

Research Article

# Identification and Phenotypic Antibiotic Resistance of *Escherichia coli* and *Staphylococcus aureus* Strains Isolated from Fresh and Braised Beef Meat in Abidjan

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## Abstract

The conditions of processing, distribution and sale of beef expose it to various contaminations. These contaminations can be potentially pathogenic microorganisms that would in this case represent a risk to the health of consumers. This study aims to identify potentially pathogenic strains of *Escherichia coli* and *Staphylococcus aureus* present in fresh and braised beef, as well as to determine their phenotypic antibiotic resistance profiles. Thus, 300 samples, including 100 samples of fresh beef from the slaughterhouse, 100 samples of fresh beef from the market and 100 samples of braised beef or "choukouya", were collected in Abidjan. *Escherichia coli* and *Staphylococcus aureus* were isolated and identified using biochemical and molecular methods. Microbiological analyses revealed that 100% of the fresh beef samples from the slaughterhouse and market were contaminated with *E. coli* and *S. aureus*. Braised beef had a contamination rate of 6% (*E. coli*) and 30% (*S. aureus*). A total of 144 (92.9%) out of 155 *Escherichia coli* strains and 76 (57.6%) out of 132 *Staphylococcus* strains were confirmed as *Escherichia coli* and *Staphylococcus aureus*, respectively, after molecular identification. The prevalences of *E. coli* and *S. aureus* in slaughterhouse meat were 92.5% and 84.2%, respectively. They were 93.8% and 59.4% in fresh meat and 100% and 38.6% in braised beef. The susceptibility of the strains to antibiotics was assessed by the agar diffusion method. Strains isolated from fresh slaughterhouse and market meats were more resistant to the antibiotics tested. Only one strain (0.7%) producing extended-spectrum beta-lactamases (ESBL) was detected in *Escherichia coli*, and no methicillin resistance was observed in *Staphylococcus aureus*.

## Keywords

Beef Meat, Hygiene, Antibiotic Resistance, *E. coli*, *S. Aureus*, Food Safety

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## 1. Introduction

Providing sufficient, safe, and nutritious food to meet the population's dietary needs and preferences remains a significant challenge. The microbiological quality of food is a major concern for the entire food chain, from raw materials to finished products. Despite efforts to adhere to good hygienic practices at various stages, meats are still susceptible to contamination by spoilage bacteria, hygiene indicator flora, and pathogenic bacteria such as *Listeria monocytogenes*, *Salmonella*, shiga toxin-producing *E. coli*, *Staphylococcus aureus*, *Campylobacter*, etc. [1]. Meats contaminated by these pathogenic bacteria are regularly involved in foodborne illnesses, as evidenced by recurring crises in this sector [1].

The World Health Organization reports that hundreds of millions of people worldwide suffer from foodborne illnesses, with animal-derived foods being a leading cause [2]. In Côte d'Ivoire, livestock farming plays an important role in both socioeconomic growth and Ivorian nutrition. It remains a significant source of income and employment and contributes to food security [3]. Livestock products contribute 45% to the agricultural gross domestic product (GDP) and 2% to the total GDP [3]. The most consumed meats are beef, poultry, pork, mutton, and goat. Consumption reached 13.0 kg per person/year in 2017, including 49 kg of beef (2016), 42 kg of pork, 26 kg of poultry, and 12 kg of ovine and goat meat (including edible offal from slaughter) [4].

Beef holds an important place in Ivorian nutrition and dietary habits, although it is often implicated in cases of foodborne illness worldwide. Whether braised, grilled, or boiled, it is consumed in various forms by the population [5]. It is therefore necessary, even important, to know the characteristics of potentially pathogenic bacteria isolated from fresh and braised beef that can affect consumer health. Thus, the objective of this work is to identify potentially pathogenic strains of *Escherichia coli* and *Staphylococcus aureus* present in fresh and braised beef, as well as to determine their phenotypic resistance profiles to antibiotics.

## 2. Materials and Methods

### 2.1. Study Material and Sampling

The study was conducted on samples of fresh beef from the slaughterhouse (Figure 1) and market (Figure 2) in Port-Bouët, and braised beef or "choukouya" (Figure 3). The municipality of Port-Bouët was chosen because it has a recognized conventional slaughterhouse and is a convergence center for a variety of animals from several localities in the country. Samples were collected over four months, from March to June 2024. During this period, a total of 300 samples were collected, with 100 samples per matrix. Weekly visits to the collection sites allowed us to collect 20 samples per visit. Fresh beef samples were randomly purchased from butchers in the market and at the Port-Bouët slaughterhouse. Braised

beef or "choukouya" samples were also randomly purchased from vendors in the large courtyard of the Port-Bouët slaughterhouse.

Each sample corresponded to 500 g of fresh beef or "choukouya." Fresh meat samples were packaged in sterile Stomacher bags, and braised meat samples were kept in their original packaging. They were labeled (location, date of collection, and order number) and transported to the laboratory in coolers with cold packs.



Figure 1. Fresh beef slaughterhouse.



Figure 2. Fresh beef market.



Figure 3. Braised beef.

