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# *Hygiene Practices' Knowledge of Sales Staff and Microbiological Quality Assessment of Frozen Meat in Ouagadougou, Burkina Faso*

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***ABSTRACT***

**Background:** Meat is a vital source of nutrients essential for human health, but it can become a vector for diseases. System practices deficiencies, however, prevent consistent refrigeration safe storage in Ouagadougou. This situation can lead to hygiene lapses and microbiological contamination. Therefore, this study was performed to assess the current situation of frozen meats with the aim of encouraging a change in behavior in the event of lapses. **Methods:** Surveys were conducted at 10 sales sites to document hygiene practices, and samples were analyzed using microbiological standard methods. **Results:** Key findings revealed that 90% of samples exceeded the acceptable limit of $10^6$ CFU/g for total aerobic mesophilic flora, and 80% had thermotolerant coliforms above the permissible limit of $10^3$ CFU/g. Additionally, 90% of the samples were unsatisfactory for *Bacillus cereus* and *Staphylococcus aureus*, with significant differences ($P$=0.002); however, 40% of the samples tested positive for *Salmonella/Shigella*. Finally, surveys highlighted inadequate hygiene practices, including uncontrolled freezer temperatures (90%) and poor personal hygiene among sales staff (90%). The presence of pathogens such as *Staphylococcus aureus* and *Bacillus cereus* poses significant public health risks. **Conclusion:** This study revealed a high prevalence of meat by several pathogenic bacteria. Most people apply freezing to preserve meat but have poor knowledge of hygiene practices and do not control their freezer temperature during meat storage. This finding underscores the urgent need for strict hygiene training and regulatory oversight of preservation techniques to ensure the safety of frozen meat in Ouagadougou.

## Introduction

Meat supplies high-quality proteins and various nutrients (Leroy *et al.*, 2023). It is nutritionally and economically important in Burkina Faso, as the country ranks among the largest meat producers in West Africa (Food and Agriculture Organization, 2018). According to the

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performance indicators of livestock exports from Burkina Faso published in an evaluation of the development of integrated value chains in livestock, Burkina Faso processes 21,400 tons of meat compared to 10,200 tons that are exported each year (African Development Fund, 2023). This commodity is readily available to the population and is the most consumed source of protein.

But, preserving it safely requires functioning cold chains and proper hygienic slaughter and market practices. Practices of vendors suggest that Burkina Faso faces significant challenges regarding chilling infrastructure for meat preservation, food-safety gaps in informal markets, and energy/climate challenges and sales practices in its markets (Gemeda *et al.*, 2024, Muleta and Dida, 2025). These factors make frozen meat particularly susceptible to microbial contamination, posing a significant risk to public health. Microbial contamination of meat could be caused by species such as *Bacillus cereus*, *Staphylococcus* spp., *Salmonella/Shigella* spp., *Campylobacter jejuni*, *Listeria monocytogenes*, *Pseudomonas* spp., and thermotolerant coliforms like *Escherichia coli* (Gufe *et al.*, 2025, Morelli *et al.*, 2019). It is also mentioned in other studies that meat could be contaminated by hair, plant debris, pieces of glass, iron filings and sand due to agricultural practices and food management during processes or selling (Awuchi, 2023). These contaminants can also contribute to microbial strains dissemination in raw meat and meat products (Ali and Gujiba, 2024).

The consumption of contaminated meat can lead to outbreaks of foodborne illnesses such as salmonellosis, diarrhea, and staphylococcal food poisoning (Abebe BA *et al.*, 2020, Odetokun IA *et al.*, 2020, Shaltout S and Shaltout F, 2024). These illnesses contribute significantly to the healthcare burden in Burkina Faso, where access to medical care is already limited. Ensuring the microbiological safety of frozen meat is critical for protecting public health and reducing the prevalence of foodborne diseases in Ouagadougou.

Meat is rich in essential amino acids, particularly lysine and histidine (Hapsari and Tjandrawinata, 2025). It is also a valuable source of iron, vitamin B12, zinc, selenium and phosphorus (Bishnoi *et al.*, 2025). However, due to its exceptional nutritional qualities and high-water activity, meat is a highly perishable foodstuff. This environment could induce microbial proliferation when conditions become favorable. These microorganisms find all the nutrients they need to grow (Abou-Kassem *et al.*, 2025). They can come from the animal itself, but also from those involved in the processing chain if appropriate hygiene practices are not applied. In addition, poor meat preservation conditions contribute to a deterioration in organoleptic and nutritional quality and the spread of pathogens (Xu *et al.*, 2025).

Freezing is one of the most effective methods for preserving meat, as it inhibits the growth of spoilage and pathogenic microorganisms. However, the effectiveness of freezing depends on maintaining consistent temperatures below 0 °C, which can be challenging in regions with frequent power outages or insufficient refrigeration facilities. A low temperature (around 0 °C) is essential to reduce the rate of proliferation of microorganisms and to preserve the postmortem organoleptic properties of the meat. In contrary, the increasing of temperature causes proliferation of microorganisms and decomposition of proteins in meat due to microbial enzymes action (Comi and Iacumin, 2025, Lin *et al.*, 2022). Studies conducted on the topic from neighboring countries such as Ghana and Nigeria have documented high microbial loads in frozen meat due to poor hygiene practices and interrupted cold chains (Ghali-Mohammed I *et al.*, 2024, Louw, 2023). However, little is known about the microbiological quality of frozen meat sold in Burkina Faso, particularly in Ouagadougou, where consumption patterns and storage practices may differ. Previous research has focused largely on fresh meat or dried products, leaving a gap in understanding the risks associated with frozen meat, a preservation method that is increasingly being adopted in urban areas of sub-Saharan Africa (Henny *et al.*, 2022).

