**Prevalence and Antimicrobial Susceptibility of *Escherichia coli* in Fresh and Ready-to-Eat Camel Meat from Maiduguri Central Abattoir, Nigeria**

**Abstract**

Camel meat has gained popularity in Nigeria because of its perceived nutritional benefits and cultural significance. However, concerns about meat safety, particularly regarding foodborne pathogens such as *Escherichia coli* (*E. coli*), have arisen. This study assessed the prevalence and antimicrobial susceptibility of *E. coli* in fresh and ready-to-eat camel meat from Maiduguri Central Abattoir, with the goal of guiding public health interventions. A total of 100 camel meat samples (50 fresh and 50 ready-to-eat) were analysed via standard microbiological techniques. Antimicrobial susceptibility testing was performed using the disc diffusion method against a panel of 10 antimicrobial agent.The overall prevalence of *E. coli* was 41 (41.0%), with a significantly greater prevalence in fresh camel meat 34 (68.0%) than in ready-to-eat camel meat 7 (14.0%). All isolates (41) were susceptible to trimethoprim-sulfamethoxazole, ofloxacin, and pefloxacin. However, 32 (78%) isolates exhibited high resistance to penicillin, while 25 (61%) isolates were resistant to ceftriaxone and ciprofloxacin. The results also showed that 35 (85.4) of the isolates were multidrug resistant. These findings underscore the importance of implementing improved handling and processing procedures, judicious antibiotic use, and regular surveillance to mitigate *E. coli* contamination risks and combat antimicrobial resistance. The results of this study have significant implications for food safety and public health in Nigeria, emphasizing the importance of good hygiene practices and responsible antibiotic use in the camel meat industry.

**Keywords**

Camel meat, *E. coli*, antimicrobial susceptibility, food safety, public health, Maiduguri.

**Introduction**

The global demand for camel meat has increased in recent years, driven by its perceived nutritional benefits and cultural significance (Mohamed and Habib, 2023; Elkady *et al.,* 2024). As a result, camel meat has gained popularity in Nigeria, particularly in the northeastern region, due to its availability and affordability. However, this growing demand has also raised concerns about meat safety, particularly in the context of foodborne pathogens such as *Escherichia coli* (*E. coli*) a normal flora of animal and human intestines and a common bacterial contaminant in many animal-derived products (WHO, 2020). Notably, *E. coli* is a significant public health threat, causing a range of illnesses in humans, including diarrhea, urinary tract infections, and life-threatening conditions such as hemolytic uremic syndrome (HUS) (Pokharel *et al.,* 2023, Saad *et al*., 2024).

In Maiduguri, the capital of Borno State, the abattoir serves as a central hub for the camel meat trade. However, it faces significant infrastructural and operational challenges that increase the risk of microbial contamination (Jaji *et al.,* 2017). Specifically, the concurrent slaughter of different livestock species, poor sanitation, and limited access to potable water contribute to the risk of contamination with enteric pathogens such as *E. coli* (Musa *et al.,* 2017; Tegegne *et al.*, 2019).

Furthermore, the misuse and overuse of antibiotics in animal husbandry has exacerbate this issue. Antibiotics are often used inappropriately, driving the development of multidrug-resistant (MDR) bacteria, including *E. coli* (Caneschi *et al*., 2023; Matheou *et al*., 2025). In Nigeria, studies have shown that many farmers use antibiotics without proper guidance. Over 87% of farmers use antibiotics for prophylaxis (Ojo *et al*., 2016), while 80% of broiler farmers administer antimicrobials without veterinary prescriptions (Nurudeen *et al*., 2019). Herders also practice self-prescription, with 58.3% administering antibiotics without guidance and 23.2% using them as growth promoters (NmaBida & Tajudeen, 2018).

Given the increasing consumption of camel meat in Maiduguri and the public health implications of potential *E. coli* contamination, especially strains with antimicrobial resistance, there is a critical need for local data to guide preventive strategies. To the best of our knowledge, no study has investigated the antimicrobial susceptibility profiles of *E. coli* in fresh and ready-to-eat camel meat from the Maiduguri Abattoir. This study aims to address this knowledge gap by assessing the occurrence and antimicrobial susceptibility profiles of *E. coli* in camel meat obtained from butchers at the Maiduguri Abattoir, thereby contributing to existing knowledge on food safety risks associated with camel meat and helping mitigate the public health impacts of consuming contaminated or drug-resistant meat products.

