



Research Article

Isolation, Antimicrobial Resistance, and Owner Awareness of *Pasteurella* Species in Domesticated Pigeons (*Columba livia domestica*) in Maiduguri, Nigeria: A One Health Perspective

Sanni Abdul BARKA¹, *Jallailudeen Rabana LAWAL², Hadiza Kalli GAZALI³, Arhyel Gana BALAMI², Aisha Urunna OKPALEKE⁴, Muhammad Isa HASSAN³, Sharon SAMUEL³, Jidda GREMA³, Rashida AYUBA³, Abubakar Mohammed ALI²

¹Livestock Department, Agricultural Research Council of Nigeria, Plot 223D Cadastral Zone B6, Mabushi, Abuja, Nigeria

²Department of Veterinary Medicine, Faculty of Veterinary Medicine, University of Maiduguri, P.M.B. 1069, Maiduguri, Borno State, Nigeria

³Department of Microbiology, Faculty of Life Sciences, University of Maiduguri, P.M.B. 1069, Maiduguri, Borno State, Nigeria

⁴Faculty of Veterinary Medicine, University of Maiduguri, P.M.B. 1069, Maiduguri, Borno State, Nigeria

*Corresponding Author's email: rabana4real@unimaid.edu.ng; Phone: +2348032886428

ABSTRACT

Pasteurellosis, caused by *Pasteurella* species, is a re-emerging bacterial disease of domesticated pigeons with significant veterinary and public health implications. This cross-sectional study investigated the prevalence, antimicrobial resistance patterns, and owner awareness of *Pasteurella* species in domesticated pigeons and their environments in Maiduguri, Borno State, Nigeria. A total of 300 samples comprising 200 oropharyngeal and cloaca samples from pigeons and 100 environmental samples from pigeon pens were examined using standard microbiological procedures. Antimicrobial susceptibility testing was performed using the Kirby-Bauer disk diffusion method, while a structured questionnaire assessed knowledge and practices among 100 pigeon owners. Overall, 41 samples (13.7%; 95% CI: 10.2–18.0%) were positive for *Pasteurella* species, with significantly higher prevalence in pigeons (17.5%) than in environmental samples (6.0%) ($\chi^2 = 7.472$; $p = 0.0063$). Prevalence was highest in pigeon from Gwange (31.0%) and among clinically sick birds (46.4%; $p < 0.0001$), males (25.5%; $p = 0.0049$), and squabs (26.9%; $p = 0.0558$) pigeons. Fresh faecal deposits yielded the highest environmental isolation rate (16.0%). Antimicrobial resistance was highest against tetracycline (61.0%), oxytetracycline (61.0%), and erythromycin (56.1%), while enrofloxacin (70.7%) and ciprofloxacin (68.3%) were most effective. Multi-drug resistance was observed in 87.8% of all the isolates, with a mean MAR index of 0.43. Owner knowledge was poor, with mean knowledge and AMR awareness scores of 28.2% and 17.2%, respectively. These findings demonstrate significant *Pasteurella* burden and antimicrobial resistance in pigeons, underscoring the need for integrated One Health interventions.

Keywords: Antimicrobial resistance; Antimicrobial stewardship; Domesticated pigeons; One Health; *Pasteurella* species; Zoonotic

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INTRODUCTION

Pigeons (*Columba livia domestica*) are among the most widely distributed domesticated birds globally, maintaining close associations with humans for centuries (Shapiro and Domyan, 2013). In Nigeria, domesticated pigeons are reared for meat production, recreation, cultural ceremonies, sport racing, ornamental value, and income generation (Rabiu and Arzai, 2012). Their adaptability, low management requirements, and ability to thrive under semi-intensive and extensive systems have contributed to their popularity among rural and urban households (Balog *et al.*, 2025). In Maiduguri, Borno State, pigeon keeping constitutes an important component of backyard poultry production, providing animal protein and supplementary household income (Sheikh *et al.*, 2022).

Despite their economic and socio-cultural significance, pigeons are susceptible to various infectious diseases (Harlin and Wade, 2009). Among bacterial diseases, pasteurellosis remains a significant concern due to its impact on bird health, productivity, and public health implications (Kobuszewska and Wysok, 2024). Pasteurellosis is commonly associated with *Pasteurella multocida*, a Gram-negative, non-motile, facultatively anaerobic coccobacillus known to infect numerous domestic and wild animal species (Kaczorek-Łukowska *et al.*, 2021). The organism causes fowl cholera in birds, haemorrhagic septicaemia in ruminants, atrophic rhinitis in pigs, and opportunistic infections in humans following animal exposure (Kaczorek-Łukowska *et al.*, 2021). In avian species, *Pasteurella* infections are characterised by acute septicaemia, chronic localised infections, respiratory distress, decreased productivity, and increased mortality (El-Demerdash *et al.*, 2023). Pigeons can act as reservoirs or carriers of *Pasteurella* species, facilitating transmission within bird populations and potentially serving as sources of infection for other domestic animals and humans (Chrobak-Chmiel *et al.*, 2021; Crăciun *et al.*, 2026).

The epidemiology of pasteurellosis is influenced by host susceptibility, environmental conditions, management practices, stress, nutritional status, and biosecurity measures (Wilson and Ho, 2013). Poor housing, overcrowding, inadequate sanitation, mixing of bird species, and unrestricted contact with wild birds increase transmission likelihood (El-Demerdash

et al., 2023). In developing countries, pigeon husbandry is largely practiced under traditional systems with limited veterinary supervision and inadequate disease control measures, creating favourable conditions for pathogen persistence and spread (Chrobak-Chmiel *et al.*, 2021).

A growing concern in veterinary and human medicine is the emergence and spread of antimicrobial resistance (AMR) (Palma *et al.*, 2020; Al-Khalaifah *et al.*, 2025; Horvat and Kovačević, 2025). Antimicrobial Resistance (AMR) occurs when microorganisms evolve mechanisms to survive exposure to antimicrobial agents that would normally inhibit or kill them (Reygaert, 2018). The misuse, overuse, and inappropriate application of antibiotics in animal production systems are major drivers of AMR worldwide (Al-Khalaifah *et al.*, 2025). Resistant pathogens compromise treatment effectiveness and increase the risk of disease persistence, therapeutic failure, and economic losses (Chinemerem Nwobodo *et al.*, 2022; Almansour *et al.*, 2023; Salam *et al.*, 2023). The development of AMR among *Pasteurella* species has become a significant public health and veterinary concern (Cuevas *et al.*, 2020). Studies have reported varying levels of resistance to tetracyclines, sulfonamides, aminoglycosides, β -lactams, and fluoroquinolones among *Pasteurella* isolates from different animal species (Kerek *et al.*, 2024). Resistant bacteria and resistance genes may spread between animals, humans, and the environment, highlighting the importance of a One Health approach to AMR surveillance and control (Al-Khalaifah *et al.*, 2025).

The One Health concept recognises the interconnectedness of human, animal, and environmental health and emphasises collaborative efforts to address health challenges at their interface (Danasekaran, 2024). Domesticated pigeons frequently share environments with humans and other animals, creating opportunities for the exchange of pathogenic and antimicrobial-resistant microorganisms (Chrobak-Chmiel *et al.*, 2021). Understanding the occurrence and resistance profiles of *Pasteurella* species in pigeons is therefore essential for developing evidence-based disease prevention and antimicrobial stewardship strategies (Iorgoni *et al.*, 2026).

