Int.J.Curr.Microbiol.App.Sci (2025) *14*(12): 61-74

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 14 Number 12 (2025)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2025.1412.006

Evaluation of the Microbiological Quality of *Salmonella* and *Escherichia coli* Strains Isolated from Grilled Meat (Mutton/Beef) in the City of Ouagadougou, Burkina Faso

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Keywords

Grilled Meat, *Salmonella* and *Escherichia coli*, PCR analysis, Mutton/Beef

Article Info

Received:
01 September 2025
Accepted:
25 October 2025
Available Online:
10 December 2025

A B S T R A C T

Meat is an essential source of nutrients and a vital source of income, but its richness makes it highly susceptible to microbial proliferation if handled improperly. This study aimed to evaluate hygiene practices and microbiological quality (bacterial load, presence of *Salmonella* and *Escherichia coli*) of grilled meat in Ouagadougou, Burkina Faso, and to determine the pathogenicity profile of isolated *Escherichia coli* strains. A prospective study was conducted at 150 grilling sites in Ouagadougou, combining a socio-demographic survey and the sampling of 150 samples of grilled meat (mutton/beef). Conventional microbiological analyses targeted thermotolerant coliforms and *Salmonella*. Strain identification was performed using API 20E. Virulence genes (*Escherichia coli* pathovars) were detected using multiplex PCR (16-plex). The survey revealed a critical deficiency in hygiene practices, with only 23% of sites deemed satisfactory. The average thermotolerant coliform load was 3.40 $10^{(4)}$/CFU/g, well above regulatory standards. Seventy-three strains of *Escherichia coli* 48.66% (73/150) and three strains of *Salmonella* 2% (3/150) were confirmed. PCR analysis identified significant diarrhoeogenic pathovars: STEC (9.58%), STEC-ETEC (6.84%), EAEC and ETEC (1.36% each). The contamination observed reflects poor hygiene conditions and risky practices throughout the production chain, posing a real risk to consumer health. It is imperative to strengthen inspection, awareness-raising and training of stakeholders to improve the sanitary quality of grilled meat.

Introduction

West Africa is undergoing rapid urbanisation (annual urban growth rate estimated at 6.44% in Burkina Faso), prompting populations to develop survival strategies, of which the street food sector is a key example (Dione *et al.,* 2021). Street food is vital for consumers because of its socio-economic importance (Nonato *et al.,* 2016).

In Ouagadougou, this sector is dominated by micro-enterprises specialising in grilled meat and beverages, making the city a major hub for this activity (Barro *et al.,* 2007). The meat industry, which has even given rise to a festival (FESTIGRILL in 2009), is crucial for employment and the fight against poverty (Pal and Devrani, 2018).

However, meat is a highly perishable and nutritionally rich commodity, which makes it vulnerable to microbial proliferation (Bros, 2013). In Burkina Faso, livestock farming and slaughtering practices are technologically backward (Kagambèga *et al.,* 2012).

The main causes of street food unhealthiness stem from a failure to comply with good hygiene practices during processing, cooking, storage or sale (Doutoum *et al.,* 2022). The environment in which food is prepared and sold predisposes it to contamination (Mayoré *et al.,* 2024). Global studies have shown that meat products are often contaminated with pathogens (Hiba-Ryma *et al.,* 2018). Among these, *Salmonella* and *Escherichia coli* are major causes of contamination and diarrhoeal diseases (Dembélé *et al.,* 2020; Nikiema *et al.,* 2021). Foodborne diseases are a growing concern for public health (WHO, 2024).

Given the importance and sensitive nature of the grilled meat sector in Ouagadougou, frequent studies in this area are necessary.

The objective of this study is to assess the microbiological quality of *Salmonella* and *Escherichia coli* strains isolated from grilled meat (mutton/beef) in the city of Ouagadougou.

Materials and Methods

The study combined a socio-demographic survey and microbiological analyses, conducted from November 2018 to March 2019 in the city of Ouagadougou.

Socio-demographic and qualitative survey

Study sites and period

The prospective study was conducted in Ouagadougou. The choice of sampling areas was based on the density of grilling and sales sites (shown in Figure 1).

Data collection

Target sites: One hundred and fifty (150) beef and mutton sales sites.

Methods: Direct interviews using a pre-established questionnaire, observations of sales sites.

Survey content: Assessment of meat processing conditions, staff hygiene and risky practices among stakeholders.

Microbiological analyses

The analyses and antibiotic resistance profile were carried out at the Laboratory of Molecular Biology for Epidemiology and Surveillance of Water- and Food-borne Bacteria and Viruses (LaBESTA).

Sampling

Number of samples: One hundred and fifty (150) samples of grilled meat (skeletal muscle) were collected immediately after the survey.

Procedure: The samples simulated normal purchasing conditions (cuts made by the seller, packaged in the usual packaging).

Transport and storage: Samples were labelled in sterile bags, transported in a cooler with ice packs, and analysed within 2 hours of sampling.

Preparation of Solutions and Cultures

Preparation of the diluent: Use of buffered peptone water (BPW) (Liofilchem, Italy) to ensure the survival of microorganisms and as a pre-enrichment medium for *Salmonella*. Stock solution and dilutions: 25 g of sample (meat and ingredients) in 225 ml of PBT, followed by decimal dilutions in cascade up to 10^{-3}.

Dilutions 10^{-1}, 10^{-2}, 10^{-3}were seeded for coliforms.

The stock solution was incubated at 37°C for 24 hours to test for *Salmonella.*

Counting and searching for microorganisms

Seeding was carried out on the surface of a gel medium.

Principle

Seeding was carried out on the surface to count thermotolerant coliforms and detect *salmonella*. Counting is based on the principle that each microorganism, after incubation, gives rise to a detectable colony. All seeded boxes were incubated at a given temperature, aerobically, for 24 hours depending on the type of bacteria sought.