Poorly preserved meat can result in economic losses for those involved in processing and selling.



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Moreover, eating such meat can cause food poisoning and the transmission of zoonosis to consumers. In sub-Saharan Africa, the consumption of meat of poor hygienic quality is a major public health problem (Hissein AH *et al.*, 2023). To alleviate the problem of meat wastage and reduce the risk of contamination, the use of preservation methods has been proven be very important. People use several preservation techniques, including fermentation, freezing, drying, salting, and smoking. Drying and smoking are most commonly used in developing countries. Despite the growing use of freezing technology in Burkina Faso, its adoption is hindered by high electricity costs and limited access to reliable equipment. As a result, many vendors rely on aging or improperly maintained freezers, compromising the safety of the meat they sell. Although Burkina Faso has regulations in place to ensure food safety, enforcement remains inconsistent due to limited resources and a lack of regular inspections. Addressing these gaps is essential to improve meat safety standards in the country. This study aims to investigate hygiene practices and knowledge of sales staff with a focus on microbial pathogens load of frozen meat in Ouagadougou, Burkina Faso in order to identify critical points of contamination and proposing measures to improve food safety standards.

## Materials and Methods

### *Study design and site selection*

This study was conducted in Ouagadougou, Burkina Faso, and focused on frozen meat sold across 10 sales sites in various districts of the city. Sites were selected using a stratified random sampling approach to ensure representation from different socioeconomic and environmental categories. Criteria for site inclusion included active sale of frozen meat, availability of freezing equipment, and consent to participate in the study.

### *Survey design, conceptual framework and validation process*

First, a clear and precise research question guided the entire process. A conceptual framework, based on a thorough analysis of published research, was developed from the outset. This framework described the factors and variables for which there is evidence of association and included both independent and dependent variables. The conceptual framework also helped identify the variables to be collected. One of the steps in the preparatory phase was to clarify the objective of the research question. Clear research objectives are essential for collecting accurate and relevant data on the target population. Once the complete version of the questionnaire was finalized, it was reviewed by all team members and other colleagues; corrections were made, and then the questionnaire was shared with content experts, followed by pretesting with a representative group of the target population. This test led to further revisions of the questionnaire. Finally, field tests were conducted to validate the questionnaire before data collection (Metallinos-Katsaras and Beto, 2025).

### *Data collection on socio-demographic characteristics, meat preservation practices and hygiene*

Sampling was carried out over a two-month period to account for variations in supply and environmental conditions. Information on socio-demographic characteristics, preservation practices, and hygiene was collected at 10 frozen meat sales sites (named, site A to site J) using a questionnaire (supplementary material). In total, fifty agents in the chain (packaging and sales), including five per site, were surveyed. To preserve anonymity, the agents were named according to the site of activity (subject A1, ..., subject A5, subject B1, ..., subject B5, ..., subject J1, ... and subject J5 (additional material). These data were used to assess the quality of the sales sites and the knowledge and application of hygiene rules during sales activities.

### *Sampling frozen meat*

Sampling was carried out simultaneously with data collection. These activities took place at 10 frozen meat sales sites in the districts of the city of Ouagadougou. A total of 10 samples were collected for physicochemical and microbiological



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analysis. At each site, 250 g of frozen meat was collected in sterile conditions, ensuring minimal external contamination. Samples were then placed in pre-cooled containers with ice packs and transported immediately to the laboratory for microbiological analysis. Finally, Freezer temperatures at each site were measured using calibrated digital thermometers at the time of sample collection.

***Preparation of dilutions***

The stock solution and dilutions were prepared following (International Organization for Standardization, 2017). The stock solution was prepared by suspending 10 g of meat in 90 ml of physiological water under sterile conditions or 25 g of meat in 225 ml of buffered peptone water for Salmonella/Shigella testing. This concentration $10^{-1}$ solution was used to make decimal dilutions in cascade. For each of these dilutions, a volume of 1 ml of previously prepared suspension was taken and introduced into a tube containing 9 ml of physiological water.

***Enumeration and isolation of microorganisms***

Thus, the dilutions chosen, 100 µl of inoculum, homogenized by vortexing, were spread onto the agar plates using a Pasteur pipette in the form of a rake. An uninoculated plate was used as a negative control for each culture medium. The various microorganisms were counted on agar plates according to normative references in **Table 1**.

**Table 1.** Microorganisms enumerated or investigated, culture media and normative references.

| Microorganisms | Agars and culture broths used | References |
|---|---|---|
| Total aerobic mesophilic flora | Plate Count Agar | (International Organization for Standardization, 2013) |
| *Staphylococcus aureus* | Baird-Parker Agar | (International Organization for Standardization, 2021) |
| *Bacillus cereus* | *Bacillus cereus* Agar Mossel | (International Organization for Standardization, 2004) |
| *Pseudomonas* spp | *Pseudomonas* Agar P | (International Organization for Standardization, 2010) |
| Thermotolerant coliforms | Eosin Methylene Blue Agar | (International Organization for Standardization, 2017) |
| *Escherichia coli* | Eosin Methylene Blue Agar | (International Organization for Standardization, 2017) |
| *Salmonella/shigella* | Buffered peptone water, Rappaport Vassiliadis Broth, *Salmonella-Shigella* Agar | (International Organization for Standardization, 2017) |

