American Journal of Microbiological Research, 2025, Vol. 13, No. 3, 45-51
Available online at http://pubs.sciepub.com/ajmr/13/3/2
Published by Science and Education Publishing
DOI:10.12691/ajmr-13-3-2

Vendor Practices, Consumption and Contamination by *Escherichia coli* and *Staphylococcus aureus* in "Choukouya" Braised Beef in Abidjan (Côte d'Ivoire)

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Received May 01, 2025; Revised June 01, 2025; Accepted June 08, 2025

Abstract In Côte d'Ivoire, Braised beef or "Choukouya", is particularly appreciated for its unique taste. She is a staple of street food. Consequently, it may be contaminated with potentially pathogenic germs due to vendor hygiene, inadequate cooking, preparation and sales conditions, or exposure to open air on the streets. This study evaluated the levels of beef contamination sold in Abidjan by *Escherichia coli* and *Staphylococcus aureus*, while analyzing sales practices and conditions that could affect public health. A survey was conducted with 600 consumers and 150 "choukouya" vendors. Additionally, 300 beef samples fresh and braised were collected, including 100 from slaughterhouses, 100 from markets, and 100 braised samples. Contamination by *E. coli* and *S. aureus* was evaluated using enumeration methods on TBX and enriched Baird-Parker media. The results highlighted the popularity of "choukouya" in diets. However, contamination factors were identified, notably poor hygiene of meat, ingredients, vendors, and sales environments. All fresh meat samples were contaminated with *E. coli* and *S. aureus*. Average microbial loads were 2.2 ± 3.1 log10 CFU/g (*E. coli*) and 3.9 ± 3.5 log10 CFU/g (*S. aureus*) for fresh meat from slaughterhouses, and 2.1 ± 3.5 log10 CFU/g and 3 ± 3.6 log10 CFU/g, respectively, for market-sourced meat. Braised meat showed loads of 0.1 ± 0.7 log10 CFU/g (*E. coli*) and 1.2 ± 2.2 log10 CFU/g (*S. aureus*). These results underscore the urgent need to strengthen hygiene measures to ensure the safety of beef.

Keywords: *choukouya, beef, Escherichia coli, S taphylococcus aureus, infections, food safety, Côte d'Ivoire*

Cite This Article: Grah Gnambahon Ruth, Koné Tadiogo Naty Amine, Atobla Koua, Kouamé N'zebo Désiré, Benié Comoé Koffi Donatien, Yakoura Karidja Ouattara, and Dadié Adjehi, "Vendor Practices, Consumption and Contamination by *Escherichia coli* and *Staphylococcus aureus* in "Choukouya" Braised Beef in Abidjan." *American Journal of Microbiological Research*, vol. 13, no. 3 (2025): 45-51. doi: 10.12691/ajmr-13-3-2.

1. Introduction

According to the World Organization for Animal Health, meat refers to all edible parts of an animal (any mammal or bird). It is also the product of the transformation of muscle after the death of the animal [1]. In Côte d'Ivoire, meat occupies an important place in the diet and eating habits of Ivorians. The most frequently consumed meats are beef, poultry, pork, mutton and goat. In 2017, total meat consumption per capita reached 13 kg per year, including 4.9 kg of beef, 4.2 kg of pork, 2.6 kg of poultry and 1.2 kg of mutton and goat meat (including edible by-products of slaughter, called "edible offal") [2]. Beef therefore ranks first in consumption and is the second preferred source of animal protein for the population after fish. Its richness in proteins, vitamin B12 and minerals makes it essential to the human diet balance [1,3]. It is consumed in various forms including braised, dried, fried and many others [4].