## 2.2. Identification of Presumptive *Escherichia coli* and *Staphylococcus aureus* Strains

Identification of strains were carried out using classic microbiological methods. *E. coli* strains were isolated on TBX (Tryptone Bile X-Glucuronide) chromogenic selective medium, and *S. aureus* strains were isolated on Baird-Parker agar supplemented with egg yolk and potassium tellurite, according to standards. Plates were incubated at 37°C for 24 ± 2 hours for *E. coli* strains and for 24 ± 2 hours, followed by an additional 24 ± 2 hours for *S. aureus* strains. Species identification was performed after Gram staining, fresh state examination, and complementary tests, including the reduced Le Minor pole for *E. coli* and catalase and DNase tests for *S. aureus*.

## 2.3. Confirmation of Strain Identity by PCR

Phenotypic identification being presumptive, strains retained after various biochemical tests were identified by polymerase chain reaction (PCR) to confirm their identities. The total DNA of 24-hour-old young strains was extracted according to the QIAGEN extraction kit protocol (QIAamp Viral RNA Mini Kit cat. no. 52906). DNA extracts were

collected in sterile Eppendorf tubes and frozen at -20°C until use.

Amplification was performed in reaction volumes of 25 µL containing 4 µL of FirePol Master mix 5X, 1 µL of each 10 mM primer, 14 µL of nuclease-free water, and 5 µL of DNA template. The reaction mix without DNA was used as a negative control, and DNA from strains possessing the target genes served as a positive control.

Amplifications were carried out in a thermocycler under the following program: an initial denaturation at 95°C for 3 min, followed by a 30-cycle phase. Each cycle consisted of a denaturation at 94°C for 45 s, primer annealing at 58°C for 30 s, elongation at 72°C for 5 min, and a final step at 72°C for 5 min, then preservation at 4°C for the *iudA* gene search, such as Table 1.

For *clfA* gene amplification (Table 1), the program consisted of an initial denaturation at 94°C for 3 min, followed by a 30-cycle phase. Each cycle included a denaturation at 94°C for 15 min, primer annealing at 63°C for 1 min, elongation at 72°C for 1 min, and a final step at 72°C for 10 min, then preservation at 4°C.

PCR products were analyzed by agarose gel electrophoresis (1.5%). After migration, gels were visualized under UV light.

**Table 1.** Primer Sequences Used for Identifying of *E. coli* and *S. aureus*.

Genes	Sequences (5'-3')	Size (pb)	References
iudA	(F)-AAAACGGCAAGAAAAAGCAG	147	[6]
	(R)-ACGCGTGGTTACAGTCTTGCG		
clfA	(F)-CTTGATCTCCAGCCATAATTGGTGG	638	[7]
	(R)-GCAAAATCCAGCACAAACAGGAAACGA		

## 2.4. Antibigram and Detection of Extended-Spectrum Beta-Lactamase Production in *E. coli*

Phenotypic characterization of resistance in *Escherichia coli* and *Staphylococcus aureus* strains to antibiotics was performed using diffusion tests on agar according to the recommendations of the Antibigram Committee of the French Society of Microbiology (EUCAST/CA-SFM 2023). Criteria for categorization were defined as sensitive (S) and resistant (R) for each antibiotic tested.

Seventeen antibiotic disks (Amoxicillin-clavulanic acid, Amoxicillin, Cefepime, Ceftriaxone, Cefixime, Cefotaxime, Meropenem, Ertapenem, Amikacin, Gentamicin, Aztreonam, Levofloxacin, Ciprofloxacin, and Tigecycline) and eight disks (Cefoxitin, Gentamicin, Kanamycin, Moxifloxacin, Nor-

floxacin, Tetracycline, Clindamycin, and Erythromycin) were tested respectively on *E. coli* and *S. aureus* strains.

Detection of extended-spectrum beta-lactamase (ESBL) producing *E. coli* strains was performed using the double-disk synergy test according to [8]. The test involved placing a disk containing a beta-lactamase inhibitor (amoxicillin + clavulanic acid) in the center of a plate. This disk was surrounded by four disks of extended-spectrum cephalosporins (cefotaxime, ceftazidime, cefepime, and aztreonam) placed 2 cm apart. Plates were incubated at 37°C for 18 ± 2 hours. An enhancement of the inhibition zone between a cephalosporin disk and the disk containing clavulanic acid confirmed ESBL production.

## 2.5. Statistical Analysis

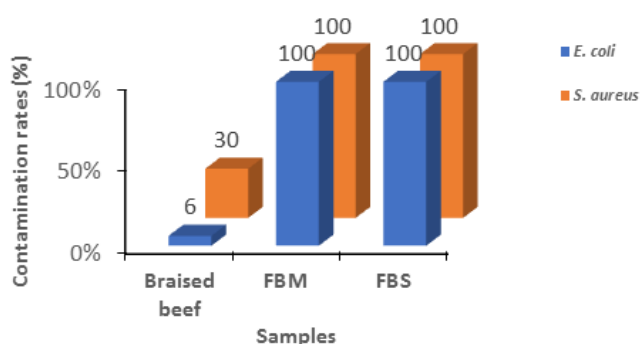
The collected data were entered and processed in the Ex-

cel 2016 database. Various statistical tests were conducted using R analysis software.