***Expression of results***

The number N of colony-forming units (CFU) per gram of sample was calculated according to (International Organization for Standardization, 2004) . Petri dishes containing between 15 and 300 colonies were selected for enumeration of total aerobic mesophilic flora using the following formula:

$$N=\frac{\sum C}{V(n1+0{,}1n2)d}$$

Petri dishes containing between 3 and 150 colonies were selected for enumeration of thermo-tolerant coliforms, *Escherichia coli*, *Bacillus cereus*, *Pseudomonas* and *Staphylococcus aureus* using the following formula:

$$N=\frac{m}{V*d}$$

For Petri dishes containing no colonies, the following formula was used:

$$N<\frac{1}{d}$$

*Legend: N=number of microorganisms in CFU/g; V= volume of the inoculum spread in each box (in mL); n1= number of petri dishes retained at the 1st dilution; n2=number of petri dishes retained at the 2nd dilution; d= factor of the first dilution retained; ΣC=sum of colonies counted on all the plates retained from the two successive dilutions; m=arithmetic mean of colonies counted on the Petri dishes*

***Criteria for assessing the microbiological***



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***quality of samples***

The results of the different counts were interpreted following a three-class plan by combining several standards for total mesophilic aerobic flora, thermotolerant coliforms, *Escherichia coli*, *Pseudomonas* sp, *Bacillus cereus* and *Staphylococcus aureus* (**Table 2**). As for *Salmonella/Shigella*, two-class plan was used (absence or presence in 25 g).

**Table 2.** Criteria for interpreting the microbiological quality of samples **(UFC/g).**

| Quality | Satisfying | Acceptable | Unsatisfactory |
|---|---|---|---|
| Total mesophilic aerobic flora | $N < 10^6$ | $10^6 < N < 10^7$ | $N > 10^7$ |
| Thermotolerants coliforms | $N < 10^2$ | $10^2 < N < 10^3$ | $N > 10^3$ |
| *Escherichia coli* | $N < 10$ | $10 < N < 10^2$ | $N > 10^2$ |
| *Pseudomonas sp* | $N < 10^2$ | $10^2 < N < 10^3$ | $N > 10^3$ |
| *Bacillus cereus* | $N < 10^3$ | $10^3 < N < 10^4$ | $N > 10^4$ |
| *Staphylococcus aureus* | $N < 5.10^2$ | $5x10^2 < N < 5x10^3$ | $N > 5x10^3$ |

Sources: (Couture, 2019, Jouve., 1995)

***Ethical considerations***

Informed consent was obtained from all survey participants, and the study was approved by the scientific committee of Laboratory of Biochemistry and Applied Immunology, University of Joseph KI-ZERBO. Participation was voluntary, and all data were anonymized to protect the identities of participants.

**Data analysis**

Statistical analyses were performed using XLSTAT software version 2019. The means of variables such as TAMF, Thermotolerant coliforms, *E. coli*, *Bacillus cereus*, *Staphylococcus aureus*, *Pseudomonas* and *Salmonella/shigella* were compared using analysis of variance (ANOVA). A one-way ANOVA was conducted to assess the effect of hygiene practices and vendors' knowledge on the microbiological quality of frozen meat. The normality of residues was assessed using a normal distribution of the Shapiro-Wilk test. When the effect of the factor was significant (P-value<0.05), multiple comparisons were performed using the Tukey's Honestly Significant Difference test (Tukey's HSD). The Tukey's HSD tests allow to identify differences between groups. Means accompanied by 95% confidence intervals were reported with their standard deviations, and significant differences were interpreted according to the results generated by XLSTAT. This analytical approach ensures a rigorous and reproducible assessment of the variations observed between sampling sites. Finally, Sphinx Plus² V5 software was used to analyze data collected during the survey and distribute the subjects surveyed according to social characteristics.

## Results

***Socio-demographic characteristics of meat sellers***

**Table 3** shows the socio-demographic characteristics of the respondents. Generally speaking, the data obtained showed that the commercial activity of frozen meat in Ouagadougou is predominantly (90%) carried out by men. People aged over 40 predominate (40%) in the frozen meat packaging and sales chain. Over 90% of sales staff have more than 10 years of experience. Only 10% of those surveyed had higher education, and their experience in this activity was less than 5 years. **Figures 1** and **2** illustrate respectively the socio-demographic characteristics of the subjects surveyed by site and the distribution of these surveyed subjects according to their socio-demographic characteristics.



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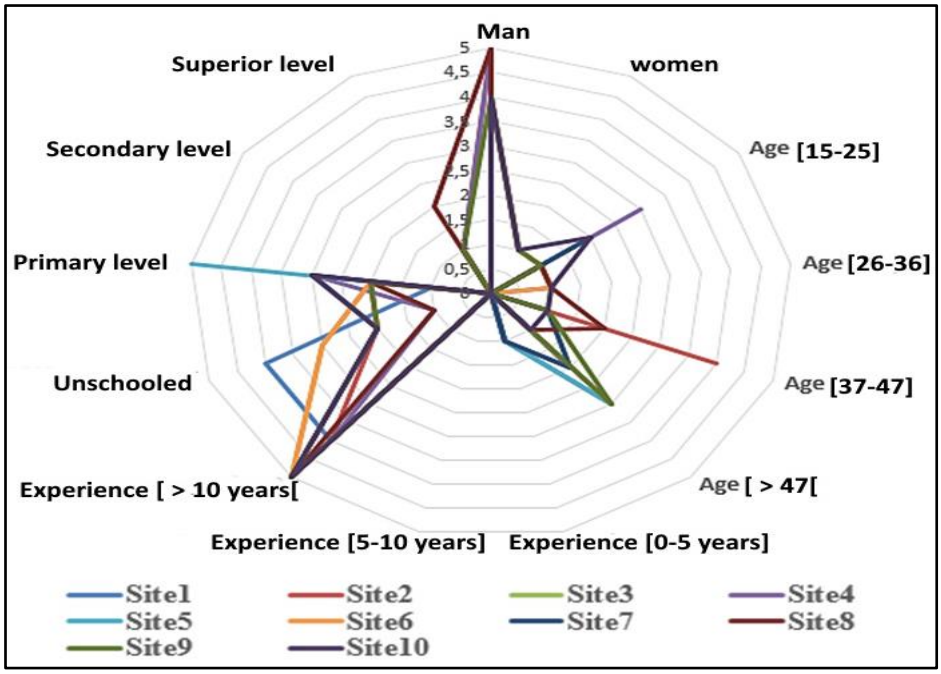