Counting thermotolerant coliforms

Thermotolerant coliforms were detected by surface seeding on Violet Red Bile Lactose (VRBL) medium. Using a sterile pipette, 0.1 ml of each dilution was deposited on the surface of each box and a rake was used to spread it. The plates were incubated at 44°C for 24 hours in accordance with standard V08-060. At the end of the incubation period, all colonies that had grown on the agar were counted. Plates containing between 15 and 150 colonies were selected for calculating the bacterial load of the sample using the formula below.

$$N = \frac{\sum C}{(n_1 + 0,1\,n_2) \times d \times V} \quad (1)$$

N = Number of colony-forming units (CFU)/gram of food;

V = volume of solution deposited;

Σc = Total number of colonies counted in boxes with colonies between 15 and 150;

n1 = number of boxes counted from the first dilution;

n2 = number of boxes counted from the second dilution;

d = dilution factor from which the first counts were made;

When fewer than 10 colonies are counted on the boxes of a sample, the arithmetic mean M of the colonies counted is considered for the evaluation of the load according to the formula below:

$$N = \frac{M}{d} \quad (2)$$

N = number of colony-forming units (CFU)/gram of flesh; M = arithmetic mean of the colonies counted on the plates; d = factor of the first dilution used.

Detection of *Salmonella*

Selective enrichment: A volume of 0.1 ml of the pre-enriched broth was withdrawn using a sterile pipette and then added to 10 ml of Rappaport Vassiliadis (RV) broth (Liofilchem, Italy). A volume of 1 ml of the pre-enriched broth was added to 10 ml of Muller Kauffman Tetrathionate (MKTT) broth (Liofilchem, Italy) supplemented with brilliant green (0.95%) and iodine (2%) contained in each sterile screw-cap tube.

The MKTT broth was incubated at 37°C for 18 to 24 hours and the RV broth was incubated at 42°C for 18 to 24 hours. Selective isolation From the RV and MKTT broths, streak plating was performed on SS (Liofilchem, Italy) and XLD (Liofilchem, Italy) agar plates. The plates were incubated at 37°C for 24 hours.

Biochemical characterisation

Biochemical identification was performed using the standardised, miniaturised Galerie API 20E system (BioMérieux) for the 20 biochemical tests.

Calculation of bacterial load

The bacterial load (N) was calculated based on the number of colonies counted (CFU) on the selected plates (between 15 and 150 colonies), using standard food microbiology formulas.

Interpretation of Microbiological Results

The results were interpreted in accordance with the recommendations of Moroccan standard 624-04 (8 April 2004), using a three-class plan for coliforms (Table 1) and a two-class plan (Table 2) for *Salmonella*.

Multiplex polymerase chain reaction (16-plex PCR)

16-plex PCR is a method that allows the simultaneous detection of 16 genes (uidA, pic, bfp, invE, hlyA, elt, ent, escV, eaeA, ipaH, aggR, stx1, stx2, estIa, estIb, and ast) belonging to the five main pathovars of *E. coli* (EHEC, EPEC, EAEC, EIEC, ETEC) in a single reaction according to the method described by Antikainen *et al.,* (2009). It comprises several chronological steps. Pure strains of *Escherichia coli* were re-isolated on MH agar and incubated at 37°C for 24 hours.

Bacterial DNA extraction: Bacterial DNA was extracted using the heating method. A mass of bacterial culture from 24-hour colonies on MH agar was taken and added to an Eppendorf tube (Hamburg, Germany) containing 1.5 ml of sterile distilled water. The mixture was placed in a boiling water bath for 10 minutes. The tube was then centrifuged at 11,337 rpm for 10 minutes. The supernatant was collected and 10 µL was migrated onto a gel to confirm the presence of DNA before being stored for PCR.

Amplification: *Escherichia coli* pathovars were detected by amplifying 16 virulence genes with specific primers in a single PCR reaction. The reaction mixture had a total volume of 20 µl and contained 1 µl of Mueller mix (Mix 1) of 12 primer pairs (Appendix 9), 1 µl of Jenni mix (Mix 2) of 4 primer pairs (Appendix 9), 1 µl of supernatant containing bacterial DNA, and 17 µl of sterile water. The reagents used in the reaction mixture are: 1 U of Top DNA polymerase, 250 mM dNTPs (dATP, dCTP, dGTP, dTTP), 10 mM Tris-HCl (pH 9.0), 30 mM KCl, 1.5 mM $MgCl_2$, and the loading buffer, all contained in the prefabricated premix. The Mix-DNA mixture was made under another hood previously sterilised with UV radiation for 20 minutes, where the premix was added. The amplification programme in the thermocycler (Perkins Helmer Cetus, USA) was 98°C for 30 seconds (initial denaturation) followed by 35 cycles, each consisting of a denaturation step for 30 seconds at 98°C, a hybridisation step for 60 seconds at 62.5°C, and an elongation step for 90 seconds at 72°C. A final elongation was performed at 72°C for 10 minutes.

Agarose gel electrophoresis: The tubes containing the amplicons (PCR products) were subjected to detection by agarose gel electrophoresis. The agarose gel (SIGMA A-9539 Agarose for gel electrophoresis) concentrated at 2% (weight/volume) was prepared in 0.5× Tris Borate EDTA (TBE) buffer (Prolabo-France) (100 mM Trizma base, 100 mM boric acid, 2 mM EDTA); the DNA was stained by adding 8 µl of ethidium bromide (EBT, 10%) and poured onto the gel support for electrophoresis. The electrophoresis tank (APPELEX) was filled with 0.5×TBE buffer until the gel was completely immersed. Ten µl of the PCR product was added to each well of the gel. A 100 bp molecular weight marker (Norgen, Biotech Corp) appropriate for the different weights corresponding to the different amplicons was used. Electrophoretic migration was performed at 120 volts for 120 min. Visualisation was performed under a UV (ultraviolet) lamp (TLUM COVER SYTC 1295), and the gel was photographed.

