

Prevalence of Antibiotic-Resistant *Enterobacteriaceae* Isolated from Grilled Meats and Human Feces in Two Regions of Chad

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Abstract The uncontrolled use of antibiotics to improve the productivity of food-producing animals and to treat human diseases poses a significant risk to public health. Residual antibiotics in animal tissues can promote the selection of resistant bacteria, posing serious health risks to consumers. The aim of this study was to assess the diversity and antibiotic resistance profiles of *Enterobacteriaceae* isolated from grilled meat and consumer stool samples. A cross-sectional study was carried out in two towns in Chad-Abeche and Mongo-between February and July 2024. Bacteria were identified from grilled meat and stool samples using standard bacteriological methods. The Kirby-Bauer disk diffusion method was used to determine the antibiotic resistance profiles of the isolated strains. A total of 196 samples were collected, including 151 stool samples and 45 grilled meat samples. The culture results identified 37 (24.50%) positive stool samples and 11 (24.44%) positive grilled meat samples. *Escherichia coli* was the most frequently isolated species (43.53%), followed by *Pantoea spp* (18.82%) and *Serratia ficaria* (8.24%). High resistance rates have also been observed against ciprofloxacin (78.33%), ceftriaxone (70%), amoxicillin-clavulanic acid (65%), cefotaxime (51.67%), and cefoletin (50%). Imipenem showed excellent activity (sensitivity of 95%), while gentamicin had moderate effectiveness (31.66%). ESBL-producing isolates were found in both sources (7.06%). The results suggest that the consumption of grilled meat could contribute to the spread of enterobacteria in the population.

Keywords: Antibiotic resistance, Chad, Enterobacteria, grilled meat, stools

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1. Introduction

Antibiotic resistance poses a serious global threat to human health [1,2]. According to [3], 4.71 million deaths were associated with bacterial AMR, of which 1.14 million deaths were attributed to AMR. Low-income countries are particularly vulnerable to antibiotic resistance due to the unregulated sale of antibiotics, their misuse and overuse, inadequate healthcare infrastructures, poor infection control practices and environmental contamination. These factors contribute to the emergence and spread of resistant bacteria, leading to prolonged hospitalization, morbidity, mortality and increased pressure on individual and healthcare system resources [4,5,6]. Among resistant bacteria, certain *Enterobacteriaceae* are of particular concern due to their

role in complicating infection management. These bacteria are commonly found in the digestive tracts of humans and animals, and can be transmitted by direct contact or indirectly via contaminated food and water. As a result, they are major contributors to community-acquired and nosocomial infections [7]. *Enterobacteriaceae* are responsible for serious infections, and many members of this family are increasingly resistant to β -lactam antibiotics, including carbapenems [8]. Antibiotic resistance in *Enterobacteriaceae* is a growing global concern due to the production of extended-spectrum β -lactamases (ESBL) and their ability to acquire resistance genes via mobile genetic elements. Beta-lactam antibiotics, once the cornerstone of the treatment of enterobacterial infections, have lost their effectiveness due to widespread misuse in human and veterinary medicine. In Chad, with its galloping population growth and increased demand for food away from home, grilled meat is widely consumed

and enjoyed by the entire population. It has even become a dietary habit for Chadians due to its availability and accessibility. However, it could serve as a vehicle for the bacteria responsible for bacterial infections, particularly food-borne toxin infections, if not prepared under hygienic conditions. Most bacterial infections have been treated inconsistently with antibiotics, leading to antibiotic resistance. Like other African countries, Chad faces a major AMR challenge due to limited health resources, lack of specialized training, inadequate regulation, distribution and use of pharmaceutical products [9]. The widespread illegal sale of antibiotics in markets and unregulated distribution through pharmacies exacerbate the problem of AMR in Chad. In addition, antibiotics can be consumed indirectly from meat containing antibiotic residues, or contaminated by antibiotic-resistant bacteria during mishandling in restaurants. This transmission of multi-resistant bacteria via grilled meat could represent a major public health challenge. Poor hygiene and sanitation during food processing can lead to contamination, posing serious health risks and economic burdens. Understanding the relationship between resistant strains found in hospital and community settings is essential for tracking the emergence of antibiotic resistance. While some research has looked at antibiotic resistance and unsanitary street food, very little of the research in Chad has explored the correlation between antibiotic-resistant bacteria found in ready-to-eat meat and those isolated from consumers. This study is among the first in Chad to assess the correlation between foodborne and human Enterobacteriaceae resistance profiles.