**Figure 1.** Sociodemographic characteristics of respondents.

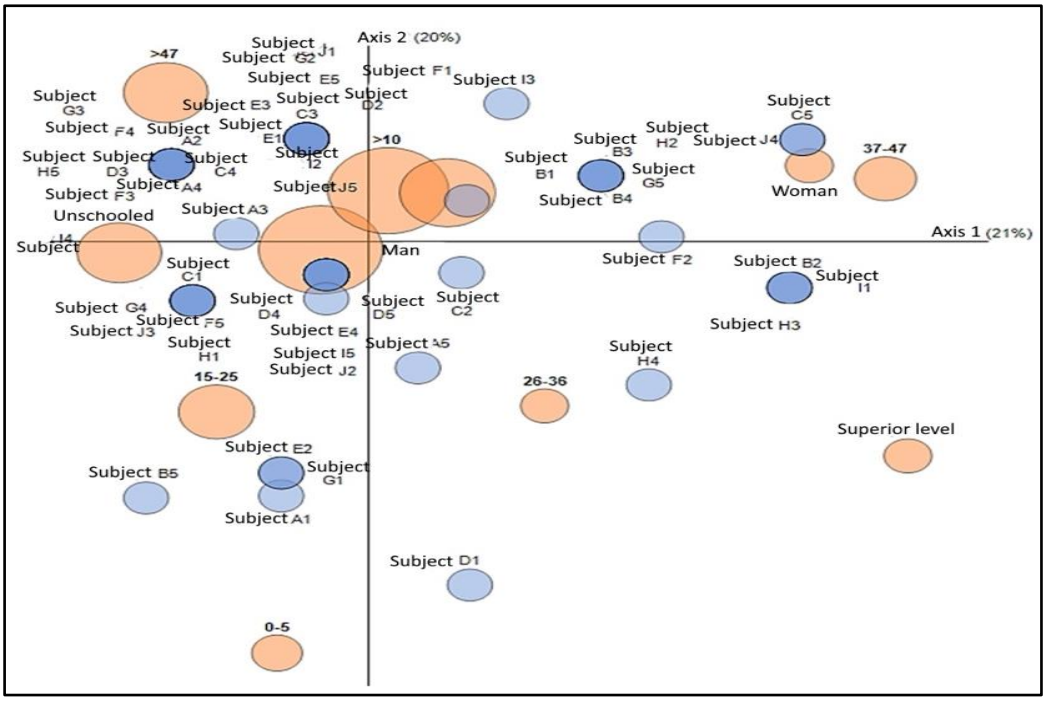


**Figure 2.** Distribution of respondents according to social characteristics

**Legend:** 0-5; 5-10 and >10 are time intervals of experience in the activity of selling and packing meat (in years), 15-25; 26-36; 37-47 and >47 were age groups of subjects surveyed; unschooled, primary, secondary and superior are levels of education of respondents.



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**Table 3.** Socio-demographic characteristics of frozen meat sellers.

| Variables | n | % |
|---|---|---|
| Sex | | |
| Man | 45 | 90 |
| Women | 5 | 10 |
| Age (year) | | |
| 15-25 | 15 | 30 |
| 26-36 | 5 | 10 |
| 37-47 | 10 | 20 |
| 47< | 20 | 40 |
| Years of experience | | |
| 0-5 | 5 | 10 |
| 5-10 | 0 | 0 |
| 10< | 45 | 90 |
| Education level of sellers | | |
| Unschooled | 20 | 40 |
| Primary | 25 | 50 |
| Secondary | 0 | 0 |
| Superior | 5 | 10 |

**Knowledge of good sales hygiene practices**

**Table 4** presents the aspects of good hygiene practices and the state of meat sales outlets. The results of the surveys showed that sellers of frozen meat are supplied by three abattoirs in the city of Ouagadougou. Around 80% of meat sellers obtain their supplies from the refrigerated abattoir at Kossodo. Most meat is transported by motorbike. At the sales outlets, health checks are carried out once a year (80% of respondents). In addition to the fact that inspections are rarely carried out by the authorities, almost 90% of sellers have no training in good hygiene practices in the sale of fresh and frozen meat. Half of those surveyed pack and sell their meat in roofed sheds. Around 60% of these premises had an acceptable level of hygiene. Working equipment was also found to be 60% acceptable from a hygiene point of view. However, the surveys reported no satisfactory results for the hygiene of the sales premises and equipment. Only 10% of sales staff reported acceptable personal hygiene and clothing. Meat is handled without gloves during weighing and packaging. However, sales staff do not handle money or telephones during this activity. Nearly 70% of meat sales outlets are close to open gutters that drain household wastewater. **Figure 3** illustrates the distribution of sales sites according to the hygiene parameters of the sales premises and the training received in good hygiene practices. The subjects surveyed at site 8 had received training in meat handling hygiene and in good hygiene practices. However, staff at the other 9 sites had received neither training in meat handling hygiene nor in good hygiene practices.