**Sampling Technique**

This study used a nonprobability convenience sampling method to collect camel meat samples from consenting butchers at the Maiduguri abattoir. Sampling was carried out over a three-month period (July to September 2024), resulting in a total of 100 camel meat samples. These included 50 fresh raw camel meat samples and 50 ready-to-eat roasted camel meat samples. For each sample, approximately 10 gram of meat was collected using sterile forceps and aseptically transferred into individually labeled sterile polythene bags. The samples were then immediately packed in iceboxes and transported to the Bacterial Zoonoses Laboratory, Department of Public Health and Preventive Medicine, University of Maiduguri, for microbiological analysis.

**Isolation and identification of *E. coli***

The isolation of *E. coli* was performed following the method described by Quinn *et al*. (2002), with slight modifications. Briefly, 5 gram of each sample was enriched in 90 ml of peptone water (HiMedia, Mumbai, India) and incubated at 37°C for 24 h. The enriched samples were then inoculated onto MacConkey Agar (MCA) (HiMedia, Mumbai, India) via the four-flame technique, and the plates were incubated at 37°C for 24 h. Pink-colored colonies, presumptive of *E. coli*, were selected for further analysis.

Gram-staining was performed according to the method described by Merchant and Packer (1969) to determine the Gram reaction, size, shape, and arrangement of bacterial cells. Gram-negative, pink-colored, rod-shaped cells arranged singly or in pairs were suggestive of *E. coli.*

A single well-isolated colony was selected from MacConkey Agar (MCA) and streaked onto Eosin Methylene Blue Agar (EMB) (HiMedia, Mumbai, India). After incubation at 37°C for 24 h, colonies exhibiting a characteristic green metallic sheen were presumptively identified as *E. coli*. The combination of colony morphology and color on both MCA and EMB agar plates, along with Gram staining results, were used for the initial identification of *E. coli* colonies (Eaton *et al.,* 1995).

Colonies with typical characteristics were then subcultured in nutrient broth and agar for further biochemical examination. Standard biochemical tests, including catalase, indole, methyl red, Voges-Proskauer, nitrate reduction, citrate utilization, and urease production, were performed to confirm the identification of *E. coli* (Jarvis *et al.,* 1994; Brenner *et al.,* 2005; MacFaddin, 2000; Chakraborty, 2011). Additionally, the triple sugar iron test was conducted according to Vanderzant and Splittstoesser (1992), and carbohydrate fermentation tests were performed via the method described by Simmons (Cheesbrough, 1985).

**Antimicrobial susceptibility testing**

Antimicrobial susceptibility testing was performed using the disc diffusion method against a panel of 10 Antimicrobial agent. The Kirby–Bauer disk diffusion method was used in accordance with the method of Clinical and Laboratory Standards Institute (CLSI) guidelines (2023). Mueller–Hinton agar plates were inoculated with a standardized bacterial suspension adjusted to match the 0.5 McFarland turbidity standard (approximately 1.5 × 10⁸ CFU/mL). Turbidity was verified both visually and with a nephelometer. Antibiotic discs (Table 1) were then applied on the agar surface using sterile forceps and a disc dispenser. Following incubation at 37°C for 18–24 hours, the zones of inhibition around the discs were measured and interpreted according to the CLSI M100 guidelines (2023), with the breakpoints outlined in Table 1.

**Table 1 Breakpoint of antibiotics in accordance with the Clinical and Laboratory Standards Institute (CLSI, 2023)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Antimicrobial Class** | **Antibiotic** | **Concentration** | **Susceptible** | **Intermediate** | **Resistant** |
| Aminoglycosides | Gentamicin (CN) | 10 µg | ≥15 | 13-14 | ≤12 |
| Beta-lactams | Amoxicillin/Clavulanic acid (AU) | 20 µg/10 µg | ≥ 18 | 14-17 | ≤13 |
| Sulfonamides | Sulfamethoxazole/Trimethoprim (SXT) | 1.25 µg23.75 µg | ≥16 | 11-15 | ≤10 |
| Aminoglycosides | Streptomycin (S) | 10 µg | ≥15 | 12-14 | ≤11 |
| Beta-lactams | Penicillin (PN) | 10IU | ≥21 | 18-20 | ≤17 |
| Cephalosporins | Ceftriaxone (CEP) | 30 µg | ≥23 | 20-22 | ≤19 |
| Fluoroquinolones | Ofloxacin (OFX) | 5 µg | ≥ 16 | 13-15 | ≤12 |
| Quinolones | Nalidixic acid (NA) | 30 µg | ≥19 | 14-18 | ≤13 |
| Fluoroquinolones | Ciprofloxacin (CPX) | 5 µg | ≥21 | 16-20 | ≤15 |
| Fluoroquinolones | Pefloxacin (PEF) | 5 µg |  ≥19 | 16-18 | ≤15 |