### 3. Results

#### 3.1. Contamination Rate of Fresh Beef Samples from the Market and Abattoir, and of Braised Beef by *E. coli* and *S. aureus* Strains

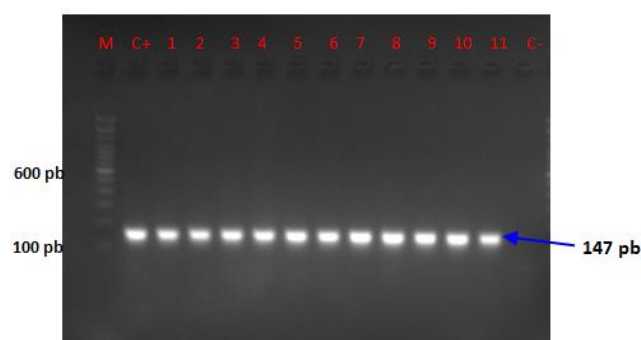
All 200 samples of fresh beef from the Port-Bouët market and abattoir were contaminated with both *E. coli* and *S. aureus*. Braised or choukouya beef samples, on the other hand, had contamination rates of 6% for *E. coli* and 30% for *S. aureus* (Figure 4).



**Figure 4.** Contamination Rates of Braised beef Samples, Fresh Beef from market (FBM), and Fresh Beef from slaughterhouse (FBS) by *E. coli* and *S. aureus* Strains.

#### 3.2. Profile of *E. coli* and *S. aureus* Strains Confirmed by Detection of *iudA* and *clfA* Genes

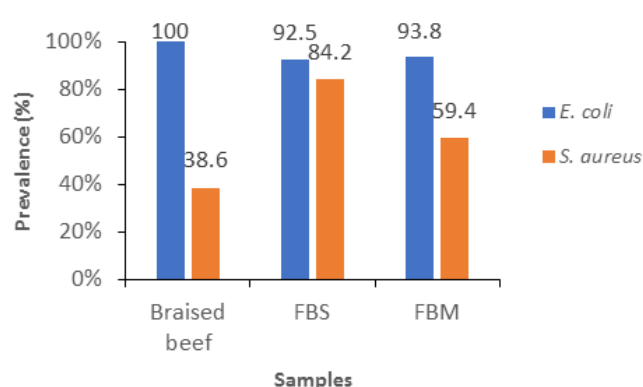
A total of 155 strains of *E. coli* and 132 strains of *S. aureus* identified through morphological and biochemical tests were used for molecular characterization. The *iudA* gene specific to *E. coli* was detected in 92.5% (62/67) of abattoir fresh beef strains, 93.8% (76/81) of market fresh beef strains, and 100% (7/7) of braised beef strains. The *clfA* gene specific to *S. aureus* was detected in 84.2% (32/38) of abattoir fresh beef strains, 59.4% (22/37) of market fresh beef strains, and 38.6% (22/57) of braised beef strains. Figures 5 and 6 respectively show the electrophoretic profiles confirming the strains and Figure 7 show the proportion of strains harboring the targeted genes for the different samples.



**Figure 5.** Electrophoretic Profile of PCR Products showing *iudA* gene detected in *E. coli*. M: molecular marker, C (+): positive control (reference strain possessing the target gene); C-: negative control (reaction mix without DNA); E1 to E11: isolates positive for *iudA* gene.



**Figure 6.** Electrophoretic Profile of PCR Products showing *clfA* gene detected in *S. aureus*. M: molecular marker, C (+): positive control (reference strain possessing the target gene S1 to S20 isolates positive for *clfA* gene; C (-): negative control (reaction mix without DNA).



**Figure 7.** Prevalence of *E. coli* and *S. aureus* in Braised beef Samples, Fresh Beef from slaughterhouse (FBS), and Fresh Beef from Market (FBM).

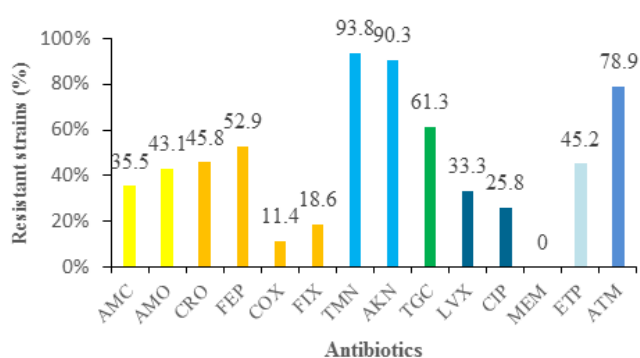
#### 3.3. Antibiotic Resistance of *E. coli* and *S. aureus* Isolated from Fresh and Braised Beef Samples

The levels of resistance among *E. coli* and *S. aureus* strains varied depending on the antibiotics tested, as well as

