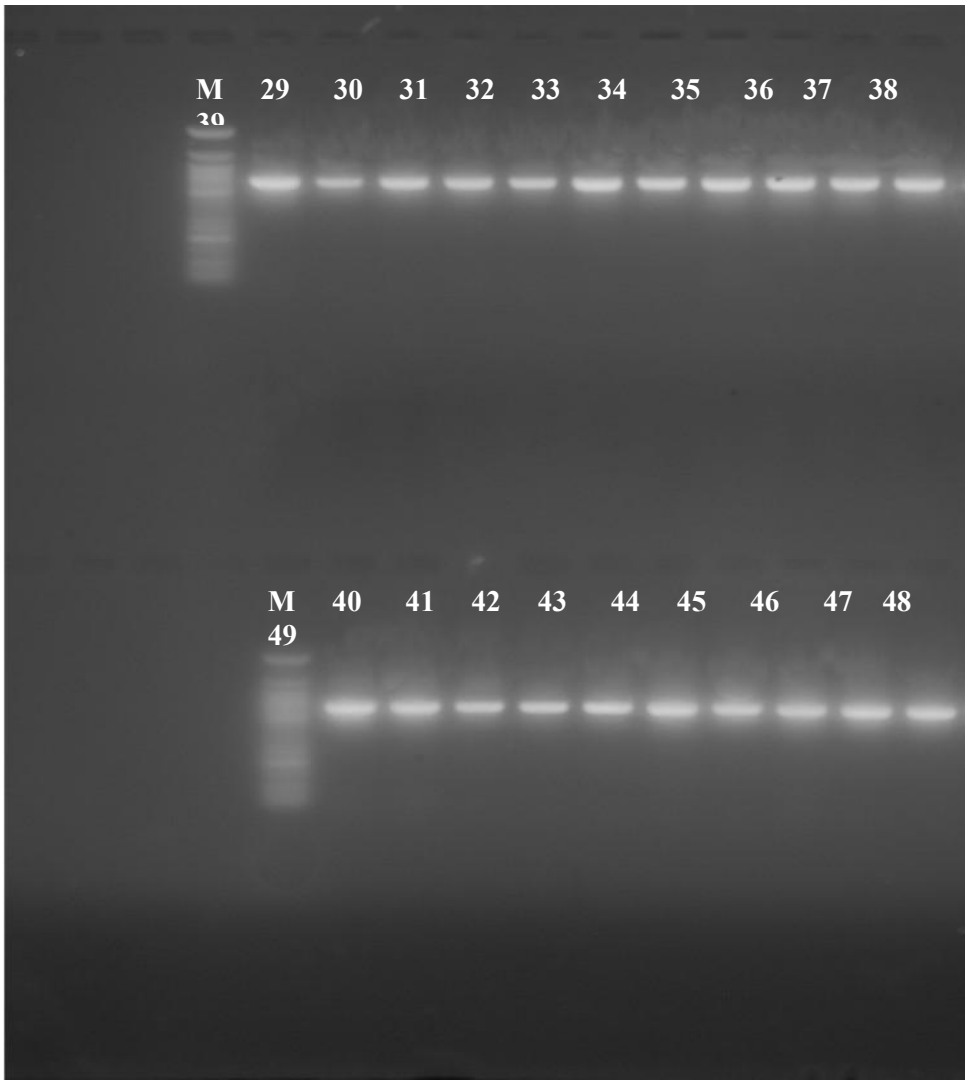



Figure 2: Agarose Gel Electrophoresis for Amplification of 16S rRNA Gene of Genus *Campylobacter* Among Chickens and Hands of the Chicken Handlers in Maiduguri Metropolis (2nd Set). M: Molecular marker (50 bp, Fermentas), Lane 1: positive control; Lane 29- 50: positive *Campylobacter* isolates.

**Table 3: Multiplex PCR speciation of Campylobacter isolates by sample source with 95% CIs**

| Source | Total Isolates | C. jejuni n (%; 95% CI) | C. coli n (%; 95% CI) | Unspeciated n (%) |
|---|---|---|---|---|
| **Local chickens** | 21 | 9 (42.9%; 21.8–66.0) | 2 (9.5%; 1.2–30.4) | 10 (47.6) |
| **Broilers** | 23 | 10 (43.5%; 23.2–65.5) | 1 (4.3%; 0.1–21.9) | 12 (52.2) |
| **Hand swabs** | 5 | 0 (0.0%; 0.0–52.2) | 0 (0.0%; 0.0–52.2) | 5 (100.0) |
| **Total** | 49 | 19 (38.8%; 25.0–54.3) | 3 (6.1%; 1.3–16.7) | 27 (55.1) |

### Risk of Campylobacter Infection by Chicken Type: Logistic Regression

Binary logistic regression (Table 4) confirmed that local chickens were 2.82 times more likely to harbour *Campylobacter* infection compared to broilers (OR=2.82; 95% CI: 1.39–5.69; p=0.004). The chi-square test also showed a statistically significant association between chicken type and *Campylobacter* positivity ($\chi^2$=8.80, p=0.003). The source of birds (supplied by farmers vs. raised by sellers) showed a higher prevalence among seller-raised birds (6/13; 46.2%) than among farmer-supplied birds (43/199; 21.6%), though this difference should be interpreted with caution, given the small seller-raised sample size.