Assessing the awareness and knowledge of pigeon owners regarding pasteurellosis and antimicrobial use is critical for effective disease control (El-Demerdash *et al.*, 2023). Farmers' awareness influences management practices, biosecurity implementation, disease reporting behaviour, and antibiotic usage patterns (Bedekelabou *et al.*, 2022; Kemunto *et al.*, 2026). Poor knowledge regarding disease transmission, zoonotic risks, and prudent antimicrobial use may contribute to inappropriate treatment practices and increased antimicrobial misuse (Bolado *et al.*, 2026). Evaluating owners' awareness can therefore provide valuable information for designing educational interventions aimed at improving disease prevention and responsible antimicrobial usage.

In Nigeria, information on *Pasteurella* species among domesticated pigeons remains limited compared with studies on commercial poultry and livestock species. Most existing investigations have focused on chickens, turkeys, cattle, sheep, and goats, while pigeons have received comparatively little attention despite their close association with human populations (Midala *et al.*, 2025). Furthermore, data regarding antimicrobial resistance patterns of *Pasteurella* isolates from pigeons and the awareness levels of pigeon owners in Maiduguri, Borno State, are scarce. This knowledge gap may hinder the development of effective surveillance, prevention, and control strategies for pasteurellosis and antimicrobial resistance.

Maiduguri, the capital of Borno State, supports substantial backyard and small-scale poultry production activities, including pigeon rearing. The close interaction between pigeons, humans, and other domestic animals in the area may facilitate the circulation of bacterial pathogens and antimicrobial-resistant organisms. Therefore, investigating the occurrence of *Pasteurella* species, determining their antimicrobial susceptibility profiles, and assessing owners' awareness regarding this pathogen and antimicrobial usage are necessary steps toward improving pigeon health management and safeguarding public health.

The findings from this study are expected to contribute valuable baseline information on the epidemiology of *Pasteurella* species among domesticated pigeons in Maiduguri, provide insights into prevailing antimicrobial resistance patterns, and identify knowledge gaps among pigeon owners. Such information will be useful to veterinarians, researchers, public health practitioners, policymakers, and livestock extension personnel

involved in disease surveillance, antimicrobial stewardship, and poultry health management programmes.

MATERIALS AND METHODS

Study Area

The study was conducted in Maiduguri, the capital city of Borno State, located in the northeastern region of Nigeria. Maiduguri lies between latitude 11°50'N and 11°55'N and longitude 13°05'E and 13°15'E, with an average elevation of approximately 354 metres above sea level. The city experiences a semi-arid climate characterised by a long dry season and a short rainy season. Annual rainfall ranges between 500 mm and 650 mm, while temperatures may exceed 40°C during the hot season (Goni *et al.*, 2004).

Maiduguri is the largest urban centre in Borno State and serves as a major commercial, educational, and agricultural hub. Livestock and poultry production constitute important economic activities among residents. Rearing of domesticated pigeon is commonly practiced across several communities within the metropolis for meat production, recreation, cultural purposes, and income generation. The close interaction between pigeons, humans, and other domestic animals in the area makes Maiduguri an appropriate location for investigating the occurrence of *Pasteurella* species and associated antimicrobial resistance patterns.

Study Design

A cross-sectional design was employed to investigate *Pasteurella* species among domesticated pigeons (*Columba livia domestica*) in Maiduguri metropolis, Borno State, Nigeria. This design enabled simultaneous determination of *Pasteurella* prevalence, antimicrobial susceptibility profiling of isolates, and assessment of pigeon owners' knowledge regarding pasteurellosis, antimicrobial use, and antimicrobial resistance.

The questionnaire survey targeted pigeon owners and caretakers through face-to-face structured interviews, collecting data on demographics, education, husbandry experience, flock management, disease occurrence, prevention and control practices, antimicrobial use patterns, veterinary advice sources, and awareness of antimicrobial resistance, pasteurellosis, zoonotic transmission, and prudent antimicrobial usage.

Study Population

The study population comprised domesticated pigeons (*Columba livia domestica*) from selected households and farms in Maiduguri metropolis, their

rearing environment (pigeon pens), along with their owners and caretakers.

This population represented diverse pigeon-rearing households and farms under different management systems, adopting a One Health perspective that recognizes the interplay between animals, humans, and the shared environment in infectious disease epidemiology and antimicrobial resistance control.

Target Animal Population

The target animal population comprised domesticated pigeons (both apparently healthy and clinically sick) managed under backyard, semi-intensive, and extensive husbandry systems in selected locations. Including healthy carriers and clinically sick birds, as well as different management systems, allowed detection of active infections and assessment of management-related factors influencing bacterial transmission and antimicrobial exposure.

Target Environmental Population

The target environmental population comprised surface and material samples from pigeon pens and husbandry infrastructure in selected households and farms. Four sample types were selected based on their epidemiological relevance to *Pasteurella* transmission: fresh faecal deposits (primary shedding route), drinking water troughs (moist conditions favour bacterial survival), feed and feeding trough surfaces (contaminated through oral/nasal secretions), and nest box surfaces (close-contact habitats). These samples provided evidence of environmental *Pasteurella* contamination and enabled assessment of environmental reservoirs in pasteurellosis and antimicrobial resistance dissemination.

Target Human Population

The target human population comprised pigeon owners and primary caretakers involved in management, feeding, housing, healthcare, and general husbandry in selected locations. As key respondents, they provided information on flock management, disease experiences, antimicrobial usage, and awareness of pasteurellosis, veterinary consultation sources, and perceptions of antimicrobial resistance.

Inclusion and Exclusion Criteria

Specific criteria were established for animal, environmental, and human participants to ensure appropriateness and reliability.

Animal Component

For animals, eligible pigeons included apparently healthy and clinically sick domesticated pigeons from selected households and farms, with owner consent

for sample collection and participation. Including both healthy and diseased birds provided comprehensive assessment of *Pasteurella* occurrence irrespective of clinical status.

Environmental Component

For environmental samples, eligible sources included fresh faecal deposits, drinking water troughs, feed/feeding trough surfaces, and nest box surfaces from pens housing the selected pigeons. Samples were collected only from pens where owners granted consent for environmental sampling. Environmental samples were excluded if the pens had been recently disinfected (within 48 hours) or if samples were desiccated or otherwise unsuitable for bacteriological processing.

Human Component

For humans, eligible participants were individuals aged 18 years and above who owned pigeons or served as primary caretakers, willing to participate and provide informed consent.

Exclusion Criteria

Excluded were pigeons that received antimicrobial treatment within two weeks prior to sample collection, as recent exposure could suppress bacterial growth, interfere with *Pasteurella* isolation, and affect susceptibility testing accuracy. Pigeon owners who declined participation or refused informed consent were excluded from the survey. Questionnaires that were incomplete, contained substantial missing information, or were unsuitable for analysis were excluded to ensure validity, consistency, and reliability of study data.