The braised form, commonly called "barbecue" in Europe, "Dibi" in Senegal, "Tchatchanga" in Benin and "Choukouya" in Ivory Coast, is particularly appreciated by Ivorians. Approximately 62.4% of the population consumes meat in this form [5]. It is widely consumed in leisure places, recreational places and festive events [6,7]. It is sold on the edges of the streets, in markets and neighborhoods, making it a street food. Consequently, it can be contaminated by potentially pathogenic germs including Escherichia coli and Staphylococcus aureus due to the hygiene of the seller, inadequate cooking, preparation and sale conditions, or exposure to the open air. The large share of this informal activity, as well as survey data linking it to foodborne diseases, make braised beef a significant threat to public health [8,9]. However,

given the limited data on the sale, consumption and microbiological quality of braised beef “choukouya” in Abidjan, it is crucial to assess its safety. Thus, the objective of this study was to assess the contamination levels of beef sold in Abidjan by Staphylococcus aureus and Escherichia coli while identifying attitudes and conditions of sale that could impact public health.

2. Material and Methods

2.1. Biological Material

The biological material consisted of fresh beef sourced from the Abidjan city slaughterhouse (Figure 1), fresh beef from the Port-Bouët market (Figure 2), and braised beef (Figure 3).

Figure 1. Fresh beef from slaughterhouse

Figure 2. Fresh beef from market

Figure 3. Choukouya braised beef from vendors

2.2. Study Area

The study was conducted in the autonomous district of Abidjan (latitude 5°18’34’’ N and longitude 4°00’45’’ W), located in the Lagunes region in southern Côte d’Ivoire. Since 2001, Abidjan has been designated an "autonomous district" covering 2,119 km². It encompasses the ten communes of the former city of Abidjan (422 km²) and four peripheral sub-prefectures, which were previously rural but are now urbanized due to the city's expansion. As of the 2021 census, Abidjan had a population of 6,321,017, representing 21.5% of the country's total population [10]. Abidjan is not only Côte d’Ivoire’s largest city but also home to the country's largest livestock market. Among the district's communes, Port-Bouët, Koumassi, Treichville, Marcory, and Yopougon were selected for conducting the survey with consumers and vendors of braised beef (Figure 4). Port-Bouët was chosen due to the presence of a slaughterhouse in the area, the high number of choukouya beef vendors, and a dedicated space for selling this type of meat. Koumassi, Treichville, and Marcory were selected for their proximity to Port-Bouët and their high concentration of choukouya beef vendors. Finally, Yopougon was included because of its large population and notable presence of choukouya beef vendors.

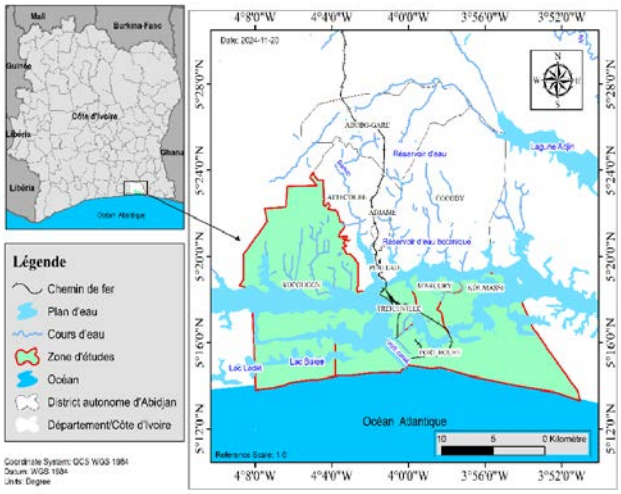

Figure 4. Geographical map of Abidjan showing the study sites

2.3. Survey of Vendors and Consumers of Braised Beef

2.3.1. Population Size for the Survey

The size of the population to be surveyed was determined using the formula for calculating the sample size in probabilistic studies [11].

$$n = \frac{Z^2 \times p(1-p)}{e^2} \quad (1)$$

In this formula: n is the minimum population size for the survey; Z is a constant from the normal distribution ; for a 95% confidence level, (Z = 1.96); p is the prevalence of consumption and sale of braised beef ; e chosen margin of error (5%).