**Table 4: Logistic regression for Campylobacter infection risk by chicken type (broilers = reference)**

| Variable | Category | Campylobacter Positive n (%) | OR | 95% CI | p-value |
|---|---|---|---|---|---|
| Chicken type | Broilers (reference) | 23 (17.0) | 1.00 | — | — |
| | Local chickens | 21 (35.0) | 2.82 | 1.39–5.69 | 0.004* |

** p < 0.05 statistically significant; OR = odds ratio; CI = confidence interval.*

## Discussion

This study documented a *Campylobacter* prevalence of 23.1% (95% CI: 17.5%–29.6%) across all sample types in Maiduguri's LBMs, a finding that falls within the range of recent Nigerian reports. Benshak et al. (2023) reported a comparable 23.0% in Plateau State, and Nwankwo et al. (2016) documented 30.0% in Sokoto State. Sub-Saharan African regional data show broad variation: 22.5% in Ghana (Akosua et al., 2017), 28.9% in Ethiopia, and 69.8% in Tanzania (Mdegela et al., 2006), differences attributable to market hygiene standards, flock management, seasonal variation, and sampling period (Mary et al., 2004).

The significantly higher prevalence in local chickens (35.0% vs. 17.0% in broilers; OR=2.82; p=0.004) is consistent with Mdegela et al. (2006) and is biologically plausible. Local chickens in Nigeria are reared under extensive free-range conditions, with unrestricted access to soil, water, and wildlife, environments in which *Campylobacter* carriage is sustained through horizontal transmission (Njoga et al., 2020). Intensive broiler production, by contrast, imposes partial environmental barriers. This finding has direct implications for risk communication: traders and consumers should be advised that local chickens carry a demonstrably higher risk of contamination than commercial broilers.

The 29.4% positivity rate among hand swabs from chicken handlers, despite the small sample size (n=17), is consistent with the documented role of direct occupational contact as a transmission pathway (Klous et al., 2016). Approximately 48% of human campylobacteriosis cases worldwide are attributed to contaminated poultry handling (Greig & Ravel, 2009), and the current finding reinforces the need for mandatory hand hygiene protocols and the provision of personal protective equipment at Nigerian LBMs.

The confirmation of *C. jejuni* as the dominant species (38.8% of all isolates vs. 6.1% *C. coli*) aligns with global epidemiological patterns (Coker et al., 2002) and earlier Nigerian reports from Kogi and Enugu states (Njoga et al., 2019; Ohanu & Offune, 2009). The lower *C. coli* recovery likely reflects its lower thermotolerance at avian body temperature. The 55.1% of isolates unspeciated by the two-target multiplex may represent *Campylobacter lari*, *C. upsaliensis*, or other thermophilic species, and may also reflect mixed caecal colonisation where a single dominant subtype suppresses co-colonisers (Stern et al., 2001). Future studies should incorporate whole-genome sequencing or

extended multiplex assays to resolve this unspeciated fraction.

A methodological strength of this study was the two-tier molecular confirmation: conventional PCR at the genus level followed by multiplex PCR at the species level, which minimised false-positive culture results (Adzitey et al., 2013). The use of *C. jejuni* ATCC 33560 as a quality control organism in all PCR runs further assured analytical validity. The primary limitation was the small hand swab sample size (n=17), which yielded wide 95% CIs (10.8%–56.4%), reducing the precision of occupational exposure prevalence estimates. Future surveillance studies should enrol larger cohorts of chicken handlers with structured occupational histories.

## Conclusions

*Campylobacter jejuni* and *C. coli* are prevalent in chickens and on the hands of handlers at LBMs in Maiduguri Metropolis, northeastern Nigeria. The exact 95% CI-adjusted prevalence estimate of 23.1% (17.5%–29.6%) and the 2.82-fold higher odds of infection in local chickens relative to broilers confirm the disproportionate public health risk posed by indigenous free-range poultry in this setting. Routine multiplex PCR surveillance at LBMs, strengthened biosecurity, mandatory hand hygiene infrastructure, and targeted health education for chicken handlers are essential to reduce zoonotic *Campylobacter* transmission in northeastern Nigeria.