2. Materials and Methods

2.1. Study Design and Ethical Approval

A prospective cross-sectional descriptive study was carried out from February to July 2024 in the laboratories of the Mongo provincial hospital, the Centre Hospitalier Universitaire (CHU) Abeche, the CHU National de Reference and the food analysis laboratory at the Faculty of Human Health Sciences. The two towns selected for the study (Abeche and Mongo) are located in central and eastern Chad (Figure 1). These two Sahelian, livestock-raising areas are characterized by their strategic location (crossroads), the number of collective restaurants, and the availability and accessibility of grilled meat. The study protocol was approved by the Ethnic Committee of Adam Barka University in Abeche (Agrément no 002/PR/PM/MESRSFP/SEM/SG/UNABA/CUERSH/2024). Authorizations to collect stool samples were obtained from hospital directors: CHU-A (no. 430 /CHUA/SAF/SSG/2024), Mongo Provincial Hospital (no. 17 /HPM/SAF/SSG/2024). Verbal informed consent was obtained from each participant or guardian. Consent was administered by the survey team, trained to respect ethical procedures such as professional secrecy, security of information collected and anonymity. Each patient and producer of the grilled meat received a brief explanation of the objective, sample collection methods, anticipated benefits and risks of the study.

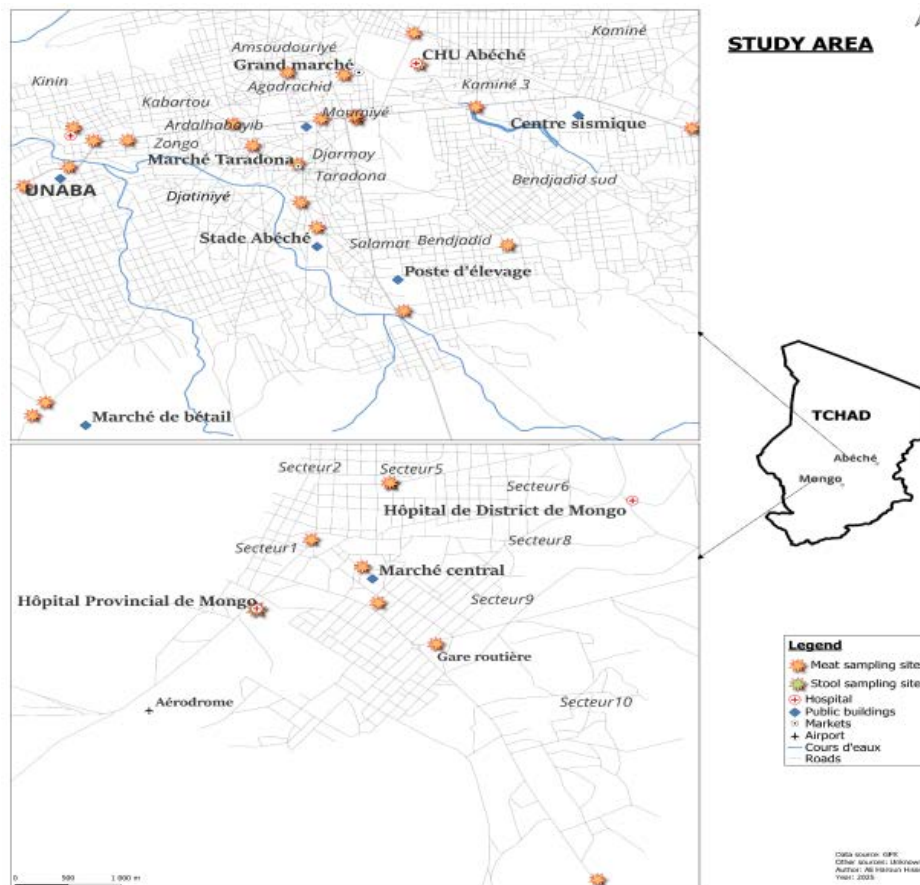


Figure 1. Sample collection sites (Hissein, 2024)

2.2. Study Area and Population

Seventeen grilled meat sampling sites were chosen according to consumer traffic and included markets, roadside stops, neighborhoods and road junctions. Suppliers were selected according to the strategic location of the restaurants, the quantity of grilled meat and the regular number of consumers. On the other hand, the selection of eligible patients included those who regularly consumed only grilled meat in the selected locations, were aged 15 or over, regardless of sex, and had digestive symptoms. Patients who were not illegible included those who rarely or occasionally ate grilled meat or other foods, patients from outside the study areas or in transit, patients who had eaten dishes containing several added ingredients, and those with non-digestive illnesses.