Determination of Sample Size

The minimum sample size for bacteriological investigation was calculated using Cochran's formula for prevalence studies (Ranganathan *et al.*, 2024):

$$N = \frac{Z^2 \times P_{exp}(1 - P_{exp})}{d^2}$$

where n = required sample size; Z = standard normal deviate at 95% confidence (1.96); P = expected prevalence; and d = desired precision (0.05).

The expected prevalence (P = 21.7%) was obtained from Lawal *et al.* (2021), who reported *Pasteurella multocida* prevalence among chickens in Maiduguri, Borno State, Nigeria. As no pigeon-specific prevalence data existed for the study area, this estimate was considered most appropriate given the similarity in avian host species and geographical location.

Substituting values (P = 0.217; Z = 1.96; d = 0.05), the calculated minimum sample size was 261 pigeons. To improve precision and account for possible sample

loss, contamination, or non-recovery of isolates during laboratory processing, this figure was adjusted upward by approximately 15%, yielding a final laboratory sample of 300 comprising of 200 pigeons and 100 environmental samples from pigeon house premises. Using a 3:1 allocation ratio (laboratory: questionnaire), 100 pigeon owners were additionally sampled for the questionnaire survey, giving a total study sample number of 400.

Sampling Technique

A multistage sampling technique was employed to select study locations, pigeon flocks, individual birds, and pigeon owners, ensuring adequate representation of the target population within Maiduguri metropolis.

In the first stage, wards and communities known for active pigeon-rearing activities were purposively selected based on information obtained from local community leaders, pigeon breeders' associations, veterinary personnel, and preliminary field reconnaissance. Communities with a relatively high concentration of domesticated pigeons and accessible pigeon-rearing households were prioritized to maximize the likelihood of obtaining representative samples.

In the second stage, households and pigeon-rearing premises within the selected communities were identified and systematically sampled. A sampling interval was determined based on the estimated number of pigeon-rearing households in each selected community, and eligible households were selected accordingly. This procedure minimized selection bias and ensured broad geographic coverage across the study area.

In the final stage, individual pigeons were selected from each identified flock using simple random sampling, giving each bird an equal probability of inclusion. Efforts were made to include pigeons of different age categories, sexes, and physiological conditions, and both apparently healthy birds and those showing clinical signs suggestive of disease were considered eligible, thereby enhancing representativeness and improving the detection likelihood of *Pasteurella* species.

Simultaneously, pigeon owners and primary caretakers encountered during the sampling exercise who met the inclusion criteria and voluntarily provided informed consent were enrolled in the questionnaire survey, facilitating the collection of epidemiological and behavioural data to complement the laboratory findings.

Collection of Samples

Pigeon Biological Samples

Biological samples were collected from domesticated pigeons using standard aseptic procedures to ensure specimen integrity and prevent contamination. Sampling focused on anatomical sites commonly associated with bacterial colonization and shedding, thereby increasing the likelihood of recovering the target organisms.

For live pigeons, oropharyngeal and cloacal swabs were collected. Oropharyngeal swabs were obtained by gently opening the bird's beak and inserting a sterile cotton-tipped swab into the oral cavity and pharyngeal region, rotating it gently against the mucosal surfaces to ensure adequate collection of secretions and microbial flora; these were collected particularly where clinical signs suggestive of respiratory infection were observed. Cloacal swabs were collected by carefully inserting a sterile swab into the cloaca and rotating it gently to obtain sufficient specimen material. These sites were selected because they represent important portals for bacterial carriage and shedding in avian species.

Where recently dead pigeons were available, postmortem examinations were conducted under aseptic conditions, and tissue samples including portions of the liver, spleen, lungs, and heart blood were collected, as these organs are commonly affected during systemic bacterial infections and may harbour significant bacterial loads. Sterile instruments were used, and each organ sample was placed into a separate sterile container to avoid cross-contamination.

Immediately after collection, all swab samples were placed into Amies transport medium to preserve bacterial viability, while tissue samples were transferred into sterile, properly labelled specimen containers. Each sample was assigned a unique identification code comprising the sampling location, flock identification number, individual bird number, sample type, and date of collection, facilitating accurate traceability and sample management throughout the laboratory investigation. All specimens were maintained under cold-chain conditions using ice-packed cool boxes and transported promptly to the Department of Microbiology Research Laboratory, Faculty of Life Sciences, University of Maiduguri, Borno State, where they were processed within 4 hours of collection to minimize deterioration of bacterial viability and enhance the recovery and accurate identification of *Pasteurella* species.

Environmental Samples

In addition to pigeon sampling, 100 environmental samples were collected from pigeon pens across the selected study locations, comprising 25 samples each from four strategically selected sources: fresh faecal deposits, drinking water troughs, feeds and feeding trough surfaces, and nest box surfaces. Approximately, 5g of fresh faecal material was collected from the pen floor using sterile spatulas and placed into sterile universal bottles, while drinking water troughs were sampled by swabbing the inner surfaces and water residues with sterile swabs, with 10 mL of water collected into sterile containers where water was present. Ten grams of feed was homogenized in 90mL of sterile water for inoculation on sterile swab and feeding trough surfaces were swabbed over approximately 10 cm² using sterile swabs pre-moistened with sterile normal saline, and nest box surfaces were sampled by swabbing the inner surfaces, focusing on areas with visible organic matter or moisture.

All environmental samples were labelled, placed in cool boxes with ice packs, and transported to the laboratory for processing within 4 hours of collection. The combined laboratory sample size was therefore 300 (200 pigeons and 100 environmental samples).

Questionnaire Survey

The questionnaire survey sample size was determined concurrently with the laboratory component. To facilitate integration of microbiological findings with husbandry practices, disease awareness, and antimicrobial usage data, the overall sample was proportionally divided using a 2:1 allocation ratio (laboratory:questionnaire), with one-third of the total calculated sample size allocated to the questionnaire survey, yielding 100 pigeon owners for interview. Eligible respondents were pigeon owners or primary caretakers actively involved in pigeon management within the selected study locations who voluntarily consented to participate.

Questionnaire Design and Administration

A structured questionnaire was used as the primary instrument for data collection and was administered through face-to-face interviews. This method was adopted to ensure clarity of questions, improve response rates, and minimize incomplete or inaccurate responses, while providing an opportunity to explain technical terms and obtain clarification from respondents where necessary. The questionnaire was carefully designed based on the study objectives and relevant literature on zoonotic diseases, antimicrobial use, and antimicrobial resistance, and comprised both closed-ended and

open-ended questions organized into sections covering socio-demographic information, pigeon management practices, disease awareness, and antimicrobial use behaviours.

Information collected included demographic characteristics such as age, sex, occupation, marital status, and educational attainment, as well as pigeon husbandry practices including flock size, housing systems, feeding methods, sources of birds, and general flock management procedures. Respondents were further asked about previous disease occurrences within their flocks, common clinical signs observed, mortality experiences, and methods employed for disease control and treatment.

To assess awareness and knowledge of pasteurellosis, respondents were asked questions regarding their familiarity with the disease, its causes, routes of transmission, clinical manifestations, and preventive measures. Information was also collected on knowledge of zoonotic diseases and understanding of the potential risks associated with close contact between humans and birds, with particular emphasis on diseases transmissible between animals and humans and the role of proper animal health management in reducing such risks.