Given the lack of national data on the consumption rate of braised beef, a prevalence of p = 50% was used for this study to estimate the survey population size. With a prevalence of 50%, the minimum required sample size would be 384. In total, 750 individuals were surveyed, including 150 vendors and 600 consumers.

2.3.2. Survey of Vendors

The survey of vendors was conducted in the selected communes over two months, from January to February 2023, targeting 150 vendors (30 per commune). Only vendors selling choukouya braised beef were approached and interviewed with their consent. The survey was conducted using a pre-designed questionnaire completed based on the vendors' responses. The questionnaire covered sociodemographic characteristics such as age, gender, and nationality, as well as sales practices, the selling environment, and hygiene conditions (of both the vendors and the sales locations).

2.3.3. Survey of Consumers

The survey of consumers was also conducted in the same selected communes from January to February 2023, involving 600 consumers (120 per commune). Participants were randomly selected among buyers of braised beef "choukouya", as well as individuals present near the sales points or simply passing by. The questionnaire covered various aspects, including the participants' level of knowledge and consumption habits related to beef, the form and frequency of consumption, and any history of symptoms experienced after consuming "choukouya". Sociodemographic data such as age, gender, and nationality were also collected with the participants' consent.

2.4. Collection and Analysis of Fresh and Braised Beef Samples

2.4.1. Sample Size Determination

The sample size for fresh and braised beef was determined using the same formula applied to calculate the survey population size.

To account for the type of matrix and the bacterial strains being investigated, prior study data were considered. According to research by [5] conducted in Bouaké and Korhogo, the prevalence of *E. coli* strains in fresh and braised beef was 88.9% and 66.7%, respectively, while the prevalence of *S. aureus* strains was 100% in both fresh and braised beef.

Based on an expected prevalence of 80%, the minimum probabilistic sample size would be 246. However, to account for uncertainties, 300 samples of fresh beef and braised "choukouya" beef were collected for this study.

2.4.2. Sampling

A total of 300 samples (n=300) were collected randomly from butchers and vendors in the Port-Bouët commune. This included 100 samples of fresh beef from the slaughterhouse, 100 samples of fresh beef purchased from the market, and 100 samples of braised beef. After purchase, each sample was labeled with the location, date of collection, and sample number, then quickly stored and transported to the laboratory in coolers with ice packs to ensure optimal conditions for the analyses.

2.4.3. Preparation of Mother Suspension and Dilutions

The mother suspensions and decimal dilutions were prepared according to the [12] AFNOR NF V08-010-2 : 1996 standard. Fresh and braised meat samples were aseptically weighed, cut with sterile scissors, and ground in a mortar that had been previously disinfected and sterilized with a Bunsen burner flame. Then, 10g of the ground sample was transferred into 90mL of buffered peptone water contained in sterile test tubes. The resulting mother suspension was used to prepare a series of serial dilutions. A volume of 1 mL from the mother suspension was taken with a sterile graduated pipette and added to 9 mL of buffered peptone water in a sterile test tube. This mixture was homogenized, and decimal serial dilutions were made up to the 10^{-4} dilution for the fresh meat samples and to the 10^{-1} dilution for the braised meat samples.

2.4.4. Enumeration of *Staphylococcus aureus*

The enumeration of *S. aureus* was carried out by counting characteristic colonies after plating on Baird-Parker agar supplemented with potassium tellurite and egg yolk, following the [13] AFNOR NF V 08-057-1 standard. 0.1 mL of the mother suspension and decimal dilutions were spread onto the surface of Baird-Parker agar (Biomerieux, France). The inoculated Petri dishes were incubated at 37°C for 24 hours, and if no colonies were visible, the incubation was extended for an additional 24 hours. After 48 hours, characteristic *S. aureus* colonies (black, shiny, convex, surrounded by a clear halo) were counted. For enumeration, only plates containing between 15 and 150 characteristic colonies were considered.