2.3. Sample Collection and Transport

2.3.1. Stool Samples

Stool samples were collected in sterile containers, after informed verbal consent from the participants or their guardians. A structured questionnaire was used to record sociodemographic data, including age, sex, place of residence, education level, frequency and place of grilled meat consumption and date of onset of symptoms. Patients who consented to participate and met the inclusion criteria were randomly selected during consultations. Samples collected in the laboratory were labeled with identification numbers and collection dates, and immediately sent to the bacteriology unit for analysis. Samples collected in the city's health centers were also transported to the analysis center in a cooler containing cold accumulators to maintain the cold chain during transport. Sample collection and transport time did not exceed 45 minutes. All samples were processed immediately on arrival, without any prior storage.

2.3.2. Sample of Grilled Meat

The grilled meat tasted was beef, camel, goat and mutton, depending on the customer's preference. A total of 45 samples were collected: 15 from markets, 15 from truck stops, 10 from neighborhoods and 5 from street vendors. Sampling was stratified by location, with a predefined number of samples per stratum. The restaurants were first grouped by crown. Each crown had a predefined number of grilling points. Samples of grilled meat were then collected randomly and aseptically from suppliers in each crown. The sellers cut the meat into small pieces, which were then wrapped in sterile aluminum foil. The interval between sampling and delivery to the laboratory was no more than one hour. During transport, samples were placed in sterile stomacher[®] bags, labeled and stored in coolers with ice packs. Each stomacher[®] bag was labeled with a unique sample number, collection date and location. In the laboratory, samples were aseptically processed in a laminar flow hood and equilibrated at room temperature for 30 minutes prior to microbiological analysis.

2.4. Microbiological Analysis

2.4.1. Culture of Stool Samples

Approximately 0.5 mL of each stool sample was inoculated onto a selective medium for bacteriological analysis. Media included previously prepared Eosin Methylene Blue (EMB), Hektoen Enteric and *Salmonella-Shigella* (SS) agars (Table 1). Plates were incubated at 37°C for 18 to 24 hours.

2.4.2. Culture of Grilled Meat Samples

Grilled meat samples were minced with a sterile knife and homogenized in a sterile mortar. Twenty-five grams of homogenized meat were added to 225 mL of peptone water. After a 30 minutes rest at room temperature, 0.1 mL of the solution was inoculated onto EMB agar. Cultures were incubated aerobically at 44°C for fecal coliforms and at 37°C for other germs for 24 hours. Isolation of *Salmonella* and *Shigella* followed the NF ISO 6579 (2002) protocol, involving four sequential steps:

- Pre-enrichment step: 25 g of sample meat was aseptically removed and placed in 225 mL of sterile peptone water, then incubated at 37°C for 24 hours.

- Enrichment step: After one night of pre-enrichment, 1 mL of the pre-enriched stock solution was removed and inoculated into Rappaport-Vassiliadis Soja (RVS) broth in tubes under sterile conditions. The tubes were then incubated again at 37°C for 24 hours.

- Isolation step: 0.1 mL of Rappaport-Vassiliadis broth was spread on Hektoen or *Salmonella-Shigella* agar under aseptic conditions. Twenty-four hours after incubation at 37°C.

2.4.3. Isolation and Purification

Green or bluish colonies with or without black centers on Hektoen agar were presumed to be *Salmonella* or *Shigella*. Colonies with a metallic green sheen on EMB agar were presumed to be *Escherichia coli*. A representative isolated colony was subcultured on Mueller-Hinton agar for biochemical characterization after 24 hours incubation in a bacteriological oven at 37°C.

2.4.4. Strain Identification

Bacterial identification was based on morphological and biochemical characteristics. Pure colonies were first characterized by Gram staining, followed by a panel of biochemical tests.

Gram staining

Gram staining is the basis of bacteriology. It enabled us to distinguish between Gram-positive (purple) and Gram-negative (pink) bacteria according to their wall structure. Staining was performed after successive use of stains (crystal violet, Lugol's, alcohol acetone, safranin) according to a well-defined time for each reagent. Observation was carried out using a microscope with a 100 mm immersion objective.

Oxidase test

This is a test that allows for the detection of the enzyme oxidase in bacteria. Consequently, a disk impregnated with oxidase reagent was placed on absorbent paper, and then a well-isolated colony of the strain to be studied was taken using a Pasteur pipette and spread on its surface. A positive reaction results in the appearance of a purple color on the surface of the disk, while a negative reaction remains unchanged.