**Data analysis**

The data were analysed via the Statistical Package for Social Sciences (SPSS) version 20. Descriptive statistics, including frequency and percentage, were used to summarize the prevalence of *E. coli* in various meat types. Chi-square (χ²) tests were conducted to assess the relationship between *E. coli* occurrence and meat category (fresh vs. ready-to-eat), with statistical significance determined at p < 0.05.

**Results**

The results of the occurrence of *E. coli* in camel meat samples from Maiduguri Central Abattoir are presented in Table 2. Accordingly, 34 (68.0%) of the 50 fresh camel meat samples tested positive for *E. coli*, with a 95% confidence interval of 53.8--79.6. In contrast, 7 (14.0%) out of 50 ready-to-eat camel meat samples were positive, with a 95% confidence interval of 6.4–26.7. Overall, *E. coli* was detected in 41 (41.0%) out of 100 samples, with a 95% confidence interval of 31.5–51.1.

Table 3 shows the prevalence of *E. coli* in fresh camel meat and ready-to-eat camel meat. Among the 50 fresh camel meat samples examined, 68.0% (34/50) were positive for *E. coli*. In contrast, of the 50 ready-to-eat camel meat samples examined, 14.0% (7/50) were positive. There was a statistically significant association between the prevalence of fresh camel meat and ready-to-eat camel meat (p value <0.0001; odds ratio = 13.0536; 95% CI= 4.8--35.3).

All 41 *E. coli* isolates were highly susceptible to trimethoprim-sulfamethoxazole, ofloxacin, and pefloxacin (100% each). In contrast, high resistance was observed against penicillin (78%), ceftriaxone (61%), and ciprofloxacin (61%). A moderate susceptibility rate of 25 (61.0) was recorded for streptomycin, and 25 9 (22.0%) each were recorded for gentamicin and nalidixic acid. (Figure 1).

Table 4 shows Multidrug resistance (MDR) profile of *Escherichia coli* isolates from camel meat samples in Maiduguri, Borno State, Nigeria. Of the 37 MDR isolates, 15 were resistant to three drugs (Penicillin, Ciprofloxacin, Ceftriaxone), 7 were resistant to four drugs (Penicillin, Ciprofloxacin, Ceftriaxone, Nalidixic Acid), 6 were resistant to five drugs (Penicillin, Ciprofloxacin, Ceftriaxone, Nalidixic Acid, Streptomycin), 4 were resistant to six drugs (Penicillin, Ciprofloxacin, Ceftriaxone, Nalidixic Acid, Streptomycin, Amoxicillin/Clavulanate), and 3 were resistant to seven drugs (Penicillin, Ciprofloxacin, Ceftriaxone, Nalidixic Acid, Streptomycin, Amoxicillin/Clavulanate, Gentamicin).

**Table 2: Prevalence of *E. coli* in camel meat samples from the Maiduguri Central Abattoir**

|  |  |  |  |
| --- | --- | --- | --- |
| **Meat Type** | **No. Examined** | **No. (%) Positive** | **95% CI** |
| Fresh Camel Meat | 50 | 34 (68.0) | 53.8 - 79.6 |
| Ready-to-Eat Camel Meat | 50 | 7 (14.0) | 6.4 - 26.7 |
| **Total** | **100** | **41 (41.0)** | **31.5 - 51.1** |

**Table 3: Risk analysis of *E. coli* contamination in fresh and ready-to-eat camel meat samples**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Meat Type** | **No. Examined** | **No. (%) Positive** | ***p* value** | **Odd Ratio** | **95% CI** |
| Fresh Camel Meat | 50 | 34 (68.0) | <0.0001 | 13.0536 | **4.8-35.3** |
| Ready-to-Eat Camel Meat | 50 | 7 (14.0) |  |  |  |

Figure 1: Antimicrobial biogram profile of *Escherichia coli* isolates from camel meat samples in Maiduguri, Borno State, Nigeria.