2.4.5. Enumeration of *Escherichia coli*

The enumeration of *E. coli* was performed on a selective chromogenic medium, TBX (Tryptone Bile X-Glucuronide) (Biomerieux, France). 0.1 mL of the mother suspension and decimal dilutions were spread onto the surface of pre-poured TBX agar in sterile Petri dishes. The plates were incubated inverted at 37°C for 24 hours. After 24 hours, characteristic *E. coli* colonies (blue or blue-green in color) were counted. For enumeration, only plates containing between 15 and 150 characteristic colonies were considered.

2.5. Statistical Analysis

The survey data were entered and processed using IBM SPSS Statistics 26 software. Graphs were created using Excel 2016. The calculation of microbial loads was carried out using R software.

3. Results

3.1. Socio-demographic Characteristics of Sellers

All the braised beef “choukouya” sellers interviewed were male (100%). Most of them (48.7%) were aged 30–45 years and the majority were foreign nationals (59.3%). Among them, 82% sold only beef, while 9.3% sold both beef and chicken choukouya, 6% sold both beef and mutton choukouya, and 2.7% sold a mixture of beef, mutton and chicken choukouya. The majority of the sellers interviewed were illiterate (62.7%) or had a

primary education level (30.7%), with 50.7% having less than 5 years of experience (Table 1).

Table 1. Socio-demographic Characteristics of sellers

Characteristics	Respondents (N=150)	Frequency	Proportion (%)
Gender	Men	150	100
	Women	0	0
Marital Status	Single	58	38.7
	Married	92	61.3
Education level	Illiterate	94	62.7
	Primary	46	30.7
	Secondary	8	5.3
	Higher Education	2	1.3
Age	Less than 18 years	4	2.7
	18-30 years	62	41.3
	30-45 years	73	48.7
	Over 45 years	11	7.3
Nationality	Ivorian	61	40.7
	Other nationality	89	59.3
Years of Experience	Less than 5 years	76	50.7
	5-15 years	64	42.7
	More than 15 years	10	6.7

3.2. Hygiene, Preparation, and Sales Conditions of Braised Beef

The majority of vendors reported washing the meat (84.7%) and the vegetables (75.3%) used for preparing "choukouya". However, some vendors (15.3%) stated they did not wash the meat, and 24.7% did not wash the vegetables. After cooking, the meat is mostly wrapped in paper used for packaging cement (66%), typically purchased from suppliers of fresh meat. Leftover meat is either stored in a refrigerator (84%) or at room temperature (16%). Most of the vendors surveyed operate their businesses along the roadside (58.7%), inside a market (14%), or in residential neighborhoods (27.3%). More than half of the vendors (64.7%) were considered to have sufficient personal hygiene, while 52.7% of the vendors were operating in an environment that was deemed unsatisfactory in terms of cleanliness (Table 2).

Table 2. Conditions of Sale and Preparation of Braised Beef

Characteristics	Respondents	Count (N=150)	Proportion (%)
Washing of meat before cooking	Yes	127	84.7
	No	23	15.3
Washing of vegetables before cooking	Yes	113	75.3
	No	37	24.7
Meat packaging method	Paper	99	66.0
	Plastic bag	4	2.7
	Aluminum foil	8	5.3
	Paper + bag	39	26.0
Meat storage method	Room temperature	94	62.7
	Refrigerator	46	30.7
	Freezer	8	5.3
Vendor's location	Roadside	88	58.7
	Inside	41	27.3
	neighborhood	21	14.0
	In a market		
Vendor's hygiene	Clean	97	64.7
	Dirty	53	35.3
Vendor's environment	Clean	71	47.3
	Dirty	79	52.7