Chemical identification bands

After the Gram stain and the oxidase test, the isolates were subjected to identification using test panels with the following media: Kligler-Hajna, Simmons Citrate, Urea-Indole, Mannitol-Mobility (Table 1). These tests evaluated characteristics such as citrate utilization, indole production, gas and hydrogen sulfide (H₂S) production, urease activity, and carbohydrate fermentation.

2.4.5. Biochemical Confirmation Test Panels (API20^E)

The species identification was confirmed using the API20E system (Table 1). The species confirmation was performed by suspending one to two well-isolated and purified colonies in 5 mL of physiological saline. The inoculum was adjusted to 0.5 McFarland standard. Then, the bacterial suspension was introduced into each tube of the gallery to avoid bubble formation. The box was then closed and incubated at 37°C for 18 to 24 hours in aerobic conditions. The reactions were interpreted visually or after the addition of specific reagents (TDA, IND, and VP), and the results were converted into numerical code. Table 1 below summarizes all the culture and identification media used.

Table 1. Summary of reagents used for culture

Media and reagents	Brand	Batch number	Country
Methylene Eosin Blue (EMB)	HiMedia	0000525534	India
Hektoen Enteric Salmonella-Shigella (SS)	Bio Mériex SA	557859	France
Mueller-Hinton (MH)	Bio Mériex SA	1008679070	France
Buffered Peptone Water (BPW)	HiMedia	1010019370	France
Kit Gram	HiMedia	564114	India
Kligler-Hajna	Bio Mériex SA	232720	France
Simmons Citrate	HiMedia	423468	India
Mannitol-Mobility	HiMedia	418517	India
API20E	HiMedia	572730	India
Urea-Indole	Bio Mériex SA	101005503	France
	Bio Mériex SA	101005503	France

2.4.6. Antibiotic Susceptibility Testing

Eleven isolates were tested for antimicrobial susceptibility using the Muller Hinton agar disk diffusion method, as recommended by the Comité de l'Antibiogramme de la Société Française de Microbiologie (CASFM, 2024). Eleven antibiotics were tested: ciprofloxacin (5 µg), amoxicillin + clavulanic acid (30 µg), ceftriaxone (30 µg), cefotaxime (30 µg), cefepime (30 µg), cefoxitin (30 µg), imipenem (10 µg), gentamicin (10 µg), erythromycin (15 µg), norfloxacin (10 µg) and nalidixic acid (30 µg). Two to three pure colonies of each bacterial isolate were picked and inoculated into a dry tube containing 5 mL of sterile peptone water. The suspension was adjusted to achieve a turbidity equivalent to the 0.5 McFarland standard. The entire dish was flooded and then adjusted to obtain homogeneous inoculation. Excess liquid was discarded and the dishes were left at room temperature for 15 minutes. After incubation, 6 discs of the antibiotics to be tested were placed on the inoculated agar, with 15 mm between the disc and the edge of the plate and 30 mm between two discs. The diameters of the

zones of inhibition were measured in millimeters using a graduated ruler and interpreted according to the standards of the Antibiogram Committee of the French Society for Microbiology (EUCAST. V1.0. 2024), comparing critical diameters (mm) in sensitive (S ≥) or resistant (R <). Antibiotic disc cartridges were stored dry in the refrigerator at + 2 to + 8°C. Expiration dates were validated in accordance with the manufacturer's instructions. *Escherichia coli* ATCC 25922 was used as a quality control strain for disk diffusion tests.

2.4.7. ESBL Detection

ESBL production was detected using the double-disk synergy test with third-generation cephalosporins and clavulanic acid. The isolate was inoculated into 5 mL of sterile peptone water. The mixture was homogenized to a solution corresponding to the 0.5 McFarland standard, before being poured onto Mueller-Hinton agar. Next, the discs were aseptically placed 30 mm apart on the inoculated plate so that amoxicillin-clavulanic acid (30 µg) was located in the center. After incubation for 24 hours at 37°C. A positive result was indicated by a keyhole or the appearance of a "champagne cork" between the clavulanic acid and cephalosporin discs.

2.5. Data Analysis

Data were entered and analyzed using XLSTAT 2024 software. Strain identification was performed using API Web (version 4.1) and the catalog. The χ^2 (chi-square) test was applied to compare categorical variables, with significance set at $P \leq 0.05$. Multidrug resistance has been defined as resistance to at least three antibiotics from different antimicrobial classes.

The sample analysis process is shown in the following diagram (Figure 2).