**Table 4.** Status reports and hygiene aspects.

| Variables | Modalities | n | % |
|---|---|---|---|
| Place of origin of the meat | Kossodo Slaughterhouse | 8 | 80 |
| | Pabré slaughterhouse | 1 | 10 |
| | Saaba slaughterhouse | 1 | 10 |
| Frequency of health checks of staff | Every 3 months | 0 | 0 |
| | Every 6 months | 1 | 10 |
| | Annually | 8 | 80 |
| | In case of illness | 1 | 10 |
| Place of slaughter | Kossodo | 8 | 80 |
| | Pabré | 1 | 10 |
| | Saaba | 1 | 10 |
| Meat handling hygiene training | Yes | 1 | 10 |
| | No | 9 | 90 |
| Slaughter time of an animal whose meat is to be sold tomorrow | 00h-5h | 10 | 100 |
| Meat preservation methods known to sellers | Freezing | 8 | 80 |
| | Freezing and salting | 1 | 10 |
| | Freezing and smoking | 1 | |



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| | | | |
|---|---|---|---|
| Means of preservation available to sellers | Freezer | 10 | 100 |
| Freezer temperature | Uncontrolled | 9 | 90 |
| | Temperature at 6 °C | 1 | 10 |
| Inventory of sale | Roof shed | 5 | 50 |
| | House | 5 | 50 |
| State of cleanliness of the environment[a] | Clean | 0 | 0 |
| | Acceptable | 6 | 60 |
| | Limited cleanliness | 3 | 30 |
| | Limited cleanliness and presence of cobwebs | 1 | 10 |
| State of the meat cutting table | Clean | 0 | 0 |
| | Acceptable | 5 | 50 |
| | Limited cleanliness | 5 | 50 |
| Meat display condition with change in color | Yes | 1 | 10 |
| | No | 9 | 90 |
| Meat vendors' attire | Clean | 0 | 0 |
| | Acceptable | 1 | 10 |
| | Limited cleanliness | 9 | 90 |
| Work equipment | Clean | 0 | 0 |
| | Acceptable | 6 | 60 |
| | Limited cleanliness | 4 | 40 |
| Seller's cleanliness status | Uncovered hair | 8 | 80 |
| | Dirty and uncut nails | 0 | 0 |
| | Limited cleanliness of hands | 2 | 20 |
| Presence of insects (flies, spiders, ants) | Yes | 8 | 80 |
| | No | 2 | 20 |
| Handling money or phones while cutting meat | Yes | 0 | 0 |
| | No | 10 | 100 |
| Handling meat with your hands | Without glove | 10 | 100 |
| | With glove | 0 | 0 |
| Presence of stray animals and birds | Cat | 4 | 40 |
| | Dog | 3 | 30 |
| | Chickens | 2 | 20 |
| | More than two | 1 | 10 |
| Presence of puddle of water near the place of sale | Yes | 1 | 10 |
| | No | 9 | 90 |
| Presence of gutters | Yes | 7 | 70 |
| | No | 3 | 30 |
| Knowledge of good hygiene practices | Yes | 1 | 10 |
| | No | 9 | 90 |
| Training on good hygiene practices | Yes | 1 | 10 |
| | No | 9 | 90 |

*[a]: The cleanliness of the environment was assessed using a scale. A score was assigned to each level of the scale. Score 1=clean (no soiling or only a few traces), score 2=acceptable (some soiling present but limited), score 3=limited cleanliness (significant soiling, covering some areas), score 4=limited cleanliness with cobwebs (thick soiling and cobwebs present). The state of the meat cutting table, the vendor's attire, and the state of the work equipment were assessed using a scale with three separate levels associated with one score. Score 1=clean (no soiling), score 2=acceptable (some soiling present but limited), score 3=limited cleanliness (significant soiling).*



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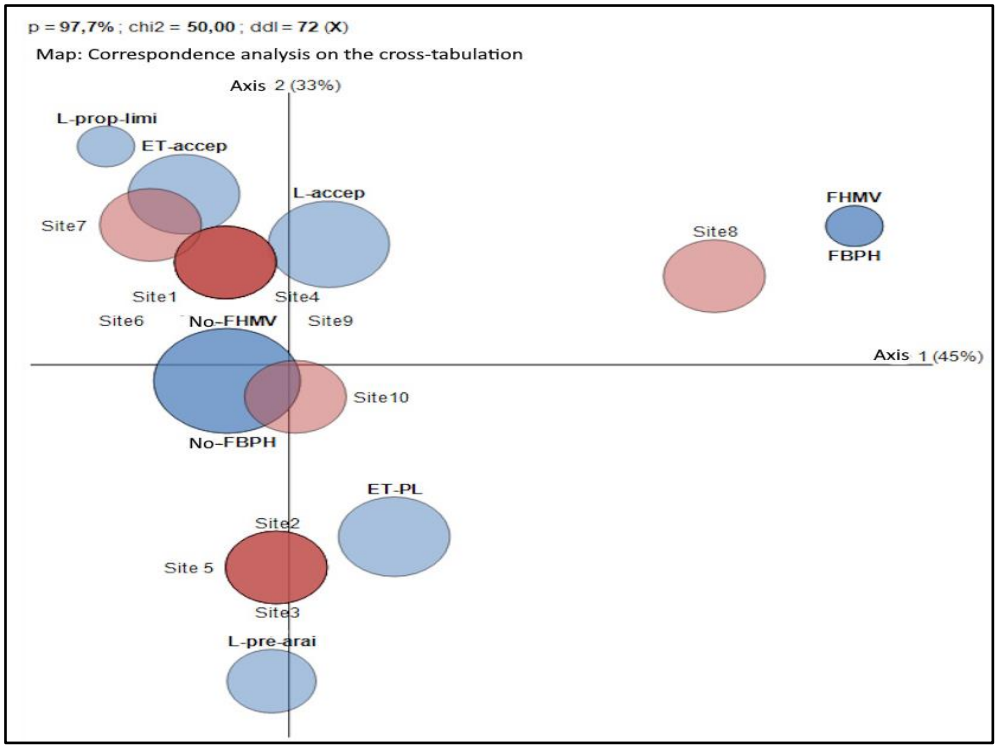


**Figure 3.** Distribution of sales sites according to hygienic characteristics.

**Legend:** L-pre-arai: state of cleanliness of environment (limited cleanliness and presence of cobwebs); L-pro-limi: state of cleanliness of environment (limited cleanliness); L-accep: state of cleanliness of environment (acceptable); ET-accep: state of meat cutting table (acceptable); ET-PL: state of meat cutting table (limited cleanliness); No-FBPH: site whose subjects have not received training in good hygiene practices; FBPH: sites whose subjects have received training in good hygiene practices; No-FHMB: sites whose subjects have not received training in meat handling hygiene; FHMB: sites whose subjects have received training in meat handling hygiene.