3.3. Socio-Demographic Characteristics of Consumers

The profile of beef consumers was determined following the consumption survey. 100% of those interviewed stated that they know and consume beef. The majority were men (57.5%) with an age range between 18 and 30 years (50%). Most of them were Ivorian (81.2%), had a higher education level (46.2%), and were single (70.5%) (Table 3). The different forms of consumption identified were: braised, in sauce, fried, dried, and boiled. Among these, 45.5% of consumers prefer the grilled form, 36.2% prefer it in sauce, 10.5% prefer it fried, and 7.8% prefer it boiled. The braised form, or "choukouya," is mostly consumed on the side of the streets (49.5%), in local bars (4.8%), and in homes (9.7%). The results regarding the frequency of consumption show that 15.5% of consumers eat grilled beef at least once a day (Figure 5).

Table 3. Socio-Demographic Characteristics of Consumers

Characteristics	Respondents	Count (N=600)	Proportion (%)
Gender	Men	345	57.5
	Women	255	42.5
Marital status	Single	423	70.5
	Maried	177	29.5
Education level	Illiterate	79	13.2
	Primary	89	14.8
	Secondary	155	25.8
	Higher Education	277	46.2
Age	Less than 18 years	92	15.3
	18-30 years	300	50.0
	30-45 years	186	31.0
	Over 45 years	22	3.7
Nationality	Ivorian	487	81.2
	Foreign	113	18.8
Religion	Christian	409	68.2
	Muslim	178	29.7
	Buddhist	6	1.0
	Animist	7	0.11

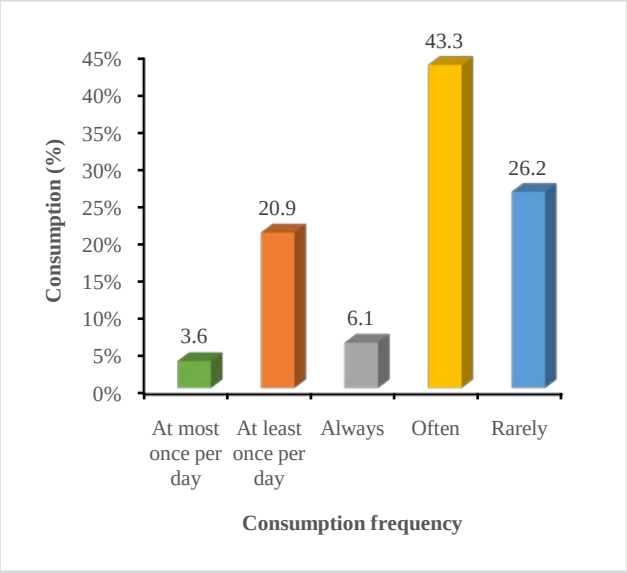

Figure 5. Consumption Frequencies of braised beef

3.4. Symptoms Associated with the Consumption of braised Beef

Among the 100% of consumers surveyed, 69% stated that they consume beef in braised form, 74.3% in sauce, 41.2% fried, 27.2% boiled, and 14.2% dried. Among the consumers of the grilled form "choukouya," 27.6% reported experiencing discomfort after consuming beef in this form. The recorded discomforts included nausea, vomiting, abdominal pain, and diarrhea. Diarrhea was the most commonly recorded symptom (52.9%), followed by abdominal pain (20.7%), diarrhea associated with abdominal pain (7.4%), and nausea associated with vomiting (5%) (Figure 6). These discomforts affected mainly consumers in the age range of 18-30 years (50.4%) (Figure 7).