**Table 4: Multidrug resistance (MDR) profile of *Escherichia coli* isolates from camel meat samples in Maiduguri, Borno State, Nigeria**

|  |  |  |
| --- | --- | --- |
| **No. of Antimicrobial** | **Resistant Pattern** | **No. (%) of Isolate** |
| 3 | Pen, Cip, Cep | 15 (36.6) |
| 4 | Pen, Cip, Cep, NA | 7 (17.1) |
| 5 | Pen, Cip, Cep, NA, Strep | 6 (14.6) |
| 6 | Pen, Cip, Cep, NA, Strep, AMC | 4 (9.8)  |
| 7 | Pen, Cip, Cep, NA, Strep, AMC, Gen | 3 (7.3) |
| Total Resistan  |  | 35 (85.4) |

**Discussion**

The findings of this study provide valuable insights into the prevalence of *Escherichia coli* (*E. coli*) in fresh and ready-to-eat camel meat. The overall prevalence of *E. coli* in camel meat was 41.0%, which raises substantial concerns about the microbial quality and safety of camel meat consumed in Maiduguri, Northeast Nigeria.

The statistical analysis revealed a significant association between the type of meat and *E. coli* prevalence (p < 0.0001). Fresh camel meat was approximately 13 times more likely to be contaminated with *E. coli* than ready-to-eat camel meat. The high prevalence rate of *E. coli* in fresh camel meat (68.0%) underscores the need for improved handling and processing procedures to mitigate the risk of contamination.

In contrast, the relatively lower prevalence rate in ready-to-eat camel meat (14.0%) suggests that processing and handling procedures may play a crucial role in reducing *E. coli* contamination. This finding aligns with the general understanding that heat treatment during processing may reduce the microbial load, thereby increasing food safety (Tang *et al.,* 2020; Elkady *et al.,* 2024).

Our findings on the prevalence of *Escherichia coli* in fresh camel meat are notably greater than those reported in previous studies from similar settings. For example, Rahimi *et al*. (2012) reported a prevalence of 2.0%, whereas Sallam *et al*. (2023) reported 38.2% in fresh camel meat from Fars and Khuzestan Provinces in Iran and Egypt, respectively. Similarly, Al-Ajmi *et al*. (2020) detected *E. coli* in 4.3% of camels sampled in Al Ain, United Arab Emirates.

The contamination of fresh camel meat with *E. coli* frequently occurs during meat processing, particularly in abattoirs. As we observed in our study, cross-contamination can arise from faulty evisceration, exposure to contaminated environments, and improper handling practices during slaughter and processing. This is consistent with previous reports by Sallam *et al*. (2023) and Hunduma *et al*. (2024), which highlight the critical role of proper hygiene and handling practices in minimizing microbial contamination of meat products. Implementing strict sanitation protocols and Good Manufacturing Practices (GMPs) in abattoirs can help reduce the risk of *E. coli* contamination and improve the overall safety of fresh camel meat.

Nigeria faces a significant challenge with antimicrobial resistance (AMR), driven by the overuse and misuse of antimicrobials in both human and animal healthcare (Awulu *et al*., 2025). The country is projected to experience a significant increase in antimicrobial use in food animals, further exacerbating the problem (Van Boeckel *et al*., 2015). Specifically, over 70% of farms in Nigeria use antimicrobials for growth promotion and routine operations (Alhaji *et al*., 2023), and in the public health sector, antimicrobials are often prescribed without prior laboratory diagnosis (Babatola *et al*., 2021; Chukwu *et al*., 2020). The antimicrobial susceptibility profiles of the 41 *E. coli* isolates from camel meat samples revealed notable patterns of susceptibility and resistance to various antibiotics. The results indicate that the isolates were highly susceptible to three antibiotics, namely trimethoprim-sulfamethoxazole, ofloxacin, and pefloxacin, with 100% of the isolates being susceptible to each of these antibiotics. The high susceptibility of *E. coli* isolates to trimethoprim-sulfamethoxazole, ofloxacin, and pefloxacin may be attributed to their relatively limited use in veterinary medicine in our region, reducing selective pressure for resistance. On the contrary, 48.4% of *E. coli* O157:H7 and O55:H7 isolates in Camel Meat were resistance to trimethoprim-sulfamethoxazole (Sallam *et al*., 2023)