**Microbiological characteristics of frozen meats**

The microorganism loads sought in the frozen meat samples analyzed are recorded in **Table 5**. As for **Figure 4**, it summarizes the assessments of the microbiological quality of each sample analyzed according to the interpretation criteria. Total mesophilic aerobic flora loads of the frozen meat analyzed in this study varied from $9.00\pm1.00x10^6$ CFU/g to $8.67\pm3.75x10^8$ CFU/g. All the samples analyzed were unsatisfactory for the Total aerobic mesophilic flora (TAMF). The thermotolerant coliform and *E. coli* loads varied respectively from less than 10 CFU/g to $2.75\pm2.25x10^5$ CFU/g and from less than 10 CFU/g to $5.20\pm0.00x10^4$ CFU/g with significant differences ($P<0.05$). The samples analyzed were 80% unsatisfactory and 50% satisfactory for thermotolerant coliforms and *E. coli* respectively. *Bacillus cereus* loads varied from less than 10 CFU/g (E2) to $2.62\pm1.19x10^6$ CFU/g (E9) with 90% of the samples analyzed being unsatisfactory and significant differences ($P=0.002$). *Staphylococcus aureus* loads varied from $5.00\pm0.00x10^3$ CFU/g (E6) to $8.36\pm6.84x10^6$ CFU/g (E9) with 90% of the samples being unsatisfactory. *Pseudomonas* loads were less than 10 CFU/g of the frozen meats analyzed with 100% satisfactory quality for this parameter. Frozen meat analyses revealed the presence of *Salmonella-Shigella* with 40% of non-satisfaction. As for the total quality taking into account all the parameters studied, all the samples were of unsatisfactory microbiological quality.



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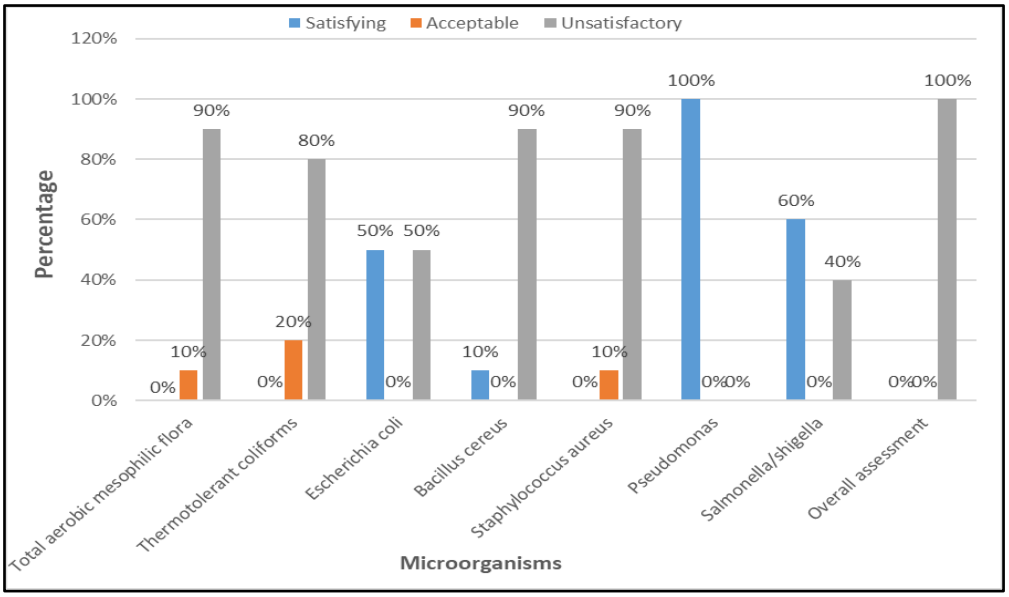


