**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. The overall prevalence of *E. coli* was 41.0%, with a significantly greater prevalence in fresh camel meat (68.0%) than in ready-to-eat camel meat (14.0%). The isolates All isolates (no. of isolates) are susceptible to trimethoprim-sulfamethoxazole, ofloxacin, and pefloxacinbut \_\_\_ isolates (78%) are highly resistant to penicillin, \_\_\_\_ (61%)to ceftriaxone,and \_\_\_\_ (61%) to ciprofloxacin . 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 significantimplications 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*) (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).

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 have accelerated selection pressure for multidrug-resistant (MDR) bacteria, including *E. coli*, compromising the efficacy of critical antibiotics and representing a looming challenge in the treatment of infectious diseases (Caneschi *et al.,* 2023; Matheou *et al*., 2025).

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. Therefore, this study aimed to assess the occurrence and antimicrobial susceptibility profiles of *E. coli* in fresh and ready-to-eat camel meat obtained from butchers at the Maiduguri Abattoir. By doing so, this study contributes to the existing knowledge on food safety risks associated with camel meat and helps 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 1 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 g 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 via the Kirby–Bauer disk diffusion method in accordance with the 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)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Antibiotic Class** | **Antibiotic** | **Concentration** | **Susceptible** | **Intermediate** | **Resistant** |
|  | Gentamicin (CN) | 10 µg | ≥15 | 13-14 | ≤12 |
|  | Amoxicillin/  Clavulanic acid (AU) | 20 µg/  10 µg | ≥ 18 | 14-17 | ≤13 |
|  | Sulfamethoxazole/Trimethoprim (SXT) | 1.25 µg  23.75 µg | ≥16 | 11-15 | ≤10 |
|  | Streptomycin (S) | 10 µg | ≥15 | 12-14 | ≤11 |
|  | Penicillin (PN) | 10IU | ≥21 | 18-20 | ≤17 |
|  | Ceftriaxone (CEP) | 30 µg | ≥23 | 20-22 | ≤19 |
|  | Ofloxacin (OFX) | 5 µg | ≥ 16 | 13-15 | ≤12 |
|  | Nalidixic acid (NA) | 30 µg | ≥19 | 14-18 | ≤13 |
|  | Ciprofloxacin (CPX) | 5 µg | ≥21 | 16-20 | ≤15 |
|  | 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).

The *E. coli* isolates are highly susceptibile 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 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 susceptibility profile of *Escherichia coli* isolates from camel meat samples in Maiduguri, Borno State, Nigeria

**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 relatively high prevalence of *E. coli* in fresh camel meat samples observed in our study may be attributed to cross-contamination during meat processing in abattoir. Fault evisceration and exposure to contaminated environments during slaughter and handling may contribute to this contamination, as similarly reported by Sallam *et al.* (2023) and Hunduma *et al.* (2024).

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 that 100% of the isolates were susceptible to each of these antibiotics.

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. High resistance to ceftriaxone and ciprofloxacin is a serious concern, as these drugs are currently the drugs of choice in the treatment of infection in humans.

The observed resistance to ceftriaxone, a third-generation cephalosporin, is surprising given its limited use in animal husbandry in the study area. Ceftriaxone is, however, a commonly used antibiotic for treating human infections in the region, suggesting potential transmission of resistant strains from animals to humans or the emergence of resistance through other mechanisms.

The high resistance to penicillin is not surprising, given the consistency with findings of Ronald *et al*. (2023), who reported extensive resistance of foodborne *E. coli* isolates to β-lactams in meat from Kenya. This trend is likely due to widespread antibiotic misuse in animal husbandry, highlighting the need for judicious antibiotic use and surveillance.

The susceptibility patterns to gentamicin, augmentin, 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 augmentin, whereas 39% were resistant.

The findings of this study have important implications for the treatment and control of *E. coli* infections in camels. The high susceptibility to trimethoprim-sulfamethoxazole, ofloxacin, and pecloxacin suggests that these antibiotics could be used as first-line treatments for *E. coli* infections in camels as well as in foodborne *E. coli* infections in humans. However, the high resistance rates to penicillin, ceftriaxone, and ciprofloxacin highlight the need for judicious use of these antibiotics in veterinary and human medicine and the importance of responsible antimicrobial stewardship.

**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 isolates presented high resistance rates to penicillin (78%), ceftriaxone (61%), and ciprofloxacin (61%) but high susceptibility to trimethoprim-sulfamethoxazole, ofloxacin, and pefloxacin (100% susceptible each).

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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