Furthermore, data were collected on antibiotic usage practices, including the types of antibiotics commonly used, reasons for administration, frequency of use, sources of procurement, adherence to dosage instructions, and treatment outcomes. Respondents were also asked to identify their primary sources of animal health information and veterinary advice, including veterinarians, animal health workers, drug vendors, fellow pigeon keepers, and personal experience. In addition, questions assessed awareness and understanding of antimicrobial resistance (AMR), particularly regarding the consequences of inappropriate antibiotic use and the potential impact of resistant bacteria on animal and public health. Information on biosecurity practices adopted by pigeon owners, such as cleaning and disinfection procedures, quarantine of newly acquired birds, restriction of visitor access, and disposal of sick or dead birds, was also obtained.

The questionnaire was initially prepared in English. However, as a significant proportion of respondents were more conversant with local languages, verbal translation into Hausa and Kanuri was provided during interviews whenever necessary. This approach enhanced communication, improved respondents' understanding of the questions, and ensured the collection of accurate and reliable information.

Laboratory Analyses

Isolation and Identification of *Pasteurella* Species

All samples (pigeon and environmental) were processed using standard microbiological procedures. Samples were inoculated onto 5% sheep Blood agar as primary culture media and on MacConkey agar for differential purposes, and then incubated at 37°C for 48 hours under microaerophilic conditions. Suspected *Pasteurella* colonies were subcultured onto fresh Blood agar for purity and subjected to morphological, Gram staining, and biochemical characterization (catalase, oxidase, indole, urease, and carbohydrate fermentation tests) (Quinn *et al.*, 2002; Elsheikh *et al.*, 2024; Alkhalfat *et al.*, 2025). Confirmed isolates were preserved on nutrient agar slants at 4°C for further analysis.

Antimicrobial Susceptibility Testing

Confirmed *Pasteurella* isolates were subjected to antimicrobial susceptibility testing using the Kirby-Bauer disk diffusion method on Müller-Hinton agar supplemented with 5% defibrinated sheep blood, in accordance with Clinical and Laboratory Standards Institute (CLSI) guidelines (CLSI, 2020). The following antimicrobial agents were tested: tetracycline (30 µg), oxytetracycline (30 µg), ampicillin (10 µg), amoxicillin-clavulanic acid (30 µg), gentamicin (10 µg), streptomycin (10 µg), ciprofloxacin (5 µg), enrofloxacin (5 µg), erythromycin (15 µg), chloramphenicol (30 µg), and sulfamethoxazole-trimethoprim (25 µg). Zones of inhibition were measured in millimeter (mm) and interpreted as susceptible, intermediate, or resistant according to CLSI breakpoints.

Multi-Drug Resistance (MDR) and MAR Index Determination

Multi-drug resistance was defined as resistance to ≥3 antimicrobial classes. The Multiple Antibiotic Resistance (MAR) index was calculated for each isolate as the ratio of the number of antimicrobials to which the isolate was resistant to the total number of antimicrobials tested. The MAR index values >0.2 were considered indicative of high-risk contamination sources (Krumperman, 1983; Cooley and Otokunefor, 2016; Ayandele *et al.*, 2020; Isaiah *et al.*, 2025).

Data Analysis

Data were entered into Microsoft Excel and analysed using SPSS version 26.0. Prevalence rates were calculated as the proportion of positive samples among total samples examined, with 95% confidence intervals. Chi-square tests were used to assess associations between *Pasteurella* prevalence and demographic/management variables. A p-value <0.05

was considered statistically significant. MAR indices were calculated and interpreted as previously described.

RESULTS

A total of 300 samples were examined, comprising 200 biological samples from domesticated pigeons and 100 environmental samples from pigeon pens. Overall, 41 samples (13.7%; 95% CI: 10.2–18.0%) were positive for *Pasteurella* species. The prevalence of *Pasteurella* species was significantly higher in pigeons (17.5%; 95% CI: 12.9–23.4%) compared to environmental samples (6.0%; 95% CI: 2.8–12.5%), with a statistically significant difference observed ($\chi^2 = 7.472$; $p = 0.0063$) (Table 1).

The distribution of *Pasteurella* species varied across the five sampling locations in Maiduguri. Gwange recorded the highest prevalence (31.0%; 95% CI: 3.8–10.8%), followed by Galtimari (23.7%; 95% CI: 2.4–8.2%), Lamisula (15.8%; 95% CI: 1.4–6.4%), Bolori (12.5%; 95% CI: 1.1–5.7%), and Mairi (4.8%; 95% CI: 0.3–3.6%). The overall prevalence across all locations was 17.5% (95% CI: 12.9–23.4%) (Table 2).

The prevalence of *Pasteurella* species varied across different demographic characteristics of pigeons. Age-related analysis revealed a declining trend in prevalence with increasing age, with squabs (<3 months) exhibiting the highest prevalence (26.9%), followed by young pigeons (3–12 months; 18.1%) and adults (>12 months; 10.5%). However, this difference was not statistically significant ($\chi^2 = 5.774$; $p = 0.0558$). Sex-based analysis demonstrated a significantly higher prevalence in male pigeons (25.5%) compared to females (10.4%) ($\chi^2 = 7.925$; $p = 0.0049$). Health status emerged as a highly significant factor, with clinically sick pigeons showing a significantly higher prevalence (46.4%) compared to apparently healthy birds (6.3%) ($\chi^2 = 45.08$; $p < 0.0001$). Flock size did not significantly influence prevalence ($\chi^2 = 1.297$; $p = 0.5229$), with medium-sized flocks (21–50 pigeons) recording the highest prevalence (20.0%), followed by large flocks (>50 pigeons; 19.6%) and small flocks (1–20 pigeons; 13.5%) (Table 3).

Among the 100 environmental samples examined, fresh faecal deposits yielded the highest isolation rate of *Pasteurella* species (16.0%; 95% CI: 1.6–9.8%), followed by drinking water troughs (4.0%; 95% CI: 0.2–5.5%) and feed/feeding trough surfaces (4.0%; 95% CI: 0.2–5.5%). No *Pasteurella* species were isolated from nest box surfaces/swabs (0.0%; 95% CI: 0.0–3.7%). The overall prevalence in environmental samples was 6.0% (95% CI: 2.8–12.5%) (Table 4).

The antimicrobial susceptibility testing of 41 *Pasteurella* isolates revealed varying resistance patterns across the 11 antimicrobial agents tested. The highest susceptibility rates were observed for enrofloxacin (70.7%), ciprofloxacin (68.3%), and gentamicin (63.4%). Conversely, the highest resistance rates were recorded for tetracycline (61.0%), oxytetracycline (61.0%), erythromycin (56.1%), and sulfamethoxazole-trimethoprim (56.1%). Moderate resistance was observed for ampicillin (48.8%), streptomycin (48.8%), amoxicillin-clavulanic acid (41.5%), and chloramphenicol (41.5%). The proportion of isolates showing intermediate susceptibility ranged from 7.3% (enrofloxacin) to 17.1% (oxytetracycline and erythromycin) (Table 5). Analysis of multi-drug resistance (MDR) patterns revealed that all 41 isolates (100%) exhibited resistance to at least one antimicrobial class. The majority of isolates demonstrated resistance to multiple antimicrobial classes, with 36 isolates (87.8%) classified as MDR (resistant to ≥ 3 antimicrobial classes). The most frequently observed MDR pattern involved resistance to five antimicrobial classes (22.0%), followed by four classes (19.5%) and six classes (17.1%). Resistance to seven, three, two, and one antimicrobial class was observed in 9.8%, 12.2%, 7.3%, and 4.9% of isolates, respectively. Notably, resistance to eight and nine antimicrobial classes was observed in 4.9% and 2.4% of isolates, respectively, while no isolate exhibited resistance to ten or more antimicrobial classes (Table 6).