## Abbreviations

CI: Confidence Interval; LBM: Live Bird Market; OR: Odds Ratio; PCR: Polymerase Chain Reaction; PPV: Positive Predictive Value; ATCC: American Type Culture Collection; CCDA: Charcoal Cefoperazone Deoxycholate Agar.

## Declarations

### Ethics Approval and Consent to Participate

The Borno State Ministry of Health granted ethical approval. Written informed consent was obtained from all chicken handlers. All animal sampling procedures complied with veterinary ethics guidelines and caused no harm to participants or animals.

### Availability of Data and Materials

The datasets generated and analysed during this study are available from the corresponding author on reasonable request.

### Competing Interests

The authors declare no competing interests.


### Funding

No external funding was received. This work was conducted in partial fulfillment of the requirements for the degree of Master of Veterinary Science, University of Maiduguri.


### Authors' Contributions

BUM, AM, and NNA designed the study, collected the data, and wrote the first draft of the manuscript. AM, NNA, ASS, and SGA oversaw the entire research process and critically reviewed the manuscript. BUM, FEO, IDK, and BJ contributed to data collation, data cleaning, and conducted the data analyses for the study. Finally, ML conducted the literature search and contributed to the writing of the final manuscript. All authors read and approved the final version of the manuscript.


### Acknowledgements

The authors thank Mr. Elijah S. Wafar, Mr. Ifraimu U. Na'aya, and Mrs. Briskilla Ezra of the Veterinary Microbiology Department and the North-East Zonal Centre of Excellence for Biotechnology, University of Maiduguri, for laboratory and molecular support.


## References


Abubakar, D. (2019). Isolation, antimicrobial susceptibility testing and molecular characterisation of Campylobacter jejuni and Campylobacter coli from chicken and diarrhoeic human in Maiduguri, Borno State [Master's thesis, University of Maiduguri].

Adzitey, F., Huda, N., & Ali, G. R. R. (2013). Molecular techniques for detecting and typing of bacteria, advantages and application to foodborne pathogens isolated from ducks. 3 Biotech, 3(2), 97–107. https://doi.org/10.1007/s13205-012-0074-4

Akosua, B. K., Kwasi, O. D., Enoch, H. F., & Karen, A. K. (2017). Multidrug resistant Campylobacter in faecal and carcasses of commercially produced poultry. African Journal of Microbiology Research, 11(2), 271–277.

Benshak, J. A., Strachan, N., Lopes, B., Ramjee, M., Macrae, M., & Forbes, K. (2023). Identifying the sources of human campylobacteriosis in Nigeria. Acta Tropica, 237, 106702. https://doi.org/10.1016/j.actatropica.2022.106702

Carron, M., Chang, Y. M., Momanyi, K., Akoko, J., Kiiru, J., Bettridge, J., & Häsler, B. (2018). Campylobacter, a zoonotic pathogen of global importance: Prevalence and risk factors in the fast-evolving chicken meat system of Nairobi, Kenya. PLOS Neglected Tropical Diseases, 12(8), e0006658. https://doi.org/10.1371/journal.pntd.0006658

Coker, A. O., & Adefeso, A. O. (1994). The changing patterns of Campylobacter jejuni/coli in Lagos, Nigeria after ten years. East African Medical Journal, 71(7), 437–440.

Coker, A. O., Isokpehi, R. D., Thomas, B. N., Amisu, K. O., & Obi, C. L. (2002). Human campylobacteriosis in developing countries. Emerging Infectious Diseases, 8(3), 237–244. https://doi.org/10.3201/eid0803.010233

European Food Safety Authority. (2015). The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2013. EFSA Journal, 13(1), 3991. https://doi.org/10.2903/j.efsa.2015.3991

Frasão, B. D. S., Marin, V. A., & Conte-Junior, C. A. (2017). Molecular detection, typing, and quantification of Campylobacter spp. in foods of animal origin. Comprehensive Reviews in Food Science and Food Safety, 16(4), 721–734. https://doi.org/10.1111/1541-4337.12279

Greig, J. D., & Ravel, A. (2009). Analysis of foodborne outbreak data reported internationally for source attribution. International Journal of Food Microbiology, 130(2), 77–87. https://doi.org/10.1016/j.ijfoodmicro.2008.12.031

Hald, B., Skov, M. N., Nielsen, E. M., Rahbek, C., Madsen, J. J., Wainø, M., Chriel, M., Nordentoft, S., Baggesen, D. L., & Madsen, M. (2015). Campylobacter jejuni and Campylobacter coli in wild birds on Danish livestock farms. Acta Veterinaria Scandinavica, 58(11), 0192–0199.