Reference strains: The *Escherichia coli* reference strains were obtained from the bacteriology laboratory of the National Institute for Health and Welfare in Helsinki, Finland (THL): FE 102301 (cattle, Burkina Faso), FE 95562 (cattle, Burkina Faso), IHE 56822 (patient, Finland), RHE 6647 (SSI, Denmark), FE 94725 (sheep, Burkina Faso), IHE 50246 (patient, Finland) for STEC, STEC-ETEC, EAEC, EIEC, ETEC, respectively.

Interpretation: The presence of elt indicates ETEC. The presence of stx1 and/or stx2 and additional genes eaeA, escV, ent, and EHEC-hly indicates STEC. The presence of invE and/ ipaH indicates EIEC. The presence of pic and/or aggR indicates EAEC (Table 3). The uidA gene was used as a general marker for E*scherichia coli* (Antikainen *et al.,* 2009).

Statistical Data Processing

Data processing was performed using Excel 2016 (data entry) and SPSS/R (analysis) software. The ANOVA test was performed to compare the data. Location data were processed to create a map of the study area.

Results and Discussion

Socio-demographic Survey and Description of Production

Description of the Grilling Process

Grilling is a heat transfer cooking technique. After initial washing and sterilisation of the grill, the meat is placed on the embers. Cooking is done by constantly turning the meat with a long knife, and the time varies depending on

the type and size of the pieces. Oil is regularly used to soak the meat and prevent burning.

Socio-demographic Characteristics and Practices of Stakeholders

The survey covered 150 sites and used the 5M criteria (environment, raw materials, equipment, method, labour) to assess hygiene practices. A male dominance (100%), low level of education (76% illiterate) and a major deficit in hygiene training (94%) were observed. Critical practices included the widespread use of cement paper for packaging, the roaster handling money themselves (91%), and a very low rate of hand washing (16%) (Figures 2a-d; 3; 4e-h).

Microbial loads and prevalence of *Salmonella* sp. pathogens

Salmonella sp. were confirmed by the minimal agar and API 20E agar.

Counting of thermotolerant coliforms and *salmonella*

Microbiological analyses of the 150 samples (distributed across 10 study areas) revealed the average coliform load and the presence of *Salmonella*. The raw results of the microbiological analyses were processed using R software and recorded in Table 4 below.

The sample satisfaction rate was interpreted in accordance with Decree 624-04 (Morocco) (Table 5).

Prevalence of *Escherichia* coli pathovars (PCR)

Molecular analyses confirmed that 48.66% (73/150) of samples contained *Escherichia coli* strains. Fifteen diarrhoeogenic *Escherichia coli* pathovars were screened using 16plex PCR. The highest prevalence rates were observed for STEC and STEC-ETEC. The uidA gene was identified in all strains tested, confirming their membership in *Escherichia coli*. Strains that carried only the uidA gene were classified as non-diarrhoeic *Escherichia coli* (Figure 5).

The study reveals that the sector is completely dominated by men (100%), suggesting explanations based on cultural and socio-economic factors. The level of education is particularly low, with 76% of workers being illiterate. This low level of education, often linked to underdevelopment, is a direct cause of ignorance of basic hygiene and sanitation rules (Pal and Devrani, 2018). This lack of education is exacerbated by the absence of formal training in Good Hygiene and Manufacturing Practices, with 94% of actors in this study having received no training. This shortcoming is typical of the informal street food sector and accentuates the precarious nature of practices (Doutoum *et al.,* 2022). Analysis of the sales environment reveals multiple sources of contamination. In terms of the environment, 57% of sites are located near dusty roads and 37% near rubbish dumps. For tropical cities such as Ouagadougou, this proximity, combined with unpaved streets, constantly exposes food to dust (especially in the dry season), which constitutes a major health risk (Douamba *et al.,* 2022). Contamination by work equipment is considered dirty in 62% of cases, creating a high risk of cross-contamination for food. Inadequate packaging, often due to the widespread use of cement paper (82%), is particularly concerning.

This material can be a source of residual chemical contaminants, which are transferred directly to the grilled meat (Kaboré *et al.,* 2018). Due to a lack of temperature control, almost all unsold items (83%) are stored without a cold chain (refrigerator), which promotes microbial proliferation after cooking. With regard to personal hygiene, the most critical practices are: Money/food handling: 91% of grill operators handle customers' money, which is a direct route for faecal contamination.

This phenomenon is often linked to low profit margins and the inability to employ a cashier (Hiba-Ryma *et al.,* 2018). Hand washing: 84% of grill operators do not wash their hands before serving, reflecting a lack of awareness of the health consequences and a lack of supervision by hygiene services. Lack of protective equipment:

Only 10% of grill operators cover their hair. Although aprons are worn more frequently (54%), this is still lower than the proportions found in more aware contexts, such as Chad (Doutoum *et al.,* 2022).

The overall assessment of hygiene confirms this precarious situation: more than half of the sites are rated as inadequate or very poor (47%), which is mainly attributed to a lack of knowledge of the rules, a lack of resources and a lack of institutional monitoring.

The average bacterial load of 3.40 10^4 CFU/g is

significantly higher than the satisfaction limit set by the Moroccan standard (No. 624-04; 10^3 CFU/g). The results obtained are lower than those of Douamba *et al.,* (2022) with 3 10^5, and those of Kaboré *et al.,* (2018), 6.6 10^5 UFC/g) in Burkina Faso. This high level reflects poor hygiene conditions and recent faecal contamination due to the failure to apply good practices.

The presence of coliforms is directly linked to the poor handling practices observed (not washing hands, handling money at the same time).