 were sensitive to

In contrast, the *E. coli* isolates presented high levels of resistance to several antibiotics, including penicillin (78% resistant), ceftriaxone (61%), and ciprofloxacin (61%). The high resistance rates to these antibiotics may be due to their widespread use or misuse in the study area. Notably, high resistance to ceftriaxone and ciprofloxacin is a serious concern, as these drugs are currently the preferred treatment options for human infections (Sekoni *et al*., 2022). The observed 61% resistance rate to ciprofloxacin in our study starkly contrasts with findings from other research, such as Sallam *et al*.'s (2023) study, which reported a resistance rate of 22.2%, and El-Ghareeb *et al*.'s (2020) study in Saudi Arabia, which found 17.6% resistance in *E. coli* isolates from minced camel meat. These discrepancies suggest regional variations in antibiotic resistance patterns, potentially influenced by differences in antibiotic usage, bacterial strain prevalence, and sample sources. Interestingly, a study by Sallam *et al*. (2023) in Egypt reported 100% resistance to penicillin, consistent with our findings of high penicillin resistance in our study.

The presence of resistance to ceftriaxone, a third-generation cephalosporin, in camel meat samples is noteworthy, particularly given its limited application in animal husbandry within the study area. Conversely, ceftriaxone is frequently utilized in human medicine in the region (Sekoni *et al*., 2022), which may facilitate the transmission of resistant strains from humans to animals or the development of resistance via mechanisms such as horizontal gene transfer. The 61% ceftriaxone resistance rate in our study is significantly higher than the 3.97% reported by Sallam *et al*. (2023) in Egypt, suggesting potential differences in antibiotic use, bacterial strains,

The susceptibility patterns to gentamicin, Amoxicillin/Clavulanic acid, and nalidixic acid were more variable, with a mix of susceptible, intermediate, and resistant isolates. For example, 39% of the isolates were susceptible to gentamicin, 39% were resistant, and 22% exhibited intermediate susceptibility. Similarly, 61% of the isolates were susceptible to Amoxicillin/Clavulanic acid, whereas 39% were resistant.

The intermediate susceptibility patterns observed with streptomycin, where no isolate was fully susceptible and 61.0% showed intermediate responses, reflect a complex resistance dynamic that may signify evolving genetic adaptations. Aminoglycoside-modifying enzymes and efflux pump mechanisms have been implicated in streptomycin resistance among *E. coli* isolates in similar studies (Jouybari *et al*., 2021; Essalhi *et al*., 2024). The use of streptomycin in animal husbandry as a growth promoter or for routine disease control may contribute to this gradual resistance build-up.

The emergence of multidrug-resistant (MDR) bacteria poses a substantial threat to public health. Our study found a high prevalence of MDR among isolates, with 85.3% resistant to three or more antibiotics, this finding is in agreement with 85.4% reported in a previous study (Sallam, 2023) on *E. coli* O157 isolates in camel meat in Egypt. The most common MDR pattern involved resistance to critical antibiotics like penicillin, ciprofloxacin, and ceftriaxone. Similar resistance profiles have been documented in Nigeria (Adenipekun *et al*., 2015; Adesoji *et al*., 2019; Ahmed *et al*., 2019; Bamigboye *et al*., 2020; Datok *et al*., 2021; Mola *et al*., 2021; Agusi *et al*., 2024; Onwumere-Idolor *et al*., 2024). The high level of MDR observed is concerning, as it may lead to treatment failures and increased morbidity and mortality. The widespread use and misuse of antibiotics likely contributed to the development and spread of MDR bacteria. Importantly, our findings suggest that trimethoprim-sulfamethoxazole, ofloxacin, and pefloxacin could be effective first-line treatments for *E. coli* infections in camels and humans. However, the high resistance rates to penicillin, ceftriaxone, and ciprofloxacin underscore the need for judicious antibiotic use and responsible antimicrobial stewardship in both veterinary and human medicine.

**Conclusion and Recommendations**

The prevalence of *E. coli* in camel meat was 41.0% overall, with a significantly higher prevalence in fresh camel meat (68.0%) than in ready-to-eat camel meat (14.0%). The *E. coli* isolates exhibited high resistance rates to penicillin (78%, n=32) and ceftriaxone (61%, n=25), as well as ciprofloxacin (61%, n=25). Conversely, the isolates showed high susceptibility to trimethoprim-sulfamethoxazole, ofloxacin, and pefloxacin, with 100% susceptibility (n=41) to each of these antibiotics. The results also showed that 85.3% of the isolates were resistant to three or more antibiotics.

Based on these findings, implementing good hygiene practices is essential to reduce *E. coli* contamination in camel meat. Additionally, promoting the judicious use of antibiotics and conducting regular surveillance to monitor antimicrobial resistance patterns is crucial

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