Jimme, M. A., Bashir, A., & Adebayo, A. A. (2016). Spatial distribution pattern and terrain analysis of urban flash floods and inundated areas in Maiduguri metropolis, Borno State, Northeast Nigeria. Journal of Geography Information System, 8, 108–120.

Klous, G., Huss, A., Heederik, D. J. J., & Coutinho, R. A. (2016). Human–livestock contacts and their relationship to transmission of zoonotic pathogens: A systematic review of literature. One Health, 2, 65–76. https://doi.org/10.1016/j.onehlt.2016.03.001

Leaper, S., & Owen, R. J. (1981). Identification of catalase-producing Campylobacter species based on biochemical characteristics and on cellular fatty acid composition. Current Microbiology, 6, 31–35.

Mary, P. E., Christiansen, L. E., Wainø, M., Ethelberg, S., Madsen, H., & Wegener, H. C. (2004). Effects of climate on incidence of Campylobacter spp. in humans and prevalence in broiler flocks in Denmark. Applied and Environmental Microbiology, 70(12), 7474–7480.

Mdegela, R. H., Nonga, H. E., Ngowi, H. A., & Kazwala, R. R. (2006). Prevalence of thermophilic Campylobacter infections in humans, chickens and crows in Morogoro, Tanzania. Journal of Veterinary Medicine, Series B, 53(3), 116–121.

Njoga, E. O., Ezenduka, E. V., & Nwanta, J. A. (2020). Surveillance for Campylobacter infections in indigenous poultry reared in Nsukka, Nigeria. Notulae Scientia Biologicae, 12(2), 242–250.

Njoga, E. O., Nwankwo, I. O., & Ugwunwarua, J. C. (2019). Epidemiology of thermotolerant Campylobacter infection in poultry in Nsukka agricultural zone, Nigeria. International Journal of One Health, 5, 92–98.

Nwankwo, I. O., Faleke, O. O., Salihu, M. D., Musa, U., Magaji, A. A., Audu, B., & Ngulukun, S. (2017). Prevalence and molecular identification of Campylobacter species isolates from poultry and humans in Sokoto, Nigeria. Sokoto Journal of Veterinary Sciences, 15(4), 1–8.

Nwankwo, I. O., Faleke, O. O., Salihu, M. D., Magaji, A. A., Musa, U., Garba, J., & Ibitoye, E. B. (2016). Detection and viability of

Campylobacter species isolates from different species of poultry and humans in Sokoto State, Nigeria. International Journal of One Health, 2, 19–23.

Ohanu, M. E., & Offune, J. (2009). The prevalence of Campylobacter in childhood diarrhoea in Enugu State of Nigeria. Journal of Communicable Diseases, 41(2), 117–120.

Salihu, M. D., Junaidu, A. U., Magaji, A. A., Abubakar, M. B., Adamu, A. Y., & Yakubu, A. S. (2009). Prevalence of Campylobacter in poultry meat in Sokoto, Northwestern Nigeria. Journal of Public Health Epidemiology, 1(2), 041–045.

Scallan, E., Hoekstra, R. M., Angulo, F. J., Tauxe, R. V., Widdowson, M. A., Roy, S. L., Jones, J. L., & Griffin, P. M. (2011). Foodborne illness acquired in the United States—Major pathogens. Emerging Infectious Diseases, 17(1), 7–15. https://doi.org/10.3201/eid1701.P11101

Skarp, C. P. A., Hänninen, M.-L., & Rautelin, H. I. K. (2016). Campylobacteriosis: The role of poultry meat. Clinical Microbiology and Infection, 22(2), 103–109. https://doi.org/10.1016/j.cmi.2015.11.019

Stern, N. J., Cox, N. A., Bailey, J. S., Berrang, M. E., & Musgrove, M. T. (2001). Comparison of mucosal competitive exclusion and competitive exclusion treatment to reduce Salmonella and Campylobacter spp. colonization in broiler chickens. Poultry Science, 80(2), 156–160.

Stern, N. J., & Robach, M. C. (2003). Enumeration of Campylobacter spp. in broiler feces and in corresponding processed carcasses. Journal of Food Protection, 66(9), 1557–1563.

Thrusfield, M. (2010). Veterinary epidemiology (3rd ed.). Wiley-Blackwell.

Wang, G., Clark, C. G., Taylor, T. M., Pucknell, C., Barton, C., Price, L., Woodward, D. L., & Rodgers, F. G. (2002). Colony multiplex PCR assay for identification and differentiation of Campylobacter jejuni, C. coli, C. lari, C. upsaliensis, and C. fetus subsp. fetus. Journal of Clinical Microbiology, 40(12), 4744–4747. https://doi.org/10.1128/JCM.40.12.4744-4747.2002