Figure.1 Study sites in Ouagadougou

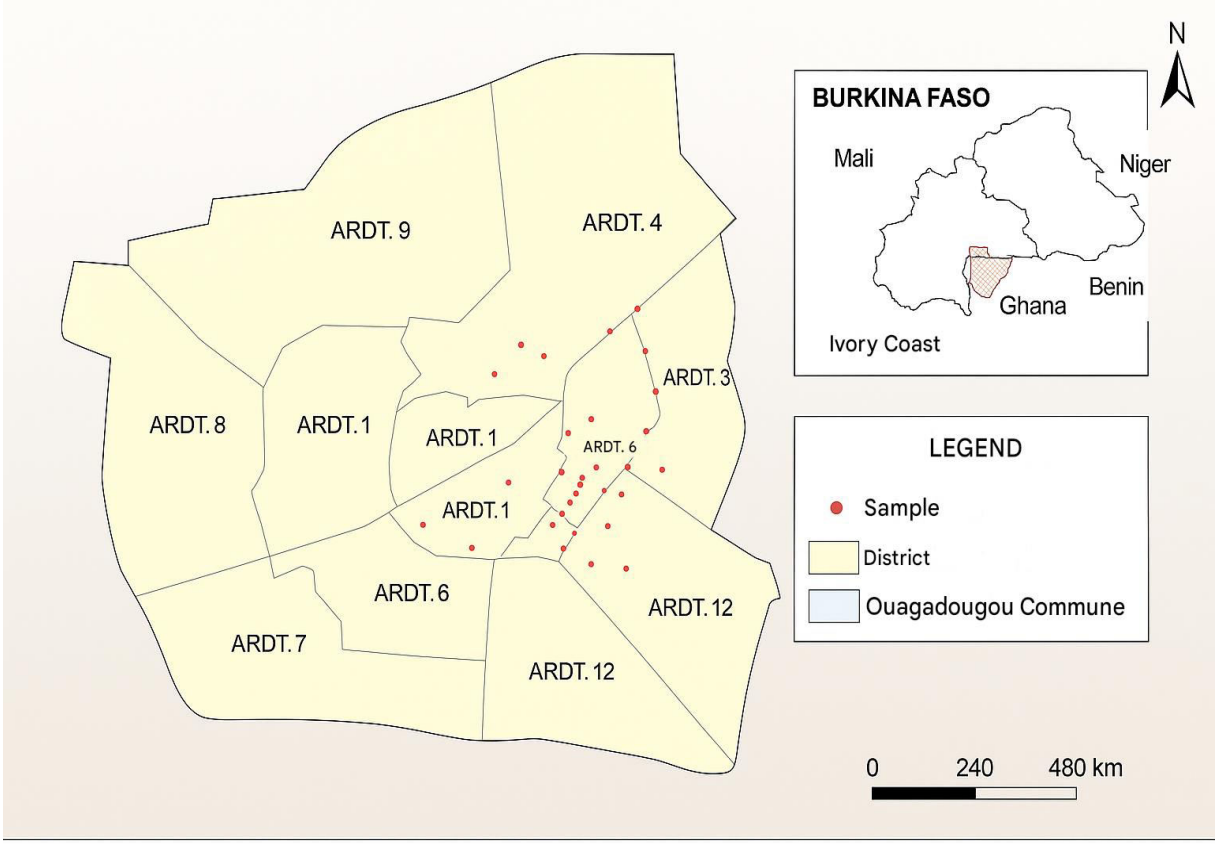


Table.1 Three-class interpretation criteria

Germs	**M**	**3m**	**10m**
Thermotolerant coliforms	10^3	3.10^3	10^4
Assessment	Satisfactory	Acceptable	Unsatisfactory

m= 10^3 g/CFU: value defined by Decree No. 624-04, M= the arithmetic mean M of the colonies counted

Table.2 Two-class interpretation criteria

Absence	**Presence**
Satisfactory	Unsatisfactory

Table.3 Primer sequences for multiplex PCR

Pathovars	Targeted gene	Primer sequences (5' to 3')	T in pb	[C] in µM	Ref
	eaeA	eae-F: TCAATGCAGTTCCGTTATCAGTT			2
		eae-R: GTAAAGTCCGTTACCCCAACCTG	482	0.1	1
STEC-ETEC	*escV*	MP3-escV-F: ATTCTGGCTCTCTTCTTCTTTATGGCTG			
		MP3-escV-R: CGTCCCCTTTTACAAACTTCATCGC	544	0.4	1
	ent	ent-F: TGGGCTAAAAGAAGACACACTG			
		ent-R: CAAGCATCCTGATTATCTCACC	629	0.4	1
	stx1	MP4-stx1A-F: CGATGTTACGGTTTGTTACTGTGACAGC			
STEC		MP4-stx1A-R: AATGCCACGCTTCCCAGAATTG	284	0.2	1
	stx2	MP3-stx2A-F: GTTTTGACCATCTTCGTCTGATTATTGAG			
		MP3-stx2A- R: AGCGTAAGGCTTCTGCTGTGAC	324	0.4	1
	ipaH	ipaH-F: GAAAACCCTCCTGGTCCATCAGG			2
		ipaH-R: GCCGGTCAGCCACCCTCTGAGAGTAC	437	0.1	2
EIEC	*invE*	MP2-invE-F: CGATAGATGGCGAGAAATTATATCCCG			
		MP2-invE-R:CGATCAAGAATCCCTAACAGAAGAATCAC	766	0.2	1
	aggR	MP2-aggR-F: ACGCAGAGTTGCCTGATAAAG			
EAEC		MP2-aggR-R: AATACAGAATCGTCAGCATCAGC	400	0.2	1
	peak	MP2-peak-F: AGCCGTTTCCGCAGAAGCC			
		MP2-pic-R: AAATGTCAGTGAACCGACGATTGG	1111	0.2	1
	astA	MP2-astA-F: TGCCATCAACACAGTATATCCG			
		MP2-astA-R: ACGGCTTTGTAGTCCTTCCAT	102	0.4	1
	elt	MP2-LT-F: GAACAGGAGGTTTCTGCGTTAGGTG			
		MP2-LT-R: CTTTCAATGGCTTTTTTTTGGGAGTC	655	0.1	1
ETEC	*estIa*	MP4-STIa F: CCTCTTTTAGYCAGACARCTGAATCASTTG			
		MP4-STIa-R: CAGGCAGGATTACAACAAAGTTCACAG	157	0.4	1
	estIb	MP2-STI-F: TGTCTTTTTCACCTTTCGCTC			
		MP2-STI-R: CGGTACAAGCAGGATTACAACAC	171	0.2	1
E. coli	*uidA*	MP2-uidA-F: ATGCCAGTCCAGCGTTTTTGC			
		MP2-uidA-R: AAAGTGTGGGTCAATAATCAGGAAGTG	1487	0.2	1