**Figure 4.** Assessments of the quality of samples analyzed according to parameters studied

**Table 5.** Microorganism load of frozen meat analyzed in CFU/g*.

| Samples of site | TAMF | Thermotolerant coliforms | *E. coli* | *Bacillus cereus* | *Staphylococcus aureus* | *Pseudomonas* | *Salmonella/ shigella* |
|---|---|---|---|---|---|---|---|
| Site 1 | $3.80\pm2.20x10^{7a}$ | $1.46\pm0.06x10^{5ab}$ | $2.07\pm0.89x10^{4b}$ | $7.15\pm4.85x10^{5ab}$ | $4.00\pm0.0x10^{5a}$ | < 10 | Presence |
| Site 2 | $2.03\pm1.28x10^{8a}$ | < 10 | < 10 | < 10 | $2.57\pm1.03x10^{6ab}$ | < 10 | Presence |
| Site 3 | $7.70\pm4.30x10^{7a}$ | < 10 | < 10 | $9.80\pm7.20x10^{5ab}$ | $1.00\pm0.00x10^{5a}$ | < 10 | Absence |
| Site 4 | $4.05\pm2.95x10^{7a}$ | $1.55\pm0.55x10^{4ab}$ | < 10 | $1.79\pm1.32x10^{6ab}$ | $1.22\pm0.32x10^{6ab}$ | < 10 | Absence |
| Site 5 | $3.45\pm2.55x10^{7a}$ | $3.00\pm0.00x10^{3a}$ | < 10 | $7.50\pm0.00x10^{4a}$ | $5.50\pm2.50x10^{5a}$ | < 10 | Absence |
| Site 6 | $2.85\pm2.15x10^{7a}$ | $5.50\pm0.00x10^{3a}$ | $5.00\pm0.00x10^{2a}$ | $1.50\pm0.00x10^{4a}$ | $5.00\pm0.00x10^{3a}$ | < 10 | Absence |
| Site 7 | $8.67\pm3.75x10^{8b}$ | $2.05\pm1.65x10^{5ab}$ | $< 10^{a}$ | $2.18\pm0.82x10^{6ab}$ | $7.28\pm4.32x10^{6ab}$ | < 10 | Absence |
| Site 8 | $1.70\pm1.30x10^{7a}$ | $1.08\pm0.82x10^{5ab}$ | $5.00\pm1.73x10^{3a}$ | $2.65\pm0.35x10^{5ab}$ | $4.00\pm0.00x10^{4a}$ | < 10 | Absence |
| Site 9 | $3.19\pm2.51x10^{8a}$ | $8.30\pm0.00x10^{4ab}$ | $5.20\pm0.00x10^{4c}$ | $2.62\pm1.19x10^{6b}$ | $8.36\pm6.84x10^{6b}$ | < 10 | Presence |
| Site 10 | $9.00\pm1.00x10^{6a}$ | $2.75\pm2.25x10^{5b}$ | $2.00\pm0.00x10^{3a}$ | $2.25\pm1.46x10^{6ab}$ | $4.35\pm1.85x10^{5a}$ | < 10 | Presence |
| *P-value** | *<0.0001* | *0.01* | *<0.0001* | *0.002* | *0.003* | - | - |

**: ANOVA by using Tukey's HSD tests; In the same column, values with the same letters in superscript are not significantly different according to ANOVA by using Tukey's HSD tests at a significance level of p=0.05.;* ***TAMF****: Total mesophilic aerobic flora.*

## Discussion

The findings of this study align with the study's primary objective of evaluating the storage conditions and microbiological quality of frozen meat sold in Ouagadougou. The high levels of contamination observed, particularly with pathogens such as *Salmonella/Shigella*, *Escherichia coli*, *Staphylococcus aureus*, and *Bacillus cereus*, underline the significant public health risks associated with improper preservation and inadequate hygiene practices. The data suggest that poor hygiene, uncontrolled freezer temperatures, and improper handling of meat contribute substantially to the microbial contamination observed in the frozen meat sold across the city.

### *Public health implications*

The presence of pathogens like *Salmonella* and *E. coli* in 40% of samples poses a direct risk to consumers, potentially leading to outbreaks of foodborne illnesses, such as gastrointestinal infections and food poisoning. These pathogens are commonly associated with fecal contamination, which may occur during slaughter or meat handling. *Staphylococcus aureus*, identified in



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90% of the samples, is of particular concern due to its ability to produce toxins that cause severe foodborne illness. In contrast to the findings, Adzitey reported only 40% *S. aureus* contamination in Ghana, suggesting possible regional differences in meat hygiene enforcement (Adzitey *et al.*, 2018). The widespread contamination highlights the urgent need for improved hygiene practices among meat vendors and better control over storage conditions. As for the loads of potential pathogens of frozen meat such as thermotolerant coliforms in the samples analyzed, 20% were of satisfactory quality and 80% were of unsatisfactory quality for the load of thermotolerant coliforms. For the loads of *Escherichia. coli* regarding the samples analyzed, 50% were of satisfactory quality and 50% of unsatisfactory quality according to a study (Jouve, 1995) . These bacteria could come from the liquids or excrement of the digestive tract of animals during evisceration (Manyi-Loh and Lues, 2023). Thus, only 10% of the samples were of satisfactory quality and 90% of unsatisfactory quality according to a study (Jouve, 1995) for *Bacillus cereus* loads. The presence of *Bacillus cereus* could be explained by a failure to comply with good hygiene practices. Indeed, *Bacillus cereus* spores are present in the digestive tract of warm-blooded animals and the air, and can thus contaminate meat during evisceration or transport. This study also highlighted the presence of *Staphylococcus aureus* strains in the contamination of frozen meat. These results show that the meat samples studied are of unsatisfactory quality according to the study by Couture (Couture, 2019). In addition, the presence of *Staphylococcus aureus* is worrying because they are one of the main producers of toxins during foodborne illnesses (Manyi-Loh and Lues, 2023). The consumption of these meats exposes customers to the risk of foodborne illness and chronic diarrhea. Indeed, *Salmonella* sp. strains are agents responsible for severe diarrhea in Burkina Faso and Africa (Bonkoungou *et al.*, 2013, Lamuka *et al.*, 2015, Paudyal *et al.*, 2017, Somda *et al.*, 2021, Traoré *et al.*, 2014). *Salmonella* are present in some samples, and most other microorganisms were often present with loads exceeding the reference values. Given the high contamination rates observed, it is evident that the current practices are insufficient to ensure the safety of frozen meat. This underscores the need for urgent interventions in both public health and meat industry regulations. The significant health risks associated with these microbial contaminants could contribute to a higher burden of foodborne diseases in Burkina Faso, where healthcare infrastructure is already under strain. Addressing these issues is critical not only to protect consumers but also to reduce the economic impact of illness-related absenteeism and healthcare costs. However, these observations cannot be generalized. The study was conducted in an urban area and did not take seasonality into account; therefore, its conclusions cannot be extended to the whole of Burkina Faso. Documented work by several researchers has already demonstrated the impact of seasons, sample size, and sampling area on the dynamics of microorganisms. These factors would have been helpful to improve this study and would be considered for virulence genes and identifying targeted bacteria.