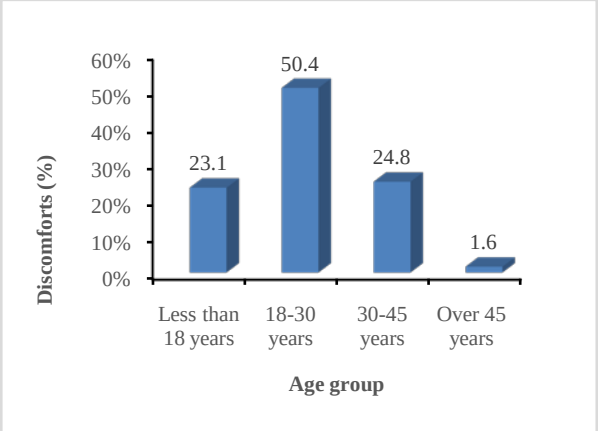

Figure 6. Symptoms Observed Among Braised Beef Meat Consumers

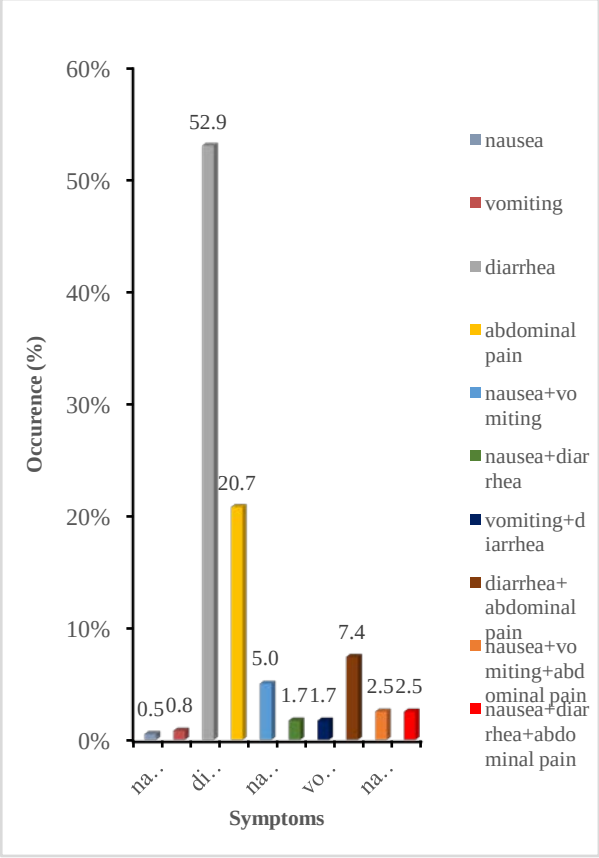

Figure 7. Frequency of Observed Discomforts by Age Group

3.5. Symptoms Associated with the Consumption of Braised Beef

All 200 fresh beef samples from the slaughterhouse and the Port-Bouët market were contaminated with *E. coli* and S. aureus, resulting in a contamination rate of 100%. The baised beef samples, or "choukouya," had a contamination rate of 6% for *E. coli* and 30% for *S. aureus* (Table 4).

Table 4. Contamination Rates of Fresh and Braised Beef Samples

Matrices	Sample Size	Microorganisms	
		E. coli	*S. aureus*
Fresh beef slaughterhouse	100	100 (100%)	100 (100%)
Fresh beef market	100	100 (100%)	100 (100%)
Braised beef	100	6 (6%)	30 (30%)

3.5. Load of *S. aureus* and *E. coli* in Fresh and Braised Beef Samples

In the fresh beef samples from the slaughterhouse, the average load of *E. c*oli was 2.2 ± 3.1 log10 CFU/g, while that of *S. aure*us reached 3.9 ± 3.5 log10 CFU/g. For the fresh beef from the market, the average load of *E. coli* was 2.1 ± 3.5 log10 CFU/g, and that of *S. aure*us was 3 ± 3.6 log10 CFU/g. Regarding the "choukouya" samples, the average load of *E. coli* was 0.1 ± 0.7 log10 CFU/g, and that of *S. aureus* was 1.2 ± 2.2 log10 CFU/g (Table 5).