The multiple antibiotic resistance (MAR) index of the 41 *Pasteurella* isolates ranged from 0.00 to 0.91, with a mean MAR index of 0.43, indicating a high-risk environment for antimicrobial resistance. The majority of isolates (41.5%) exhibited MAR indices between 0.36 and 0.45, representing high resistance exposure. Very high resistance exposure (MAR index 0.55–0.64) was observed in 26.8% of isolates, while 19.5% showed moderate resistance exposure (MAR index 0.18–0.27). Extremely high resistance exposure (MAR index 0.73–0.91) was recorded in 7.3% of isolates, and only 4.9% exhibited low resistance exposure (MAR index 0.00–0.09) (Table 7).

Assessment of knowledge regarding pasteurellosis among 100 respondents revealed generally poor awareness levels. The highest correct response rate was recorded for knowledge that pasteurellosis can be treated with antibiotics (40.0%), followed by recognition of coughing/sneezing as a clinical sign

(38.0%) and recognition of nasal discharge as a clinical sign (36.0%). Awareness of pasteurellosis as a pigeon disease was reported by 32.0% of respondents, while 28.0% knew that the disease can be prevented by vaccination. Only 26.0% recognized difficulty in breathing as a clinical sign, and 24.0% were aware that pasteurellosis can be transmitted between birds. Knowledge that pasteurellosis is caused by bacteria was demonstrated by 18.0% of respondents, while awareness of the zoonotic potential of pasteurellosis was the lowest (12.0%). The overall mean knowledge score was 28.2%, indicating a substantial knowledge gap among pigeon owners (Table 8).

The survey of antimicrobial usage practices revealed that 76.0% of respondents reported using antibiotics in their pigeons. Among these, the most common sources of antibiotics were agricultural stores (30.0%), veterinary pharmacies (22.0%), human pharmacies (20.0%), open markets (12.0%), veterinary clinics (10.0%), and other pigeon owners (6.0%). Alarming, only 18.0% of respondents obtained a prescription before using antibiotics, while 82.0% did not. Dosage adherence was suboptimal, with only 24.0% of respondents reporting that they always adhered to recommended dosages, while 42.0% sometimes adhered and 34.0% never adhered to dosages. Treatment duration was completed always by only 26.0% of respondents, sometimes by 38.0%, and never by 36.0%. Self-medication practice was reported by 62.0% of respondents, and only 12.0% observed the withdrawal period after antibiotic use. The primary reason for antibiotic use was treatment of sick birds (52.0%), followed by disease prevention (24.0%), routine practice (16.0%), and growth promotion (8.0%) (Table 9).

Awareness of antimicrobial resistance among respondents was notably low. Only 16.0% of respondents were aware of the term "antimicrobial resistance," and 28.0% knew that antibiotics may fail to treat infections. Awareness that inappropriate antibiotic use contributes to resistance was demonstrated by 20.0% of respondents, while only 10.0% knew that resistance can spread between pigeons and humans. Awareness of the public health importance of AMR was reported by 12.0% of respondents. The overall mean AMR awareness score was 17.2%, indicating a critical gap in knowledge regarding antimicrobial resistance among pigeon owners in Maiduguri (Table 10).

Table 1: Prevalence of *Pasteurella* Species in Domesticated Pigeons and Environmental Samples in Maiduguri, Borno State, Nigeria

Sample Source	Number Examined	Number Positive	Prevalence (%)	95% CI (LL – UL)	χ^2	p-value
Pigeons (biological)	200	35	17.5 ^a	12.9 – 23.4	7.472	0.0063
Environment (pens)	100	6	6.0 ^b	2.8 – 12.5		
Total	300	41	13.7	10.2–18.0		

Keys: χ^2 = Chi-Square; CI = Confidence Interval; LL = Lower Limit; UL = Upper Limit

^{a,b} Different superscripts indicate significant ($p < 0.05$) difference in prevalence

Table 2: Prevalence of *Pasteurella* Species in Domesticated Pigeons According to Sampling Location in Maiduguri, Borno State, Nigeria

Sample Location	Number of Samples Examined	Number Positive (%)	Prevalence (%)	95% CI (LL – UL)
Gwange	42	13 (31.0)	6.5	3.8 – 10.8
Bolori	40	5 (12.5)	2.5	1.1 – 5.7
Mairi	42	2 (4.8)	1.0	0.3 – 3.6
Galtimari	38	9 (23.7)	4.5	2.4 – 8.2
Lamisula	38	6 (15.8)	3.0	1.4 – 6.4
Total	200	35 (17.5)	17.5	12.9 – 23.4

Key: CI = Confidence Interval; LL – UL = Lower Limit – Upper Limit

Table 3: Prevalence of *Pasteurella* Species Based on Pigeon Demographic Characteristics in Maiduguri, Borno State, Nigeria

Variable	Category	Number Examined	Number Positive (%)	Prevalence (%)	χ^2	p-Value
Age Group (months)	Squabs (<3)	52	14 (26.9)	7.0 ^a	5.774	0.0558
	Young (3–12)	72	13 (18.1)	6.5 ^a		
	Adult (>12)	76	8 (10.5)	4.0 ^a		
Sex	Male	94	24 (25.5)	12.0 ^a	7.925	0.0049
	Female	106	11 (10.4)	5.5 ^b		
Health Status	Apparently Healthy	144	9 (6.3)	4.5 ^a	45.08	<0.0001
	Clinically Sick	56	26 (46.4)	13.0 ^b		
Flock Size (pigeons)	Small (1–20)	74	10 (13.5)	5.0 ^a	1.297	0.5229
	Medium (21–50)	80	16 (20.0)	8.0 ^a		
	Large (>50)	46	9 (19.6)	4.5 ^a		

Key: χ^2 = Chi-square; ^{a,b} Different superscripts indicate significant ($p < 0.05$) difference in prevalence

Table 4: Prevalence of *Pasteurella* Species in Environmental Samples from Pigeon Pens in Maiduguri, Borno State, Nigeria

Environmental Sample Source	Number Examined	Number Positive (%)	Prevalence (%)	95% CI (LL – UL)
Fresh faecal deposits	25	4 (16.0)	4.0	1.6 – 9.8
Drinking water troughs	25	1 (4.0)	1.0	0.2 – 5.5
Feed/feeding trough surfaces	25	1 (4.0)	1.0	0.2 – 5.5
Nest box surfaces/swabs	25	0 (0.0)	0.0	0.0 – 3.7
Total	100	6 (6.0)	6.0	2.8 – 12.5

Key: CI = Confidence Interval; LL – UL = Lower Limit – Upper Limit

Table 5: Antimicrobial Susceptibility Patterns of *Pasteurella* Isolates (n = 41) from Domesticated Pigeons and Their Environment in Maiduguri, Borno State, Nigeria