3. Results

A total of 196 samples were collected, including 151 stool samples and 45 grilled meat samples

3.1. Prevalence of Samples Contaminated with Enterobacteria

Of the 151 stool samples, 26 (17.22%) were positive for enterobacteria. In addition, 22 grilled meat samples (48.88%) were culture positive. Some samples contained several species of *Enterobacteriaceae*, ranging from 2 to 4 per sample. A statistically significant association was found between the presence of *Enterobacteriaceae* in grilled meat and stool contamination (p -value = 0.0014).

3.2. Distribution of Isolated Enterobacteriaceae by Species

Of the 15 species of *Enterobacteriaceae* identified, *Escherichia coli* accounted for 43.53% of isolates. The distribution of *Enterobacteriaceae* species isolated is summarized in Table 2.

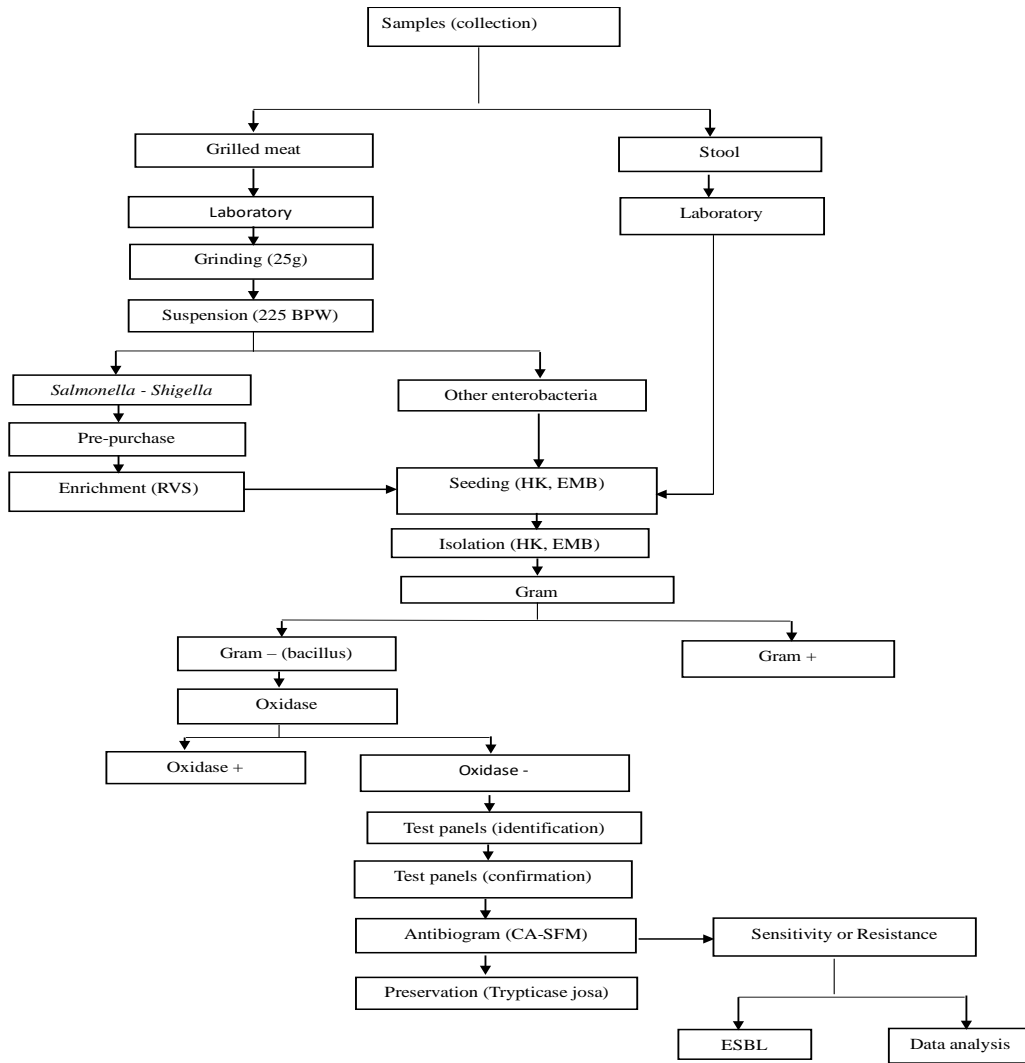


Figure 2. Methodological flow chart

Table 2. Distribution of Enterobacteriaceae by species

Strain	Strains Number(n=85)	Percentage %)
<i>E. coli</i>	37	43.53
<i>Pantoea spp</i>	16	18.82
<i>Serratia ficaria</i>	5	5.88
<i>Serratia odorifera</i>	4	4.71
<i>Serratia marcescens</i>	2	2.35
<i>Klebsiella oxytoca</i>	5	5.88
<i>Klebsiella pneumoniae</i>	1	1.18
<i>Enterobacter cloacae</i>	3	3.53
<i>Enterobacter sakazakii</i>	3	3.53
<i>Enterobacter aerogenes</i>	1	1.18
<i>Citrobacter freundii</i>	3	3.53
<i>Kluyvera spp</i>	2	2.35
<i>salmonella spp</i>	1	1.18
<i>Hafnia alvei</i>	1	1.18
<i>Providencia stuartii</i>	1	1.18
Total	85	100

3.3. Distribution of Enterobacteria Species Isolated by Type and Sampling Site

The distribution of species isolated in the two types of samples by city is shown in Table 3.

Most Enterobacteriaceae isolates were obtained from stool samples collected at CHU-A, accounting for 55.29%.

3.4. Overall Antibiotic Resistance Profile of Enterobacteriaceae Isolates

Table 4 shows that *E. coli* presented the highest overall resistance (57.71%) among both sample types, followed by *Pantoea spp* (34.90%). Stool samples showed the highest proportion of resistant bacteria (40.91%), with *E. coli* accounting for 62.30%. Multidrug resistance was observed in *Pantoea spp* (77.78%) and *E. coli*: (47.61%). All multidrug-resistant isolates were recovered from stool samples (Table 4).