Table 5. Levels of *S. aureus* and *E. coli* in Samples of Fresh and Braised Beef

Microorganisms	Matrice		
	Mean ± SD (log_{10} CFU/g)		
	Fresh beef slaughterhouse	Fresh beef market	Braised beef
Escherichia coli	$2.2±3.1^{a}$	$2.1±3.5^{a}$	$0.1±0.7^{b}$
Staphylococcus aureus	$3.9±3.5^{a}$	$3±3.6^{a}$	$1.2±2.2^{b}$

Mean values with the same letter in the same row and column are not significantly different (P > 0.05)

4. Discussion

The survey of consumers of braised beef “choukouya” made it possible to assess the place that this dish occupies in the diet of Ivorians, as well as the consumption habits associated with it. All the people interviewed in the different communes knew and consumed beef. Among the different forms of consumption, braised beef, commonly called “choukouya”, emerged as the most consumed and appreciated, with a rate of 45.5%. This preference can be attributed to several factors, including its accessibility and availability, as it is easily found in many neighborhoods, especially near maquis (local restaurants), markets and street corners. In addition, its delicious taste, attractive aroma and affordable price allow many people to enjoy it, while for others, it is simply a matter of personal preference. In fact, consumers surveyed said they preferred grilled beef for its taste (24.2%), availability (13.7%), smell (13.3%) and personal preference (15.5%).

Analysis of fresh beef samples from the slaughterhouse and market, as well as braised beef “choukouya”, revealed

that all samples were contaminated with at least one of the microorganisms studied, namely *E. coli* and *S. aureus*, with contamination levels ranging from 6% to 100%. Fresh beef had the highest contamination rate (100%). This high contamination rate could be mainly attributed to the animal itself, from which the meat is derived [1]. The skin, digestive and respiratory organs of animals serve as reservoirs for microorganisms, which could thus serve as a source of contamination. In addition, poor hygiene practices in slaughterhouses, as well as inadequate hygiene during slaughtering, skinning, storage and transport, could also lead to contamination of meat by various pathogenic germs, including those isolated in this study. The slaughterhouse therefore appears to be a critical area for bacterial proliferation [1]. In addition, climatic conditions (ambient temperature) unsuitable for the preservation of fresh meat [14], could exacerbate the bacterial load during the retail sale of meat at ambient temperature, which may exceed acceptable limits.

These factors could also explain or justify why the bacterial loads observed in the samples from the slaughterhouse were higher than those from the market. Indeed, fresh meat from the slaughterhouse had a mean *E. coli* load of 2.2 ± 3.1 log10 CFU/g and *S. aureus* of 3.9 ± 3.5 log10 CFU/g, while the mean bacterial loads of the market samples for *E. coli* and *S. aureus* were 2.1 ± 3.5 log10 CFU/g and 3 ± 3.6 log10 CFU/g, respectively. In contrast to the slaughterhouse, the meat sold in the different markets was less loaded, because the vendors took the time to clean and remove parts of the meat that could repel customers, thus reducing the bacterial load. As for the samples of braised beef "choukouya" they were contaminated by *E. coli* and *S. aureus* at respective rates of 6% and 30%. These values, which are much lower than those of fresh meat, could be explained by the fact that unlike fresh meat, braised meat undergoes several treatments before cooking, not forgetting a heat treatment consisting of eliminating or even destroying all the microorganisms that could contaminate the meat.

However, although these rates are lower, the presence of these microorganisms in cooked meats, ready to be consumed, could indicate either inadequate cooking or poor hygiene practices. Indeed, the presence of *E. coli* in braised beef indicates a hygiene deficiency [15], and a possible presence of enteropathogenic microorganisms, likely to cause foodborne infections [16]. The contamination rates observed in braised beef are much lower than those observed by [5] for the same microorganisms in their study on the microbial risks associated with the consumption of braised beef in Côte d'Ivoire, more precisely in the cities of Bouaké and Korhogo.

The level of *S. aureus* contamination in braised beef is much higher than that of *E. coli*. This difference may be due to the fact that *S. aureus*, which naturally inhabits the mucous membranes, skin and nasopharyngeal region [17], is found when there is sweat on the skin surface [18] of vendors who have constantly sweaty hands due to profuse sweating [5]. This leads to manual contamination of any object or food that comes into contact with these hands.