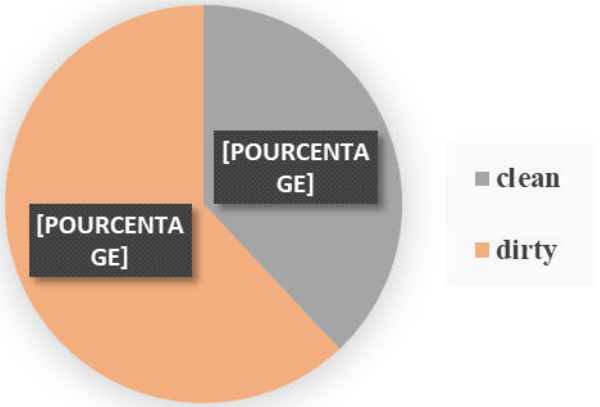
STEC: Shigalike toxin *E. coli*; **ETEC**: Enterotoxinogenic *E. coli*; **EIEC**: Enteroinvasive *E. coli*; **EAEC**: Enteroaggregative *E. coli*; Ref: Reference; T: Expected amplicon size in base pairs (bp); [C]: Concentration; 1**:** ***E. coli***: *Escherichia coli***;** Muller *et al.,* 2007; 2**:** Antikainen *et al.,* 2009

Figure.2 Sociodemographic characteristics of vendors

a)

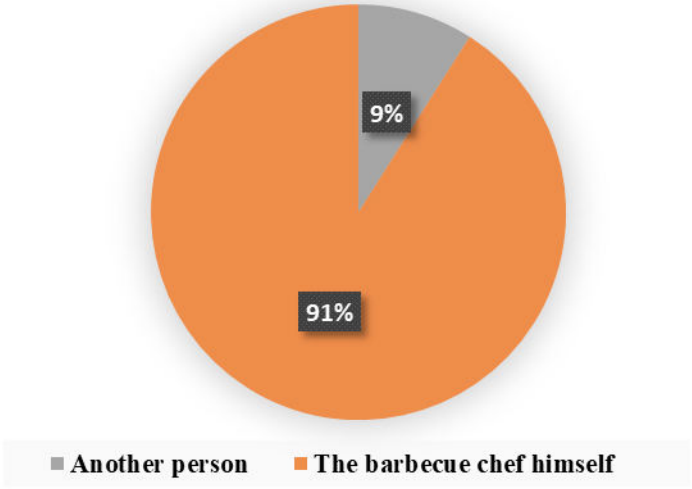
Proportion of vendors by gender

b)



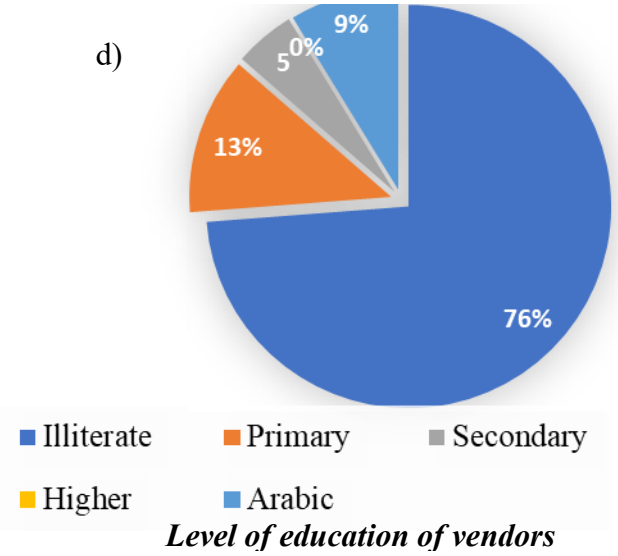
Condition of sales equipment

c)



Handling money at the time of sale

d)