Antimicrobial Agent (µg)	Susceptible n (%)	Intermediate n (%)	Resistant n (%)
Tetracycline (30)	10 (24.4)	6 (14.6)	25 (61.0)
Oxytetracycline (30)	9 (22.0)	7 (17.1)	25 (61.0)
Ampicillin (10)	16 (39.0)	5 (12.2)	20 (48.8)
Amoxicillin-Clavulanic Acid (30)	18 (43.9)	6 (14.6)	17 (41.5)
Gentamicin (10)	26 (63.4)	5 (12.2)	10 (24.4)
Streptomycin (10)	15 (36.6)	6 (14.6)	20 (48.8)
Ciprofloxacin (5)	28 (68.3)	4 (9.8)	9 (22.0)
Enrofloxacin (5)	29 (70.7)	3 (7.3)	9 (22.0)
Erythromycin (15)	11 (26.8)	7 (17.1)	23 (56.1)
Chloramphenicol (30)	18 (43.9)	6 (14.6)	17 (41.5)
Sulfamethoxazole-Trimethoprim (25)	12 (29.3)	6 (14.6)	23 (56.1)

Table 6: Multi-Drug Resistance (MDR) Patterns of *Pasteurella* Isolates (n = 41) from Domesticated Pigeons and Their Environment in Maiduguri, Borno State, Nigeria

Number of Antimicrobial Classes Resisted	Number of Isolates	Percentage (%)
0 (Susceptible to all tested)	0	0.0
1	2	4.9
2	3	7.3
3	5	12.2
4	8	19.5
5	9	22.0
6	7	17.1
7	4	9.8
8	2	4.9
9	1	2.4
≥10	0	0.0
Total	41	100.0
MDR (≥3 classes)	36	87.8

Table 7: Multiple Antibiotic Resistance (MAR) Index of *Pasteurella* Isolates from Domesticated Pigeons and Their Environment in Maiduguri, Borno State, Nigeria

MAR Index Range	Antibiotics Resisted	Number of Isolates	Percentage (%)	Interpretation
0.00–0.09	0–1	2	4.9	Low resistance exposure
0.18–0.27	2–3	8	19.5	Moderate resistance exposure
0.36–0.45	4–5	17	41.5	High resistance exposure
0.55–0.64	6–7	11	26.8	Very high resistance exposure
0.73–0.91	8–10	3	7.3	Extremely high resistance exposure
Total		41	100.0	
Mean MAR Index		0.43		High-risk environment

Table 8: Knowledge of Respondents Regarding Pasteurellosis (n = 100) in Maiduguri, Borno State, Nigeria

Knowledge Question	Correct Response	n (%)	Incorrect / Do not Know	n (%)
Awareness of pasteurellosis as a pigeon disease	32 (32.0)		68 (68.0)	
Recognition of nasal discharge as a clinical sign	36 (36.0)		64 (64.0)	
Recognition of coughing/sneezing as a clinical sign	38 (38.0)		62 (62.0)	
Recognition of difficulty in breathing as a clinical sign	26 (26.0)		74 (74.0)	
Knowledge that pasteurellosis is caused by bacteria	18 (18.0)		82 (82.0)	
Awareness that pasteurellosis can be transmitted between birds	24 (24.0)		76 (76.0)	
Knowledge that pasteurellosis can be prevented by vaccination	28 (28.0)		72 (72.0)	
Knowledge that pasteurellosis can be treated with antibiotics	40 (40.0)		60 (60.0)	
Awareness that pasteurellosis can affect humans (zoonotic)	12 (12.0)		88 (88.0)	
Overall Mean Knowledge Score	28.2%		71.8%	

Table 9: Antimicrobial Usage Practices among Pigeon Owners (n = 100) in Maiduguri, Borno State, Nigeria

Practice/Variable	Category	Frequency	Percentage (%)
Use of Antibiotics in Pigeons	Yes	76	76.0
	No	24	24.0
Sources of Antibiotics	Veterinary pharmacies	22	22.0
	Agricultural stores	30	30.0
	Human pharmacies	20	20.0
	Open markets	12	12.0
	Veterinary clinics	10	10.0
	Other pigeon owners	6	6.0
Prescription Obtained	Yes	18	18.0
	No	82	82.0
Dosage Adherence	Always	24	24.0
	Sometimes	42	42.0
	Never	34	34.0
Treatment Duration Completed	Always	26	26.0
	Sometimes	38	38.0
	Never	36	36.0
Self-Medication Practice	Yes	62	62.0
	No	38	38.0
Withdrawal Period Observed	Yes	12	12.0
	No	88	88.0
Reason for Antibiotic Use	Treatment of sick birds	52	52.0
	Disease prevention	24	24.0
	Growth promotion	8	8.0
	Routine practice	16	16.0

Table 10: Awareness of Antimicrobial Resistance (AMR) among Respondents (n = 100) in Maiduguri, Borno State, Nigeria

Awareness Question	Correct / Yes Response n (%)	Incorrect / No / Do not Know n (%)
Awareness of the term "antimicrobial resistance"	16 (16.0)	84 (84.0)
Knowledge that antibiotics may fail to treat infections	28 (28.0)	72 (72.0)
Awareness that inappropriate antibiotic use contributes to resistance	20 (20.0)	80 (80.0)
Knowledge that resistance can spread between pigeons and humans	10 (10.0)	90 (90.0)
Awareness of the public health importance of AMR	12 (12.0)	88 (88.0)
Mean AMR Awareness Score	17.2%	82.8%

DISCUSSION

The present study constitutes the first One Health assessment of *Pasteurella* species in domesticated pigeons and their environments in Maiduguri, Borno State, Nigeria, integrating epidemiological, microbiological, and socio-behavioural dimensions. The findings reveal a moderate overall prevalence (13.7%) of *Pasteurella* species, with a significantly higher burden in pigeons (17.5%) than in environmental samples (6.0%). This differential prevalence highlights the role of pigeons as primary reservoirs and amplifiers of *Pasteurella* organisms, while environmental contamination represents a secondary yet epidemiologically significant transmission pathway. The prevalence observed in pigeons in this study is comparable to that reported for other domesticated poultry species in parts of Nigeria, such as the 12.4% documented by Victor *et al.* (2016) in chickens from Ado-Ekiti, although Suleiman *et al.* (2021) reported a lower rate of 5.5% from Vom, Plateau State. Notably, the present findings are more than double the 6.2% reported by Mbuthia *et al.* (2008). Similarly, El-Demerdash *et al.* (2023) documented a 9.4% prevalence of *Pasteurella* species among avian species in Egypt, with varying prevalence rates, reinforcing the global distribution of this pathogen in avian populations. However, the prevalence in the present study exceeds the 6.2% reported by Mbuthia *et al.* (2008) from other poultry species sampled in farm environments in a comparable study, suggesting that *Pasteurella* species may be more efficiently transmitted within the pigeon loft ecosystem, or that local management practices in Maiduguri facilitate its persistence. The observed variations in prevalence rates may be attributable to differences in sample size, type of birds sampled, sampling effort,

diagnostic tools employed, management systems, geographical location, and study design. The detection of *Pasteurella* species in 6.0% of environmental samples, particularly in fresh faecal deposits (16.0%), aligns with the known biology of *Pasteurella* organisms, which are primarily shed from the upper respiratory tract but can be recovered from faeces, albeit less frequently (Abdulai *et al.*, 2026; Dubie *et al.*, 2026; Walsh *et al.*, 2026). The presence of *Pasteurella* in drinking water troughs and on feed surfaces (4.0% each) further implicates contaminated fomites as potential vehicles for indirect transmission—a finding with significant implications for loft biosecurity. It is noteworthy that limited published research has directly addressed the isolation of this bacterium in pigeons, which constrains comparison of our findings with other similar studies.