3.5. Extended-spectrum beta-lactamase (EBLSE)-producing Strains

A total of six EBLSE-producing Enterobacteriaceae strains were identified from grilled meat and stool samples. *E. coli* was the predominant ESBL-producing species, accounting for 3 isolates (50%) (Table 5).

Table 3. Distribution of *Enterobacteriaceae* by type and site of collection

Strain	Stool		Grilled meat		Total
	CHU-A	HPM	Abéché	Mongo	
<i>E. coli</i>	14	7	11	5	
<i>Pantoea</i> spp	6	3	5	2	
<i>Serratia ficaria</i>	3	1	2	1	
<i>Serratia odorifera</i>	0	0	2	0	
<i>Serratia marcescens</i>	0	0	2	0	
<i>Klebsiella oxytoca</i>	2	0	1	1	
<i>Klebsiella pneumoniae</i>	1	0	1	0	
<i>Enterobacter cloacae</i>	1	1	1	0	
<i>Enterobacter sakazakii</i>	3	0	0	0	
<i>Enterobacter aerogenes</i>	0	0	0	1	
<i>Citrobacter freundii</i>	2	1	0	0	
<i>Kluyvera</i> spp	0	0	2	0	
<i>salmonella</i> spp	1	0	0	0	
<i>Hafnia alvei</i>	1	0	0	0	
<i>Providencia stuartii</i>	0	0	1	0	
Total	34	13	28	10	85

Table 4. Resistance profile of *Enterobacteriaceae* isolates to the antibiotics tested

ATB	Stool			Grilled meat		
	Strains					
	<i>E. coli</i> n / N (%)	<i>P. spp</i> n / N (%)	<i>S. ficaria</i> n / N (%)	<i>E. coli</i> n / N (%)	<i>P. spp</i> n / N (%)	<i>S. ficaria</i> n / N (%)
NA	18/21(85.71)	6/9(66.67)	3/4(75)	15/16(93.75)	5/7(71.43)	2/3(66.67)
AMX	19/21(90.48)	8/9(88.89)	3/4(75)	14/16(87.50)	5/7(71.43)	1/3(33.33)
E	11/21(52.38)	4/9(44.44)	1/4(25)	7/16(43.75)	3/7(42.86)	0/3(0)
GN	9/21(42.86)	3/9(33.33)	0/4(0)	6/16(37.50)	0/7(0)	1/3(33.33)
AMC	18/21(85.71)	5/9(55.56)	1/4(25)	12/16(62.5)	3/7(42.86)	0/3(0)
NOR	16/21(76.20)	6/9(66.67)	2/4(50)	11/16(68.75)	5/7(71.43)	2/3(66.67)
OFX	15/21(71.4)	4/9(44.44)	1/4(25)	9/16(56.25)	2/7(28.57)	0/3(0)
CIP	17/21(80.9)	8/9(88.89)	3/4(75)	13/16(81.25)	4/7(57.14)	1/3(33.33)
CRO	16/21(76.20)	7/9(77.77)	2/4(50)	11/16(68.75)	5/7(71.43)	1/3(33.33)
CTX	14/21(66.67)	3/9(18.75%)	2/4(50)	10/16(62.50)	2/7(28.57)	0/3(0)
FOX	13/21(61.90)	5/9(55.56)	0/4(0)	9/16(56.25)	1/7(14.29)	2/3(66.67)
IMI	3/21(14.2)	0/9(0)	0/4(0)	0/16(0)	0/7(0)	0/3(0)