Level of education of vendors

Figure.3 Characteristics of the meat sales sector in public markets

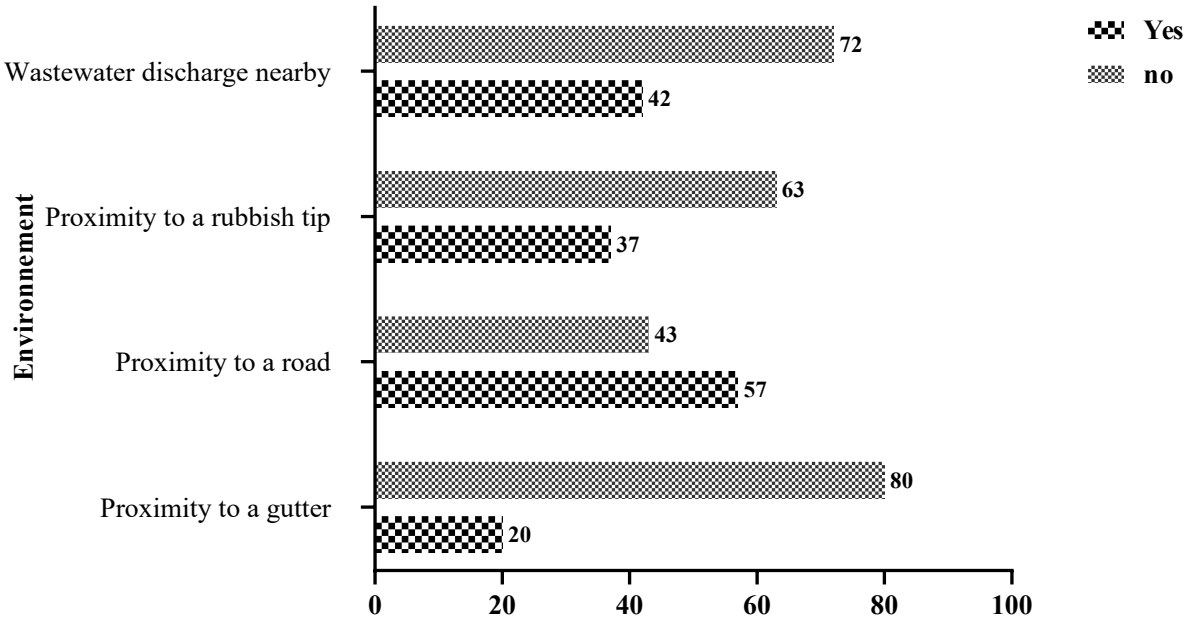
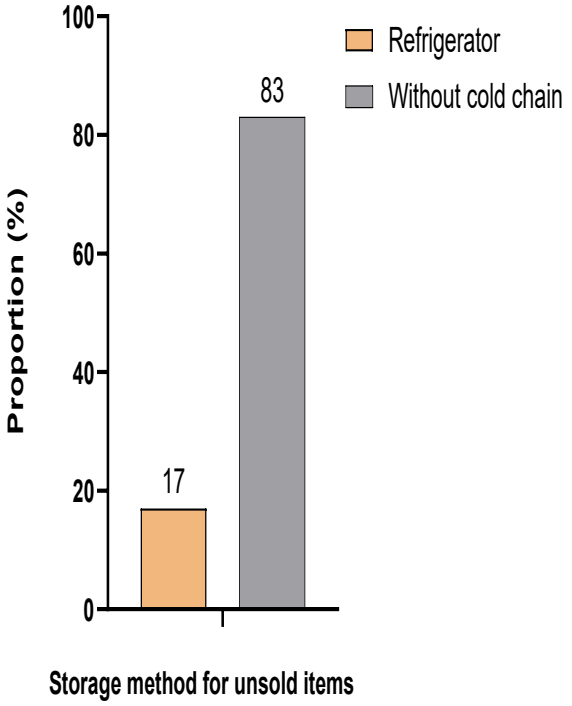
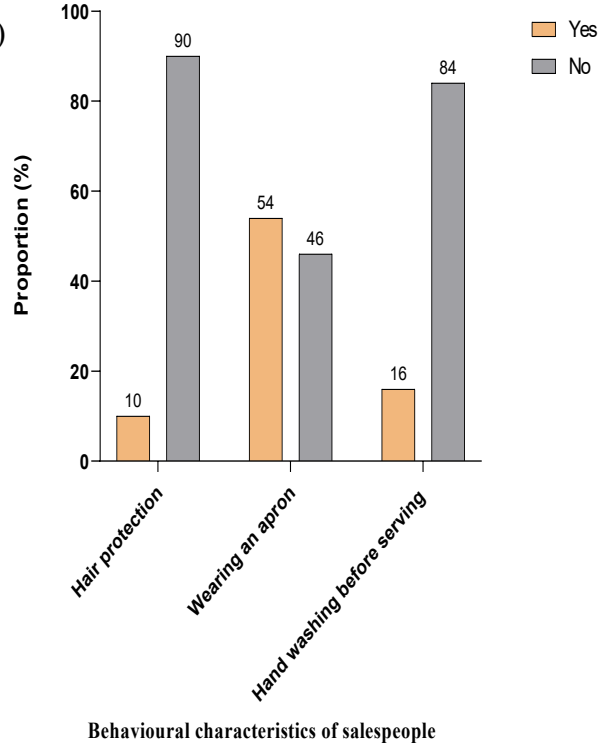


Figure.4 Characteristics of the meat sales sector in public places

e)



f)