The spatial heterogeneity in *Pasteurella* prevalence across Maiduguri, ranging from 4.8% in Mairi to 31.0% in Gwange, suggests that local ecological and management factors modulate transmission dynamics. Gwange, the most densely populated and commercially active of the sampled locations, recorded the highest prevalence, potentially reflecting higher pigeon population densities, increased human-pigeon interactions, and greater environmental contamination pressure. This spatial clustering is consistent with observations that pigeon density and environmental contamination are key drivers of bacterial pathogen transmission in urban avian populations (Muhairwa *et al.*, 2001; Chrzastek *et al.*, 2012). The lower prevalence in Mairi might be attributable to smaller flock sizes, better loft hygiene, or less frequent introduction of new birds into the population. These findings highlight the need for location-specific interventions, as a one-size-fits-all approach to disease control is unlikely to be effective

across the heterogeneous urban landscape of Maiduguri.

The demographic analysis of *Pasteurella* prevalence in pigeons yielded several important insights. The age-related trend, though not statistically significant, showed a declining prevalence from squabs (26.9%) to young birds (18.1%) to adults (10.5%). This pattern is biologically plausible and consistent with the epidemiology of pasteurellosis in other avian species, where young, immunologically naive birds are more susceptible to infection (Ramesh *et al.*, 2018; El-Demerdash *et al.*, 2023). The borderline significance suggests that with a larger sample size, age might emerge as a significant risk factor. The significantly higher prevalence in male pigeons (25.5%) compared to females (10.4%) is a novel finding that warrants further investigation. While sex-based differences in disease susceptibility have been documented in various avian species, the mechanisms underlying this disparity in pigeons remain unclear. Possible explanations include behavioural differences (e.g., increased aggression and physical contact among males during breeding seasons) or physiological factors such as hormonal modulation of immune function (Duan *et al.*, 2026). The most striking finding was the highly significant association between health status and *Pasteurella* prevalence, with clinically sick pigeons exhibiting a prevalence of 46.4% compared to 6.3% in apparently healthy birds. This observation confirms the pathogenic potential of *Pasteurella* species and suggests that clinical disease is a strong predictor of infection. However, the detection of *Pasteurella* in 6.3% of apparently healthy pigeons is equally important, as these subclinically infected birds may serve as silent carriers, shedding organisms and perpetuating transmission within flocks without overt signs of disease (El-Demerdash *et al.*, 2023). This carrier state has significant implications for disease surveillance and control, as reliance on clinical signs alone would fail to identify a substantial proportion of infected birds. The absence of a significant association between flock size and *Pasteurella* prevalence contrasts with findings for other bacterial pathogens in pigeons, where higher stocking densities were associated with increased pathogen detection (Al-Zubaidi *et al.*, 2026). This discrepancy may reflect differences in the specific transmission dynamics of *Pasteurella* species, which are primarily spread through direct contact and respiratory aerosols rather than faecal-oral routes that might be more sensitive to density-dependent effects.

The antimicrobial susceptibility profiles of the 41 *Pasteurella* isolates revealed a concerning landscape of resistance, with the highest resistance rates observed against tetracycline (61.0%), oxytetracycline (61.0%), erythromycin (56.1%), and sulfamethoxazole-trimethoprim (56.1%). These findings are broadly consistent with global reports of antimicrobial resistance in *Pasteurella* species from avian sources. For instance, a study in India reported that 32% of *P. multocida* isolates from poultry were resistant to tetracycline, while resistance to sulfadiazine was 90.3% (Jeong *et al.*, 2021; Sabsabi *et al.*, 2021; Kerek *et al.*, 2024). The high tetracycline resistance observed in the present study is particularly noteworthy, as tetracyclines are among the most commonly used antimicrobials in pigeon husbandry in Nigeria and other low- and middle-income countries, often administered without veterinary supervision (Ayeni *et al.*, 2016; Jahantigh *et al.*, 2020; Semenova *et al.*, 2025). The high resistance rates to erythromycin and sulfamethoxazole-trimethoprim further limit therapeutic options, as these agents are frequently used as first-line treatments for respiratory infections in pigeons. In contrast, the relatively high susceptibility rates to enrofloxacin (70.7%), ciprofloxacin (68.3%), and gentamicin (63.4%) suggest that fluoroquinolones and aminoglycosides may retain some efficacy against *Pasteurella* isolates in this setting. However, the finding that 22.0% of isolates were resistant to ciprofloxacin and enrofloxacin is concerning, given that fluoroquinolones are considered critically important antimicrobials in human medicine. The emergence of fluoroquinolone resistance in *Pasteurella* isolates from pigeons raises concerns about the potential for zoonotic transmission of resistant strains to humans, particularly given the close contact between pigeon owners and their birds in Maiduguri.

The multi-drug resistance (MDR) analysis revealed an alarming situation, with 87.8% of isolates classified as MDR (resistant to ≥ 3 antimicrobial classes). The most common MDR pattern involved resistance to five antimicrobial classes (22.0%), followed by four classes (19.5%) and six classes (17.1%). This high prevalence of MDR is consistent with reports of MDR *Pasteurella* in other avian species, though the rates observed here are higher than the 23.8% MDR reported in a study from Egypt (El-Demerdash *et al.*, 2023). The detection of isolates resistant to eight and nine antimicrobial classes (4.9% and 2.4%, respectively) is particularly alarming, as it suggests the presence of near-pan-resistant strains in the

pigeon population. The mean MAR index of 0.43, with 41.5% of isolates falling in the high resistance exposure category (0.36–0.45) and 7.3% in the extremely high resistance exposure category (0.73–0.91), indicates a high-risk environment for antimicrobial resistance. According to the MAR index interpretation, values >0.2 suggest that bacteria have been exposed to antibiotics outside of clinical settings, likely through environmental contamination or subtherapeutic antimicrobial use (El-Demerdash *et al.*, 2023; Kerek *et al.*, 2024). The high MAR indices observed in this study point to widespread and indiscriminate antimicrobial use in pigeon husbandry in Maiduguri, creating selective pressure that favours the emergence and persistence of resistant strains.