Legend: n=number of resistant strains; N=number of strains tested with the antibiotic;

%=percentage; *E. coli* = *Escherichia coli*, *P. spp*= *Pantoea* spp, *S. ficaria*= *Serratia ficaria*

NA= Nalidixic acid, AMX= Amoxicillin, E= Erythromycin, GN = Gentamicin, AMC= Amoxicillin + Clavulanic Acid, NOR= Norfloxacin, OFX= Ofloxacin, CRO, Ceftriaxone, CIP= Ciprofloxacin, CTX= Cefotaxime, FOX= Cefolotine, IMI= Imipenem

Table 5. Prevalence of EBLSE strains by species and sample type

Species	Stool	Grilled meat	Total
<i>E. coli</i> n (%)	2(33.33%)	1(16.67%)	50%
<i>Klebsiella pneumoniae</i> n (%)	1(16.67%)	1(16.67%)	33.34%
<i>Serratia marcescens</i> n (%)	0(0)	1(16.67%)	16.66%
Total	3(50%)	3(50%)	6(100%)

Legend: n= number of strains isolated.

4. Discussion

This study characterized the distribution of *Enterobacteriaceae* species from grilled meat and stool samples and assessed their antibiotic susceptibility profile. A total of 196 samples were analyzed, including 151 stool samples and 45 grilled meat samples. *Enterobacteriaceae* were isolated from 60% of stool samples and 40% of grilled meat samples at the study sites. The majority of isolates came from Abeche, with 40% from CHU-A and 32.94% from restaurants. This discrepancy may be attributed to variations in sample size between the two cities. The overall prevalence of *Enterobacteriaceae* was

17.22% in stool samples and 48.88% in grilled meat samples. Studies of [10,11,12], in Morocco, Egypt and Chad reported higher prevalence rates of 92.14%, 67.26% and 62.84% respectively. The presence of *Enterobacteriaceae* may reflect poor personal hygiene and inadequate food handling practices. This detection could be a real indication of contamination of ready-to-eat foods. A total of 15 species belonging to the *Enterobacteriaceae* family were identified. *Escherichia coli* (43.53%) was the most frequently isolated species in both types of sample. Similar results were reported in several hospital and meat product studies of [13] in Iran, [14] in Bangladesh, 31% and 27.45% respectively. In addition to *E. coli*, other species of *Enterobacteriaceae* were detected. These

included *Pantoea*, *Serratia* species, *Klebsiella* species, *Enterobacter* species, and *Citrobacter freundii*. *Hafnia alvei*, *salmonella* species, and *Providencia stuartii* [15,16]. *E. coli* is a common intestinal commensal found in humans, animals and the environment. Its detection may indicate fecal contamination of food or water, or cross-contamination during food handling. Contradictory results were found of [17], that the most frequent genus in ready-to-eat foods was *Klebsiella spp.* This difference could be explained by the unsanitary conditions of the environment used for food production, handling, and possible cross-contamination. *Klebsiella spp.* is a naturally occurring host in humans and can become pathogenic under certain circumstances. This bacterium can infect vulnerable individuals or those who have stayed in the hospital for a long time. Furthermore, our results highlighted a significant association between the consumption of grilled meat and fecal contamination by enterobacteria. No mandatory reportable pathogenic strain was detected in our samples. In line with the conclusions of [18], this study did not detect mandatory pathogens such as *Salmonella enterica* and *Shigella spp.* The absence of *Salmonella* may be explained by competitive flora, limitations of culture media, or the impact of high cooking temperatures. On the other hand, [19] reported in this study the presence of *Salmonella spp.* in the braised carp. Contamination of ready-to-eat grilled meat could occur due to improper handling by sellers, contaminated condiments or utensils, insufficient cooking, or exposure to flies. In this study, 7.06% of *Enterobacteriaceae* isolates produced extended-spectrum beta-lactamases (ESBLs). This prevalence of ESBL is lower than those reported of [20] in Chad, [21] in Ethiopia, with 30.9% and 21.7% respectively in clinical samples. Among the ESBL-producing strains, *E. coli* (50%) and *K. pneumoniae* (33.34%) were the most common. These results are below those of several researchers in African countries who isolated *E. coli* and *K. pneumoniae* in hospital and community settings, notably in Thailand of [22] (56.37%), in Ghana of [23] (44.6%), [24] (40.9%). The same conclusion was reported in Ethiopia of [25, 26] with 224 (84.8%), (33%) for *E. coli*, and 39 (14.8%), (32.7%) for *K. pneumoniae*. The presence of these two strains in food poses a considerable risk to consumers. These bacteria could lead to serious infections and make treatment difficult. The prevalence of *Enterobacteriaceae* producing extended-spectrum beta-lactamases has been observed in both types of samples, namely 50% in grilled meats and 50% in stool cultures. The identification of bacteria producing ESBL in cooked foods and in humans could have increased repercussions on consumer health due to the production of the enzyme beta-lactamase.