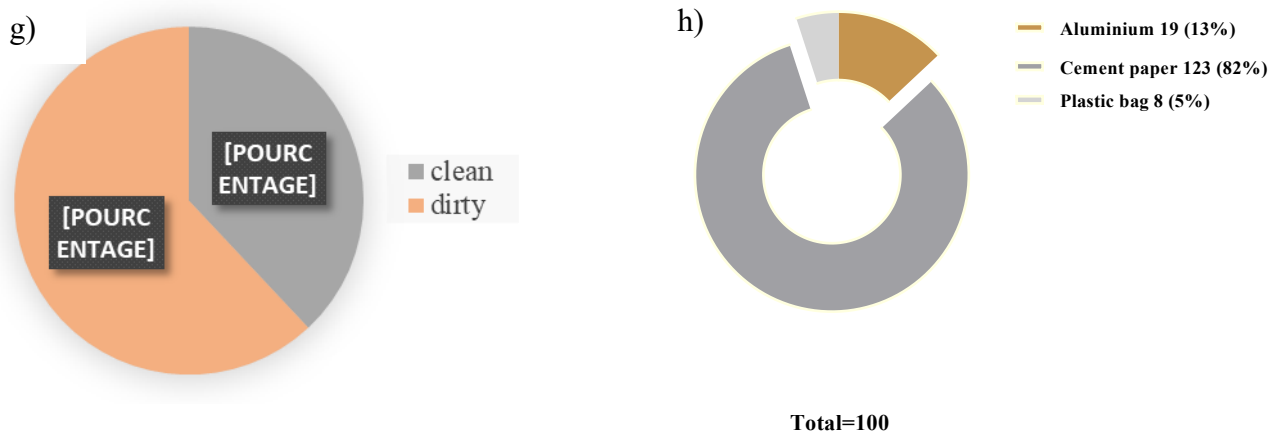
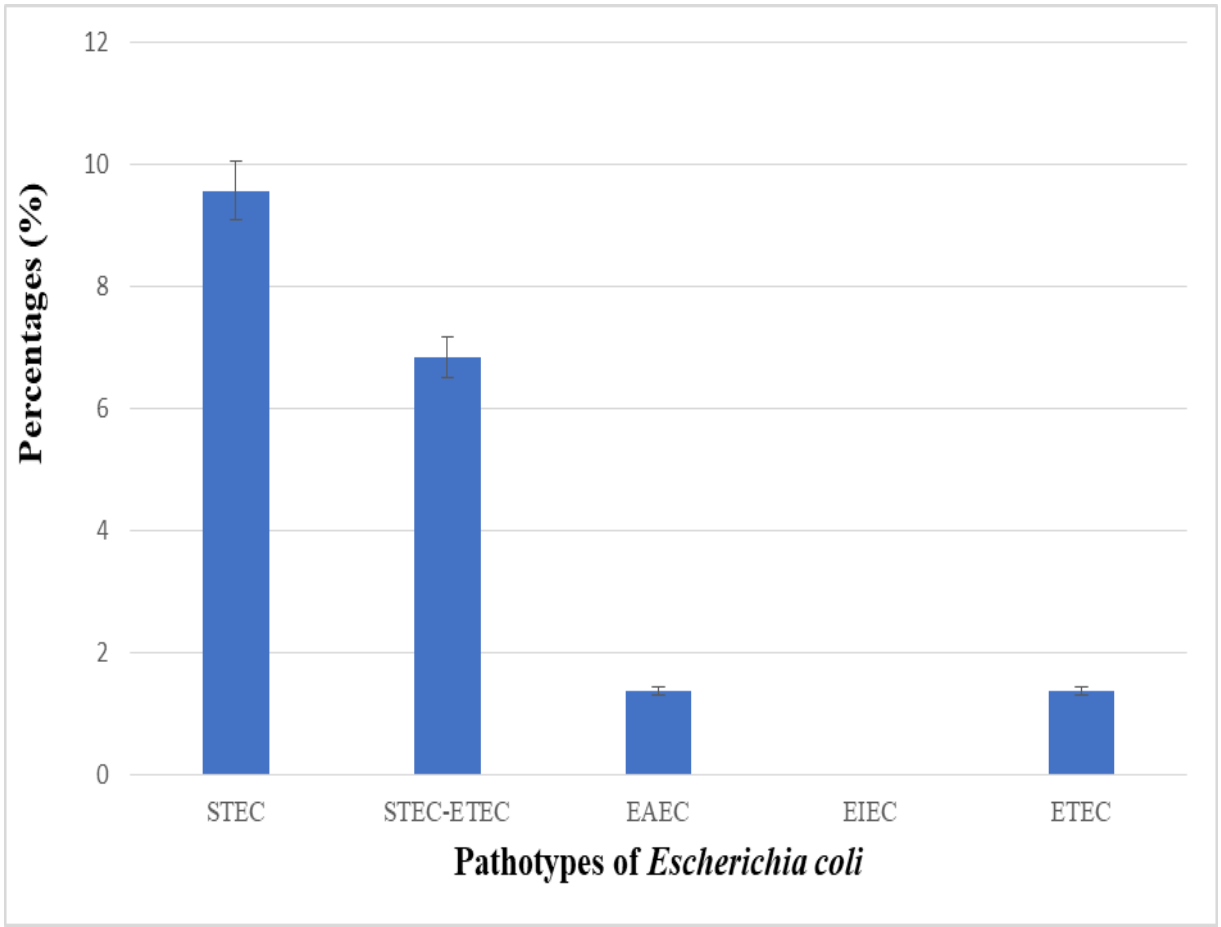


Figure.5 Prevalence of *Escherichia coli* pathovars



Caption: STEC = Shiga *toxin- Escherichia coli*; EAEC = enteroaggregative *Escherichia coli*; EIEC = enteroinvasive *Escherichia coli*; ETEC = enterotoxinogenic *Escherichia coli*

Table.4 Microbiological analysis data

Study area	Code	Thermotolerant coliforms CFU/g	Absence or presence of *Salmonella* sp. in 25g
Area 1 (N =15)	EZ1	$2.06 \times 10^{4} \pm 2.91 \times 10^{4a}$	Absence
Zone 2 (N =15)	EZ2	$3.39 \times 10^{4} \pm 3.72 \times 10^{4a}$	Absence
Zone 3 (N =15)	EZ3	$2.77 \times 10^{4} \pm 4.44 \times 10^{4a}$	Absence
Zone 4 (N =15)	EZ4	$9.88 \times 10^{4} \pm 3.06 \times 10^{5a}$	Presence
Zone 5 (N =15)	EZ5	$1.85 \times 10^{4} \pm 3.34 \times 10^{4a}$	Absence
Zone 6 (N =15)	EZ6	$2.64 \times 10^{4} \pm 4.26 \times 10^{4a}$	Absence
Zone 7 (N =15)	EZ7	$4.49 \times 10^{3} \pm 9.28 \times 10^{3a}$	Absence
Zone 8 (N =15)	EZ8	$1.18 \times 10^{4} \pm 2.88 \times 10^{4a}$	Absence
Zone 9 (N =15)	EZ9	$9.34 \times 10^{4} \pm 2.53 \times 10^{5}$	Presence
Zone 10 (N =15)	EZ10	$4.62 \times 10^{3} \pm 1.13 \times 10^{4}$	Presence
Mean ± SD		$3.40.10^{4} \pm 1.29.10^{5}$	3/150

P = 0.40 > 0.05; "a" in italics indicates that there is no significant difference (P = 0.40 > 0.05) between the coliform results according to zone.