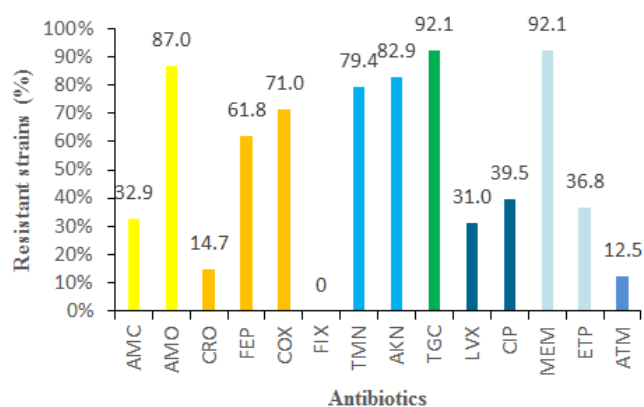


the source matrix. *E. coli* strains isolated from fresh beef from both the abattoir and market showed resistance to nearly all tested antibiotics except Meropenem and Cefixime. In contrast, strains from braised beef exhibited resistance to only half of the tested antibiotics and at lower frequencies. The highest resistance percentages were observed in strains from the abattoir and market (Figures 8, 9, 10).

*S. aureus* strains showed resistance to 7, 6, or 5 antibiotics respectively for samples from the market, abattoir, and braised beef. No resistance to Cefoxitin was observed across all three matrices. The highest resistance percentages were observed in abattoir strains with Tetracycline (72.7%) and Erythromycin (63.6%), and in braised beef with Clindamycin (62%) (Figures 11, 12, 13).



**Figure 8.** Antibiotic Resistance level of *E. coli* isolated from fresh beef from slaughterhouse.

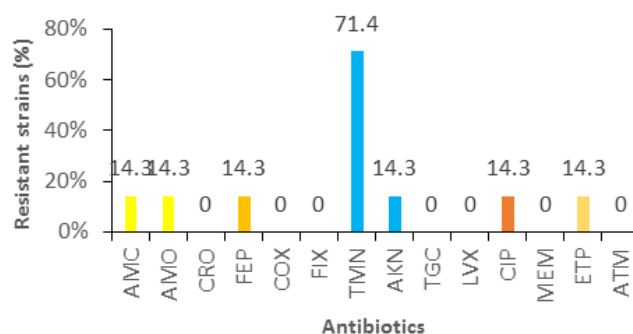


**Figure 9.** Antibiotic Resistance level of *E. coli* isolated from fresh beef from the market.

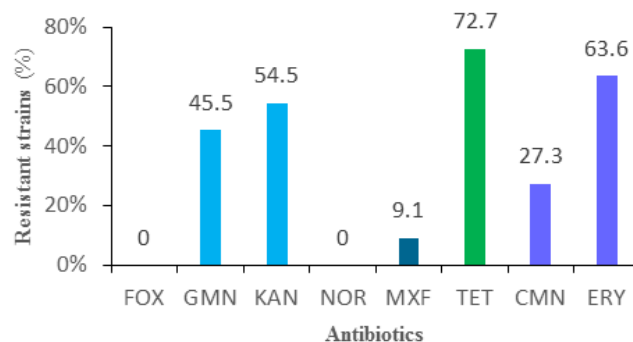
### 3.4. Phenotypic Detection of Extended-spectrum Beta-lactamase (ESBL)-producing *E. coli*

Among the 155 strains used for phenotypic detection of extended-spectrum beta-lactamase (ESBL) production, only one strain tested positive (0.6%), and it was isolated from fresh meat samples

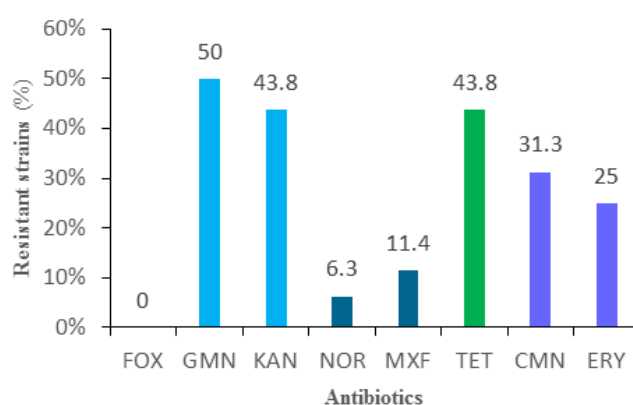
from the slaughterhouse.



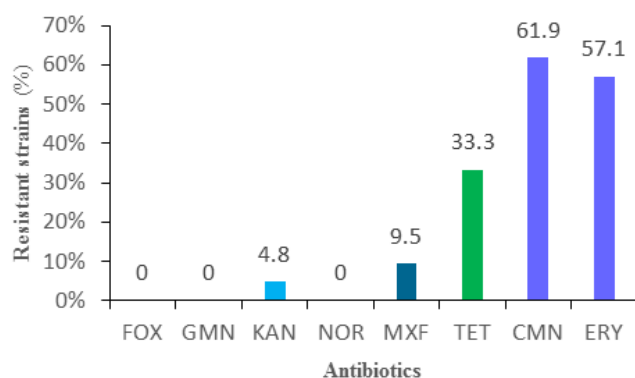
**Figure 10.** Antibiotic Resistance level of *E. coli* isolated from braised beef. AMC: Amoxicillin + Clavulanic acid; AMO: Amoxicillin; CRO: Ceftriaxone; FEP: Cefepime; COX: Cefotaxime; FIX: Cefixime; TMN: Tobramycin; AKN: Amikacin; TGC: Tigecycline; LVX: Levofloxacin; CIP: Ciprofloxacin; MEM: Meropenem; ETP: Ertapenem; ATM: Aztreonam.