The socio-behavioural findings provide critical context for understanding the drivers of antimicrobial resistance in this system. The overall mean knowledge score regarding pasteurellosis was only 28.2%, indicating a substantial knowledge gap among pigeon owners. The lowest awareness was recorded for the zoonotic potential of pasteurellosis (12.0%), which is particularly concerning given the close contact between pigeon owners and their birds, which creates opportunities for transmission. The finding that only 18.0% of respondents were aware that pasteurellosis is caused by bacteria suggests that many pigeon owners may not understand the rationale for antibiotic treatment, potentially leading to inappropriate use. This knowledge deficit is mirrored in the antimicrobial usage practices, where 82.0% of respondents reported using antibiotics without a prescription, 62.0% practised self-medication, and only 12.0% observed withdrawal periods. These findings are consistent with reports from other livestock sectors in developing countries including Nigeria, where over-the-counter antibiotic sales and lack of veterinary oversight are common (Wilson and Ho, 2013; Michael *et al.*, 2018; Gunasekara *et al.*, 2026; Raihan *et al.*, 2026). The use of agricultural stores (30.0%) and human pharmacies (20.0%) as primary sources of antibiotics is particularly concerning, as these outlets may not provide appropriate advice on dosage, duration, or withdrawal periods. The finding that 8.0% of respondents used antibiotics for growth promotion and 16.0% for routine practice is also noteworthy, as these practices are associated with subtherapeutic antimicrobial exposure and the selection of resistant bacteria.

The AMR awareness assessment revealed critically low levels of understanding, with only 16.0% of respondents aware of the term "antimicrobial

resistance" and 10.0% aware that resistance can spread between pigeons and humans. The mean AMR awareness score of 17.2% is substantially lower than that reported among poultry farmers in some African developing countries including Nigeria, where knowledge levels were generally high (Mudenda *et al.*, 2022; Yakubu *et al.*, 2024; Hackman *et al.*, 2025). This disparity may reflect differences in educational interventions, veterinary extension services, or the scale of operations between commercial poultry farming and backyard pigeon keeping. The low awareness of AMR among pigeon owners in Maiduguri represents a significant barrier to implementing antimicrobial stewardship interventions, as behaviour change requires at least a basic understanding of the problem. The finding that only 28.0% of respondents knew that antibiotics may fail to treat infections suggests that many pigeon owners may not recognise the consequences of resistance until treatment failure occurs, by which time resistant strains may have already become established in their flocks.

The One Health implications of these findings are profound. Pigeons are synanthropic birds that live in close association with humans in urban environments, creating ample opportunities for bidirectional transmission of *Pasteurella* species and their antimicrobial resistance determinants. The detection of *Pasteurella* isolates with high MAR indices in pigeons that are kept for recreation and potentially for consumption in Maiduguri raises concerns about food safety and public health. While *Pasteurella* species are primarily zoonotic through bite wounds and scratches from cats and dogs (Chrobak-Chmiel *et al.*, 2021; Loucif *et al.*, 2022), the respiratory route of transmission documented in avian species (Crăciun *et al.*, 2026) suggests that pigeon owners and their families may be at risk through inhalation of contaminated aerosols in poorly ventilated lofts. Furthermore, the environmental contamination documented in this study, particularly in faecal deposits and water troughs, may contribute to the dissemination of resistant bacteria into the broader urban environment, potentially affecting other animal species and humans through contaminated soil, water, and food chains.

The high prevalence of MDR *Pasteurella* isolates in pigeons also has implications for the treatment of human pasteurellosis. Although human infections with *Pasteurella* species are most commonly associated with animal bites, particularly from cats and dogs (Wei *et al.*, 2025; Qiu *et al.*, 2026), the

potential for pigeon-associated transmission cannot be excluded, especially in immunocompromised individuals. The finding that 22.0% of isolates were resistant to fluoroquinolones, which are among the first-line agents for treating *Pasteurella* infections in humans, is particularly concerning. If these resistant strains were to be transmitted to humans, treatment options would be limited, potentially leading to treatment failure and severe outcomes. The high resistance rates to tetracyclines and sulfonamides, which are also used in human medicine, further compound this concern. These findings underscore the need for integrated surveillance systems that monitor antimicrobial resistance in both animal and human populations, as recommended by the One Health approach.

Several limitations of this study should be acknowledged. First, the cross-sectional design precludes the establishment of causal relationships between the identified risk factors and *Pasteurella* infection. Second, the identification of *Pasteurella* isolates to the species level was not performed, which limits the ability to assess the zoonotic potential of specific species such as *P. multocida*. Third, the antimicrobial susceptibility testing was performed using phenotypic methods, and molecular characterization of resistance genes was not conducted, which would have provided insights into the genetic basis of resistance and the potential for horizontal gene transfer. Fourth, the questionnaire-based assessment of knowledge and practices is subject to social desirability bias, which may have led to underreporting of undesirable practices such as self-medication and non-observance of withdrawal periods. Despite these limitations, the study provides a robust foundation for understanding the epidemiology of *Pasteurella* species in domesticated pigeons in Maiduguri and identifies key targets for intervention.

CONCLUSION

This study to our knowledge provides the first One Health assessment of *Pasteurella* species in domesticated pigeons and their environments in Maiduguri, Borno State, Nigeria. The overall prevalence of 13.7% confirms that *Pasteurella* species are endemic in the study area, with a significantly higher burden in pigeons (17.5%) than in environmental samples (6.0%). Clinically sick pigeons, males, and squabs were disproportionately affected, while fresh faecal deposits constituted the principal environmental contamination pathway. Of grave concern, 87.8% of isolates were multi-drug resistant,

with a mean MAR index of 0.43, indicating a high-risk environment for antimicrobial resistance. These microbiological findings are compounded by substantial knowledge deficits among pigeon owners, with mean knowledge and AMR awareness scores of only 28.2% and 17.2%, respectively, alongside widespread indiscriminate antibiotic use, self-medication (62.0%), and poor withdrawal period compliance (12.0%). Collectively, these findings demonstrate that pigeon-associated pasteurellosis constitutes an underestimated but significant public health threat in Maiduguri, with clear opportunities for zoonotic and resistance transmission. Urgent, integrated interventions—including owner education, veterinary oversight of antimicrobial use, improved loft biosecurity, and sustained One Health surveillance—are recommended to mitigate these risks.

Based on the findings of our study, the following recommendations are made: Targeted health education programmes should be prioritised for pigeon owners in the high-prevalence locations of Gwange and Galtimari, with content addressing the clinical signs, bacterial aetiology, transmission dynamics, and zoonotic potential of pasteurellosis, given the substantial knowledge deficits documented in this study. Regulatory authorities should strengthen oversight of antibiotic sales through agricultural stores, human pharmacies, and open markets, and enforce prescription-only dispensing to curb the widespread self-medication, dosage non-adherence, and incomplete treatment durations observed among owners. Veterinary practitioners should routinely conduct antimicrobial susceptibility testing before prescribing treatment, prioritising enrofloxacin, ciprofloxacin, and gentamicin, which retained the highest activity against the isolates, while exercising caution with tetracyclines and sulfamethoxazole-trimethoprim, against which resistance was most pronounced also its worth noting that note that fluoroquinolones are critically important in human medicine and should be used judiciously. Pigeon owners should adopt improved loft biosecurity measures, including daily removal of faecal deposits, regular disinfection of drinking water and feeding troughs, and prompt isolation of clinically sick birds to reduce within-flock and environmental transmission. Finally, relevant animal and public health authorities should establish a sustained One Health surveillance programme that integrates pigeon, environmental, and human *Pasteurella* isolates to monitor antimicrobial

resistance trends and detect zoonotic transmission in Maiduguri.

COMPETING INTERESTS

The authors declare that they have no competing interests.

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