Table.5 Sample compliance rate

Samples	Thermotolerant coliforms	*Salmonella* sp.
Satisfactory samples	97 (65%)	147 (98%)
Acceptable samples	2 (1%)	0 (00%)
Unsatisfactory samples	51 (34%)	3 (2%)

The high incidence of faecal contamination and opportunistic pathogens in grilled meat is not coincidental, but rather a direct consequence of critical stages in the artisanal process, including prolonged environmental exposure and post-cooking recontamination, which erode the sanitary barrier and transform a nutritious food into a potential vector for foodborne infections (Kafouris *et al.,* 2020). Other potential sources of contamination include raw ingredients (onions, chillies) often grown with manure that may contain pathogenic bacteria (Hiba-Ryma *et al.,* 2018).

The detection of thermotolerant coliforms is an indirect indicator of the potential presence of pathogens, particularly *Escherichia coli* (Atlabachew and Mamo, 2021). PCR analysis confirmed the presence of diarrhoeogenic *Escherichia coli* in nearly half of the samples (48.66% of strains), including significant pathovars such as STEC (9.58%) and STEC-ETEC (6.84%). Although these prevalences are lower than those reported in some studies in Dakar (Sambé-Ba *et al.,* 2013) with 66% STEC, they confirm a serious health threat.

The presence of *Salmonella* sp. was rare (3/150). This low prevalence is probably due to the lethal effect of the heat applied during grilling, which is more effective than simple drying against *Salmonella* bacteria (Kaboré *et al.,* 2018).

The interpretation of the results according to Decree No. 624-04 reveals contrasting levels of satisfaction: faecal coliforms: 65% of samples are considered satisfactory. This rate is similar to that reported by (Kaboré *et al.,* 2018) for cooked meat in Algeria (68.74%) but is lower than other studies conducted in Burkina Faso (Ilboudo *et al.,* 2010), with 93.33%. This relatively low satisfaction rate can be explained by poor handling and poor hygiene conditions observed at the points of sale (91% of sellers handle money, 84% do not wash their hands). With regard to *Salmonella* sp.: 98% of samples were satisfactory (no *Salmonella*), and 2% were confirmed Salmonella. This rate of presence is lower than in certain

studies carried out by other authors in Niger and Burkina Faso respectively (Sanda *et al.,* 2017; Douamba *et al.,* 2022) on other grilled products.

There is a notable contrast between the assessment of hygiene conditions at the sites and the microbiological results, with only 23% of sites deemed satisfactory in terms of hygiene. Regarding microbiological analyses, 65% satisfaction for coliforms and 98% for *Salmonella*.

This contrast can largely be attributed to the effect of heat. The grilling process, although carried out in unsanitary environments, includes initial cooking (bactericidal effect) and keeping the food warm near the flame, which maintains a temperature that is unfavourable to bacterial growth (Douamba *et al.,* 2022). In addition, cutting and reheating pieces of meat before serving them to customers helps to reduce the microbial load. Thus, the continuous use of heat explains why microbiological results may be better than what observations of poor hygiene practices suggest.

In conclusion, the study evaluating the microbiological quality of grilled meat in Ouagadougou highlighted a significant contrast between the very poor hygiene practices observed at the points of sale and the levels of contamination, which were partially reduced by the application of heat.

Risky practices: Failure to comply with Good Hygiene and Manufacturing Practices (GHMP) by stakeholders (lack of training, simultaneous handling of money and food, dirty equipment, unsuitable packaging) is a major public health concern and a constant source of post-cooking recontamination.

Analysis of the samples revealed high and variable thermotolerant coliform bacterial loads, far exceeding the criteria set out in Decree No. 624-04. These levels indicate high faecal contamination and expose consumers to a potential risk of foodborne infections.

The presence of *Escherichia coli* pathovars in nearly half of the isolated strains confirms this risk, despite the low proportion of *Salmonella* observed, probably due to the lethal effect of heat.

Despite its vital socio-economic role (generating resources, reducing unemployment), the current sanitary state of the street grilled meat sector is not sustainable without intervention.

Acknowledgements

We express our deep gratitude to all the individuals and institutions that made this work possible. We also thank all the butchers who contributed to this field study by providing us with all the information necessary to make this study useful. We also thank the International Science Foundation (FIS) for the funding granted to carry out this work.

Author Contributions

This work was carried out in collaboration with all the authors. Authors HBI, NO, YC and NB designed the study and wrote the article. Authors HBI, EB, MEMN, and AS collected the samples and performed the bacterial analysis of the samples, while MBIA performed the statistical analyses and contributed to the formatting of the final document. Authors HBI, NO, YC, and EB contributed to the writing of the manuscript. All authors read and approved the final manuscript.

Data Availability

The datasets generated and/or analysed during the present study are available from the corresponding author upon reasonable request.

Ethical approval

Informed consent from providers is required in accordance with local regulations, and all participants were asked to give their verbal consent.

Declaration of competing interests

The authors declare that they have no competing financial or personal interests that could influence the work presented in this article.

Declaration of conflicts of interest

The authors declare that they have no conflicts of interest with respect to the conduct of this study and the publication of this manuscript.

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How to cite this article:

Hadiza Bawa IBRAHIM, Nafissatou OUEDRAOGO, Chaibou YAOU, Evariste BAKO, Marguerite Edith Malatala NIKIEMA, Abdallah SAWADOGO, Mahamadou Bello ISSA ADAM and Nicolas BARRO. 2025. Evaluation of the Microbiological Quality of *Salmonella* and *Escherichia coli* Strains Isolated from Grilled Meat (Mutton/Beef) in the City of Ouagadougou, Burkina Faso. *Int.J.Curr.Microbiol.App.Sci.* 14(12): 61-74.
doi: https://doi.org/10.20546/ijcmas.2025.1412.006