**Figure 11.** Antibiotic resistance level of *S. aureus* strains isolated from fresh meat from slaughterhouse. FOX: Cefoxitin; GMN: Gentamicin; KAN: Kanamycin; NOR: Norfloxacin; MXF: Moxifloxacin; TET: Tetracycline; CMN: Clindamycin; ERY: Erythromycin.



**Figure 12.** Antibiotic resistance level of *S. aureus* strains isolated from fresh beef from the market.



**Figure 13.** Antibiotic resistance level of *S. aureus* strains isolated from braised beef.

## 4. Discussion

The analysis of fresh beef samples collected from the Port-Bouët slaughterhouse and market, as well as braised beef samples commonly called "choukouya" in Côte d'Ivoire, showed that the fresh meat samples were more contaminated than the braised meat. Indeed, the contamination rates in these different matrices by *Escherichia coli* and *Staphylococcus aureus* were 100% for fresh meats and respectively 1% and 30% for braised meat. Several reasons could explain or justify these percentages.

Firstly, these high contamination rates of fresh meat could originate from two sources. One source is endogenous, that is, from the animal from which the meat is produced. Indeed, the digestive and respiratory tracts and the skin of animals are reservoirs of microorganisms and constitute the main sources of carcass contamination [9]. Another source of contamination could be due to poor hygiene in the animal slaughtering places [10], not to mention frequent unhygienic handling and cross-contaminations (Heredia, 2001), observed throughout the slaughtering, preservation, distribution, and retail sale operations of beef, which could also amplify the level of contamination ([11, 12]). According to [13], poor hygiene practices encountered during skinning and evisceration operations during carcass production are known to be significant risk factors [9] because they can lead to meat contamination by several pathogenic germs, including those isolated in our study. Secondly, the lower contamination rate of braised meat compared to fresh meats could be due to the fact that braised meat is generally subjected to high temperatures during cooking, which would be sufficient to eliminate most microorganisms. Additionally, the cooking duration and the preliminary treatments that the meat undergoes before braising, such as cleaning and the removal of questionable parts, could significantly reduce the initial number of bacteria.

The higher rate of *S. aureus* in braised meat could be due to manual contamination. This can be explained by the fact that during sales, vendors' hands are constantly moist from abundant sweating [14]. This sweat brings *Staphylococcus* to the skin surface [15]. Additionally, some ingredients used in the

preparation of choukouya, such as onions, fresh peppers, tomatoes, and powdered peppers (kankankan), are generally handled by hand and added after the meat is cooked. The presence of *E. coli* in braised beef indicates a hygiene defect [16] and a possible presence of enteropathogenic microorganisms with the potential to develop foodborne illnesses [17]. The contamination rates observed in braised beef are significantly lower than those observed by [14] for the same microorganisms in their study on microbial risks associated with the consumption of braised beef "choukouya" in Côte d'Ivoire, specifically in the cities of Bouaké and Korhogo.

Genotypic confirmation by searching for the *iudA* and *clfA* genes in *E. coli* and *S. aureus* isolates respectively, detected the presence of the *iudA* gene in 93.5% (145/155) and the *clfA* gene in 57.6% (76/132). [18] detected the presence of the *iudA* gene in 82.8% of the *E. coli* strains tested. Taha and Yassin also detected the *iudA* gene in all strains isolated from food in Iraq [19]. From the above, we can say that the *iudA* gene is generally used to specifically identify *E. coli* [20-22]. The *clfA* gene was also detected in 100% of the isolates in the studies by [23]. Also, according to the results of a study by [24], *clfA* genes were discovered in all *S. aureus* isolates, and PCR identified *clfA* genes in 100% of the isolates. This difference could be explained by the fact that the strains isolated in these studies, unlike ours, were isolated in cases of urinary tract infection, hence pathogenic [23]. However, these results indicate that the *clfA* gene is also used for the specific identification of *S. aureus*.

The results of the antibiotic sensitivity test revealed that the majority of *E. coli* and *S. aureus* strains exhibit variable sensitivity to the antibiotics tested. Regarding the *E. coli* strains, those isolated from fresh meat were much more resistant than those isolated from braised meat. This difference could be explained by the fact that the high temperature and cooking time of braised meat eliminate most of the bacteria present, including the resistant ones. Almost all the strains isolated from fresh slaughterhouse meat were resistant to the aminoglycoside family of antibiotics tested, such as Tobramycin (93.7%) and Amikacin (90.3%). 78.9% of them were resistant to Aztreonam and 61.3% to Tetracycline, while no resistance was observed for Meropenem. The strains isolated from fresh market meat showed a high level of resistance to Amoxicillin (86.9%), third-generation cephalosporins such as Cefepime (61.8%) and Cefotaxime (71.4%), but also to Tobramycin (79.4%), Amikacin (82.9%), Tigecycline (92.1%), and Meropenem (92.1%). The *E. coli* species is naturally known to belong to group 1 of Jarlier, thus sensitive to beta-lactams ([24, 25]). These observed resistance levels are therefore acquired resistances that can be explained by the adaptation of some of these strains to the concerned molecules and the acquisition of resistance factors over time. As for the observed resistance to aminoglycosides, this could also be due to acquired resistance according to [26].