In addition, observation of vendors, their sales practices and their sales environment revealed several reasons that could be responsible for the potential contamination of braised beef, including *E. coli* and *S. aureus*. The treatment of meat before cooking could be a real source of contamination. The conditions in which meat is packaged for transport are often unsatisfactory, with large quantities being transported unpackaged in wheelbarrows or car trunks. Meat is also left at room temperature on vendors' tables, uncovered, while they prepare the elements needed for cooking. During cooking, the ingredients used in the preparation of "choukouya", such as onions, tomatoes, peppers, etc., are exposed to the open air and are not washed before being added to the preparation. After cooking, the wood used to cut raw meat is also used for cooked meat.

Indeed, raw meat debris left between the wood gaps could be a source of contamination [19]. Chili powder mixed with other powders, such as “kankankan” from dubious sources, added after cooking, as well as fresh vegetables usually handled by hand, could be a source of contamination. In addition, the cement paper used to wrap “choukouya” could be a source of contamination. In fact, all vendors interviewed reported using this paper, which they usually purchase from their meat suppliers for packaging. This type of packaging, although hazardous to consumer health, is used because it is cheap, unlike aluminum foil which is a suitable but relatively expensive packaging option [19]. For this activity, vendors are usually located along the public road, and the meat is exposed to the open air. Microorganisms present in the air, dust and vehicle exhaust gases come into contact with the “choukouya” and can be sources of contamination. The seller’s environment, sometimes unsanitary, could also be a source of contamination. All these reasons listed could justify the bacterial loads of *E. coli* and *S. aureus* observed in the “choukouya”. In fact, the average bacterial load of *E. coli* was 0.1±0.7 log10 CFU/g, and that of *S. aureus* was 1.2±2.2 log10 CFU/g.

During this study, several consumers (20.2%) reported experiencing discomfort after consuming “choukouya”. These symptoms included nausea, vomiting, abdominal pain, and diarrhea. These symptoms may be due to the consumption or ingestion of food contaminated with *E. coli* or *S. aureus*. In fact, *E. coli* infections are usually caused by enterohemorrhagic *E. coli* strains, the most well-known of which is O157:H7, which has a strong epidemiological link with beef [20]. These infections occur following the consumption of contaminated and undercooked beef and can lead to hemorrhagic colitis, diarrhea, etc. [21,22]. Regarding *S. aureus* infections, symptoms include nausea, vomiting, and abdominal cramps with or without diarrhea [23]. However, the symptoms reported by consumers do not allow direct attribution of the cause to *E. coli* and *S. aureus* as the causative pathogens, as the symptoms may also have a non-infectious origin. Furthermore, no stool samples were collected from the sick consumers in this study to confirm this link. It should also be noted that these symptoms could be caused by microorganisms other than *E. coli* and *S. aureus* [1].

5. Conclusion

The information obtained from the surveys allowed for the identification of various high-risk practices that could

serve as sources of contamination for choukouya braised beef, as well as the potential health issues related to its consumption. The study also revealed that both fresh and braised beef were contaminated with *Escherichia coli* and *Staphylococcus aureus*. The fresh beef from the slaughterhouse was found to be the most contaminated, particularly with *S. au*reus, which exceeded acceptable limits by a large margin. In contrast, the choukouya braised beef was the least contaminated, with levels of *S. aureus* and *E. coli* being significantly below the acceptable limits. However, the study highlighted the need for improved safety measures and hygiene practices to ensure the beef sold to consumers is free from health risks. Ensuring better hygiene and food safety protocols is crucial to protect public health and prevent foodborne illnesses.

ACKNOWLEDGEMENTS

The authors are thankful to the slaughterhouse and market in Port-Bouët for sampling.

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