The highest resistance to beta-lactam antibiotics was recorded, particularly for amoxicillin (83.33%) and amoxicillin-clavulanic acid (65%). These results are consistent with those of [27], who reported a resistance of 88.9% each for amoxicillin and amoxicillin-clavulanic acid. On the other hand, higher values were reported in Nigeria of [28], 37 (84.1%) for amoxicillin and 37 (84.1%) for amoxicillin-clavulanic acid. The spread of antibiotic-resistant bacteria decreases the effectiveness of medications and forces stakeholders to resort to toxic drugs that are dangerous to humans. The presence of

resistant bacteria in ready-to-eat cooked foods is very concerning and requires urgent and effective intervention from the security policies of Chad. A total of 36 (59.02%) *Enterobacteriaceae* strains showed resistance to third-generation cephalosporins (C3G). This resistance rate is comparable to that obtained of [29]. This could be attributed to the method and media used for the detection of resistance. They used the vitex automated system to assess the sensitivity of bacteria to antibiotics. Resistance to ceftriaxone reached 70%, followed by cefotaxime (51.67%) and cephalothin (50%). Resistance can be acquired in various situations, including through the consumption of contaminated food, in a hospital environment, through unsafe water, or in a community setting. Notable resistance was also recorded among quinolones, particularly nalidixic acid (81.67%), ciprofloxacin (78.33%), norfloxacin (53.37%), and ofloxacin (51.67%). None of the tested isolates showed sensitivity greater than 40% to commonly used antibiotics. This high level of resistance could be explained by the lack of oversight, the non-enforcement of antibiotic monitoring regulations, the low level of hygiene in hospitals, and the illegal sale of drugs on the street. The establishment of a management and monitoring system for antibiotics is essential to guide rational prescribing and control misuse. Antibiotic sensitivity can vary according to bacterial strains based on geographic region, demographic factors, and seasonal trends [30,31]. In this study, reduced sensitivity was observed to cefotaxime (51.67%), ceftiofen (50%), and gentamicin (31.66%), except for imipenem (95%), which retains good sensitivity to *Enterobacteriaceae*. The majority of *Enterobacteriaceae*, including ESBL-producing strains, have remained sensitive to carbapenems. Although carbapenems are the treatment of choice for extended-spectrum beta-lactamase and AmpC producers, the global increase in resistance to carbapenems highlights the need for alternative therapies [32]. A recent systematic review of [33] confirmed that carbapenems are often the last-line treatment for multidrug-resistant *Enterobacteriaceae*, although the rising resistance poses a critical challenge.

5. Conclusion

The present study provided information on the prevalence and resistance of *Enterobacteriaceae* to antibiotics in grilled meat and in feces. Of the 196 samples analyzed, 48 were contaminated with *Enterobacteriaceae*, including six (6) ESBL-producing strains. The strain of *E. coli* was the most predominant in this study. With the exception of Imipenem, which maintained good activity against enterobacteria, other families of antibiotics showed a rate of resistance among enterobacteria. These data are not sufficient to assert the correlation between enterobacteria found in feces and in grilled meat. Future studies in progress could incorporate molecular typing and whole genome sequencing to better understand the dynamics of transmission. For now, this data should prompt the government to monitor the regulations governing the sale and use of antibiotics, further involve the veterinary sector in meat inspection, and strictly enforce hygiene rules in restaurants.

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Contribution of Authors

All authors contributed to the manuscript written. They read the final manuscript and approved the final submission.

Competing Interests

The authors declare that they have no competing interests.

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