The *S. aureus* strains showed much greater sensitivity to the various antibiotics tested. However, resistance was observed

in some families, such as Aminoglycosides, Tetracyclines, and MLS (Macrolides, Lincosamides, Streptogramins). Indeed, more than half of the strains from slaughterhouse meat were resistant to Kanamycin (54.5%), Tetracycline (72.7%), and Erythromycin (63.6%). A high resistance rate to Clindamycin (61.9%) and Erythromycin (57.1%) was also observed in strains isolated from braised beef. These resistance rates could be explained by the fact that these antibiotics are commonly used in veterinary medicine, particularly in cattle farming, to treat various infections contracted by the animals [27]. The microorganisms present in these animals would then have developed resistance to these antibiotics due to their frequent administration. No resistance to Cefoxitin was observed in our study. All isolated strains were methicillin-sensitive *S. aureus* (MSSA). Our results are consistent with those of [28] and [29]. However, several authors have reported the presence of MRSA in raw meat, cow's milk, and cooked meat samples ([30-32]). The presence of MRSA in livestock, particularly in food, could constitute a potential reservoir of infection for humans.

Among the 155 samples tested, only one strain (0.6%) was an ESBL producer. This rate is proportional to the 0.7% observed by [33] in bovine carcasses in Benin and the 0.4% observed by [34] in food. However, this rate is very different from those reported in hospital settings, which are 16% in Cameroon [35] and 33.3% in America [36]. Additionally, studies conducted by [37] reveal a frequency of 51.1% of *E. coli* strains among ESBL-producing strains in hospital settings. This difference can be explained by the fact that the strains isolated in hospital settings have been in constant contact with antibiotics, thus acquiring certain resistances. Moreover, the frequency of ESBL-producing Enterobacteriaceae determined in this study is lower than those of previous studies, which reported prevalences of 9% in 2008 and 56.2% in 2016 among ESBL-producing Enterobacteriaceae in Côte d'Ivoire ([38, 39]).

## 5. Conclusions

The fresh and braised beef meat tested was contaminated with *Escherichia coli* and *Staphylococcus aureus*. Fresh beef was more contaminated than braised beef. Among fresh meats, high proportions of antibiotic-resistant strains have been found. The presence of these potentially pathogenic microorganisms in these meats, particularly in ready-to-eat braised meat, represents a potential foodborne illness risk to consumers. The presence of antibiotic-resistant microorganisms in fresh meats could also pose a risk if they are not sufficiently cooked before consumption. To remedy this, safety and hygiene measures, such as proper cooking of braised beef and compliance with good hygiene practices by those involved throughout the beef processing and distribution chain, are essential.

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## Data Availability Statement

Not applicable.

## Conflicts of Interest

The authors declare no conflicts of interest.

## References

- [1] Asmai R., Triqui R., Karib H., Bouchrif B., Es-Soucratti K., En-Nassiri H. *Campylobacter* spp. in animal-origin food products. *Revue Marocaine des Sciences Agronomiques et Vétérinaires* 2019, 7(3), 463-471.  
[https://www.agrimaroc.org/index.php/Actes\\_IAPH2/art](https://www.agrimaroc.org/index.php/Actes_IAPH2/art)
- [2] Moussiliou A. Development of a method for identifying *Salmonella* in food products. Master's thesis in Biotechnology in Agri-food Industries, University of Abomey-Calavi, Benin, 2008, 52p.
- [3] Yao KR (2019). Phenotypic and molecular characterization of *Salmonella* sp. and *Escherichia coli* isolated from cattle in the Abidjan district (Côte d'Ivoire): biological impact of antibiotic use. Doctoral thesis, Félix Houphouët Boigny University, Côte d'Ivoire, 241 p.
- [4] MIRAH, 2018. Statistics on animal and fishery resources.
- [5] Assidjo E, Sadat A, Akmel C, Akaki D, Elleingand E, Yao B (2013). Risk analysis: Innovative tool for improving food safety. *African Journal of Health and Animal Production*, 11: 3-13.  
[https://issuu.com/eismv/docs/assidjo\\_et\\_al\\_2013\\_raspa\\_11\\_s\\_p3-1](https://issuu.com/eismv/docs/assidjo_et_al_2013_raspa_11_s_p3-1)
- [6] Toé E (2018). Évaluation des facteurs de risques de bio contamination par *Salmonella* et *Escherichia coli* virulent de la chaîne alimentaire des légumes à Abidjan (Côte d'Ivoire), thèse de Doctorat, Université Nangui Abrogoua, Côte d'Ivoire, 299 p.
- [7] Mason, W. J., Blevins, J. S., Beenken, K., Wibowo, N., Ojha, N. & Smeltzer, M. S (2001). Multiplex PCR Protocol for the diagnosis of staphylococcal infection. *Journal of Clinical Microbiology*. Vol 39: 3332- 3338.  
<https://doi.org/10.1128/JCM.39.9.3332-3338.2001>

- [8] Jarlier V., Nicolas MH., Fournier G. et Philippon A (1988). Extended broad-spectrum  $\beta$ -lactamases conferring transferable resistance to newer beta-lactam agents in Enterobacteriaceae: hospital prevalence and susceptibility patterns. *Reviews Infectious Diseases* 1988; 10(4): 867–78.
- [9] Berkani F (2021). Risk points for microbiological contamination of beef at slaughterhouses. Master's Thesis, Larbi Ben M'Hidi University Oum El Bouaghi, Algeria, 64p.
- [10] Larpent JP (2004). *Listeria*, Publisher: Tec & Doc Lavoisier; 3rd edition, Collection: Microbiology Monographs; 1-239.
- [11] Faye B, Loiseau G (2002). Sources of contamination in dairy chains and examples of quality approaches. In: Hanak E., Boutrif E., Fabre P., Pineiro M., Management of food safety in developing countries. Proceedings of the international workshop, CIRAD-FAO, 11-13 Dec. 2000, Montpellier, France, Cirad, Cederom.
- [12] Haeghebaert S, Le Querrec F, Bouvet P, Gallay A (2002). Collective foodborne infections in France in 2001. *BEH*, 50: 249-253.
- [13] Salifou CFA, Salifou S, Tougan PU, Ahounou GS, Youssao AKI (2010). Evaluation of the hygiene of the slaughtering process at Cotonou-Porto-Novo abattoirs using bacteriological surface examination". 13th Days of Muscle Sciences and Meat Technology, October 19-20, 2010, Clermont Ferrand, France, 175-176.
- [14] Dibi EADB, N'Goran-Aw ZEB, Akmel DC, Tano K, Assidjo EN (2017). Microbial hazards linked to the consumption of braised beef meat in Côte d'Ivoire. *International Journal of Innovation and Applied Studies*, 19(3): 496-507. <https://doi.org/10.4236/ijns.2017.81208>
- [15] Rozier J, Carlier V (1985). Bolnot, Microbiological basics of food hygiene. Paris: Sapaic éditions, 230 p.
- [16] Ghafir Y, China B, Dierick K, De Zutter L, Daube G (2008). Hygiene indicator microorganisms for selected pathogens on beef, pork, and poultry meats in Belgium. *Journal of Food Protection*, pp. 35-45-71. <https://doi.org/10.4315/0362-028x-71.1.35>
- [17] Baba-Moussa L, Ahissou H, Azokpata P, Assogba B, Atindéhou M, Anagonou S, Keller D, Sanni A, Prévost G. (2010). Toxins and adhesion factors associated with *Staphylococcus aureus* strains isolated from diarrheal patients in benin. *African Journal of Biotechnology* 9, pp. 604-611, 2010. <https://doi.org/10.5897/AJB09.1221>
- [18] Ouédraogo A, Traoré R, Ouédraogo GA, Somda NS, Cissé H, Ghogomu SM, Tchoumboungang F, Zongo C, Savadogo A (2023). Phenotypic and Molecular Characterization of *Staphylococcaceae* and *Enterobacteriaceae* Species Isolated from Smoked, Dried, and Braised Fish Marketed in Ouagadougou. *Advances in Microbiology*, 13: 48-75. <https://doi.org/10.4236/aim.2023.131004>
- [19] Taha ZM, Yassin NA (2019). Prevalence of Diarrheagenic *Escherichia coli* in Animal Products in Duhok Province, Iraq. *Iranian Journal of Veterinary Research*, 20, 255-262. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6983314/>
- [20] Kaspar CW, Hartman PA, Benson AK (1987). Coagglutination and Enzyme Capture Tests for Detection of *Escherichia coli* 1-Galactosidase, 3-Glucuronidase, and Glutamate Decarboxylase. *Applied and Environmental Microbiology*, 53, 1073-1077. <https://doi.org/10.1128/aem.53.5.1073-1077.1987>
- [21] Martins MT, Rivera IG, Clark DL, Stewart MH, Wolfe RL, Olson BH (1993). Distribution of uidA Gene Sequences in *Escherichia coli* Isolates in Water Sources and Comparison with the Expression of, B-Glucuronidase Activity in 4-Methylumbelliferyl-3-D-Glucuronide Media. *Applied and Environmental Microbiology*, 59: 2271-2276. <https://doi.org/10.1128/aem.59.7.2271-2276.1993>
- [22] Molina F, López-Acedo E, Tabla R, Roa I, Gómez A, Rebollo JE (2015). Improved Detection of *Escherichia coli* and *Coliform Bacteria* by Multiplex PCR. *BMC Biotechnology*, 15(48). <https://doi.org/10.1186/s12896-015-0168-2>
- [23] Maki N, Al-Muaala A, Sadeq Yasir Al-Ethari A, Abdul Ameer Al-Kraety I, Ghani Al-Muhanna S (2021). Molecular Detection of Clumping factor A gene and Antibiotic Susceptibility Evaluation of *Staphylococcus aureus* Isolated from Urinary Tract Infections. *Archives of Razi Institute*, 77(2): 573-578. <https://doi.org/10.22092/ARI.2022.357153.1985>
- [24] Yousefi M, Pourmand MR, Fallah F, Hashemi A, Mashhadi R, Nazari-Alam A (2016). Characterization of *Staphylococcus aureus* biofilm formation in urinary tract infection. *Iran J Public Health*. 45(4): 485-93. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4888176/>
- [25] Jarlier V. 2019. Cross-transmission in antibiotic resistance: its control in French hospitals. *Bulletin de l'Académie Nationale de Médecine*, 203(3-4): 170-178.
- [26] Ratnam S, March SB (1988). Characterization of *Escherichia coli* serotype O157: H7. *Journal of Clinical Microbiology*, 26(10): 2006-2012. <https://doi.org/10.1128/jcm.26.10.2006-2012.1988>
- [27] World Organisation for Animal Health (OIE) (2021). OIE list of antimicrobial agents of veterinary importance. June 2021.
- [28] Belal F, Bouarab H, Ben Zaid B, Boudinar A (2021). Uropathogenic *Escherichia coli*: Frequency and Antibiotic Resistance at Nedir Mohammed Hospital in Tizi-Ouzou.
- [29] Mourabit N, Arakrak A, Bakkali M, Zian Z, Bakkach J, Laglaoui A (2020). Nasal carriage of *Staphylococcus aureus* in farm animals and breeders in north of Morocco. *BMC Infectious Diseases*, 20(602). <https://doi.org/10.21203/rs.3.rs-15742/v4>
- [30] Khemiri, M, Abbassi MS, Couto N, Mansouri R, Hammami S, Pomba C (2018). Genetic characterization of *Staphylococcus aureus* isolated from milk and nasal samples of healthy cows in Tunisia: First report of ST97 t267-agrI-SCCmecV MRSA of bovine origin in Tunisia. *Journal of Global Antimicrobial Resistance*, 14: 161-165. <https://doi.org/10.1016/j.jgar.2018.03.013>
- [31] Chaalal W (2019). Molecular characterization of *Staphylococcus aureus* strains isolated from foodstuffs. PhD Thesis, University of Oran 1 Ahmed Ben Bella, Algeria, 200p.



- [32] Chairat S, Gharsa H, Lozano C, Gomez-Sanz E, Gomez P, Zarazaga M, Boudabous A, Torres C, Ben Slama K (2015). Characterization of *Staphylococcus aureus* from raw meat samples in Tunisia: Detection of clonal lineage ST398 from the African Continent. *Foodborne Pathog. Dis* 12: 686-692. <https://doi.org/10.1089/fpd.2015.1958>
- [33] Attien PS, Sina H, Wardi M, Dadie AT. (2013). Prevalence and antibiotic resistance of *Staphylococcus* strains isolated from meat products sold in Abidjan streets (Ivory Coast). *African Journal of Microbiology Research* 7: 3285-3293. <https://doi.org/10.5897/AJMR2013.5688>
- [34] Ahouadjinou H, Gbaguidi B, Haziz S, Kifouli A, Fatiou T (2016). Antibiotic resistance and virulence factors of *Escherichia coli* strains isolated from bovine carcasses in Benin. *European Scientific Journal* 12(33): 1857 – 7881. <https://doi.org/10.19044/esj.2016.v12n33p493>
- [35] Mesa RJ, Blanc V, Blanch AR, Cortés P, González JJ, Lavilla S (2006). Extended spectrum  $\beta$ -lactamase-producing Enterobacteriaceae in different environments (humans, food, animal farms and sewage). *Journal of Antimicrobial Chemotherapy*, 58(1): 211-215. <https://doi.org/10.1093/jac/dkl211>
- [36] Lonchel CM, Meex C, Gangoué-Piéboji J, Boreux R, As-soumou MC, Melin P, De Mol P (2012). Proportion of extended-spectrum  $\beta$ -lactamase producing Enterobacteriaceae in community setting in Ngaoundere, Cameroon. *BMC Infectious Diseases*, 12, 53. <https://doi.org/10.1186/1471-2334-12-53>
- [37] Dexheimer GM, Prediger J, Weidlich L, Pozzobon A (2015). Prevalence of resistance and molecular characterization of extended spectrum beta-lactamase (ESBL)-producing bacteria isolated in a hospital in Southern Brazil. *African Journal of Microbiology Research*, 9(5): 294-300. <https://doi.org/10.5897/AJMR2014.7340>
- [38] Toudji A, Djeri B, Karou D, Tigossou S, Ameyapoh Y, Souza K (2017). Prevalence of extended-spectrum beta-lactamase-producing Enterobacteriaceae strains isolated in Togo and their antibiotic sensitivity. *International Journal of Biological and Chemical Sciences* 11(3): 1165-1177. <https://doi.org/10.4314/ijbcs.v11i319>
- [39] Guessennd N, Bremont S, Gbonon V, Kacou-N'Douba A, Ekaza E, Lambert T, Dosso M, Courvalin P (2008). Quinolone resistance of qnr type in extended-spectrum beta-lactamase-producing Enterobacteriaceae in Abidjan, Ivory Coast. *Pathologie Biologie*, 56: 439-446. <https://doi.org/10.1016/j.patbio.2008.07.025>