***Policy, Infrastructure, and Hygiene Training***

A major finding of this study is the lack of proper hygiene training for meat vendors, with nearly 90% of vendors reporting no formal education in good hygiene practices. This lack of training contributes to improper handling and contamination of the meat. To mitigate these risks, it is essential that authorities implement mandatory hygiene training programs for all individuals involved in meat packaging and sales. Furthermore, regular inspections should be instituted to ensure compliance with hygiene standards, and stricter penalties should be enforced for violations. In terms of infrastructure, the study found that 90% of the freezers used by meat vendors did not have their temperatures controlled, which is a critical failure in maintaining safe storage conditions. Many vendors rely on outdated or poorly maintained refrigeration systems, which



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exacerbates the risk of microbial contamination. Local governments and meat industry should prioritize the development of affordable, reliable refrigeration systems and enforce regulations to maintain appropriate storage temperatures. Financial support or subsidies for vendors to improve freezing infrastructure could be a potential solution, particularly in urban areas where electricity access can be unreliable. The actors in meat sales and packaging chain are mainly subjects with more than 10 years of experience with a primary school education, or they are uneducated. Indeed, most of these meat packaging and sales units are managed by members of the same family. Thus, many find themselves very young in the commercial activities of the family. The latter, generally unable to combine school activities and the commercial activities of the family, no longer attend or abandon their studies very quickly. With a high percentage of actors and low levels of education and a scarcity of hygiene service checks, good hygiene practices are unknown to respondents, *i.e.* 90%. Similarly, it was reported the lack of knowledge of good hygiene practices among chicken meat sellers in the city of Ouagadougou (Assefa *et al.*, 2023, Somda *et al.*, 2021).

**Cultural and socioeconomic factors**

The socio-demographic characteristics of the vendors, predominantly male with low levels of education, suggest that cultural and socioeconomic factors may play a role in shaping the current practices. Many of these vendors may lack awareness of food safety protocols due to limited education or access to training resources. This study reported that 10% of the agents in the meat and frozen food packaging and sales process are female. This low representation of the female sex could be explained by the fact that, traditionally, the sale of fresh meat in Africa was essentially known as a male activity. The involvement of women in this activity does not result from a defiance of traditions, but rather represents an accompaniment to the development of family businesses and the promotion of gender. Similar observations were reported by studies (Hissein AH *et al.*, 2023, Ouédraogo, 2022), respectively in Burkina Faso and Chad. Addressing these gaps through targeted outreach and education programs is essential. For example, integrating food safety training into vocational education or providing accessible training programs in local languages could improve participation and effectiveness. The lack of knowledge of good hygiene practices appears to be general in meat and other meat product sales units in Ouagadougou. This finding has also been reported in several investigations in Africa in animal meat sales and packaging units (Adzitey *et al.*, 2018, Gutema *et al.*, 2021, Manyi-Loh and Lues, 2023, Ogundele *et al.*, 2022). Due to the high number of stakeholders who do not know good hygiene practices, an assessment of health quality of the meats sold on the sites was carried out. Additionally, the high cost of electricity and refrigeration in Burkina Faso remains a significant challenge. Freezing is a common preservation method, but its reliance on electricity makes it vulnerable to interruptions in power supply. Considering the high costs of maintaining refrigeration, alternatives or supplementary preservation methods, such as solar-powered refrigeration or community-based cooling systems, could be explored to improve food safety in the long term.

**Environmental and transport factors**

The study also highlighted the presence of environmental factors that may contribute to contamination, such as vendors operating in proximity to open gutters, which increases the likelihood of cross-contamination. Future studies should investigate these environmental conditions in greater detail and consider ways to mitigate their impact on food safety by improving the infrastructure of meat-selling locations and providing better sanitation. Thus, concerning the total mesophilic aerobic flora loads of the frozen meats analyzed, 90% of the samples were of unsatisfactory microbiological quality in this study. Two studies also reported TAMF loads of $1.66x10^8$ CFU/g and $1.70x10^9$ CFU/g respectively



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in fresh minced pork and beef sold from the city of Ouagadougou (Ilboudo *et al.*, 2016, Kabore *et al.*, 2018). These results reveal a low variation in the TAMF load in fresh slaughter meats compared to that of frozen meats sold in Ouagadougou. Microbial contaminants are probably brought from the slaughterhouse and during transport. Freezing has a bacteriostatic but bactericidal effect. Furthermore, transportation conditions were not directly examined in this study but may also contribute to contamination. Meat vendors often transport meat using motorbikes without adequate protection, which may expose the meat to temperature fluctuations and contamination from unsanitary surfaces. It would be beneficial to study the impact of transportation conditions on meat safety and implement guidelines for safe transportation practices.

***Comparative analysis and broader implications***

While this study is focused on Ouagadougou, its findings are likely not unique to this city. Similar challenges in meat preservation and hygiene are likely present in other urban areas of sub-Saharan Africa, where infrastructure and regulations often fall short. Comparative studies with other regions in Burkina Faso or neighboring countries could provide a broader understanding of the scale of the problem and inform region-specific interventions. These studies could also help identify common patterns in microbial contamination and hygiene practices, providing valuable data for regional health policy development.

This study provides important insights into the health risks associated with frozen meat sold in Ouagadougou and underscores the urgent need for improvements in hygiene, training, and infrastructure. The public health risks posed by microbial contamination highlight the need for coordinated efforts from government agencies, meat industry, and local communities to ensure food safety and protect public health.

Despite the valuable results provided by this study, several limitations should be considered when interpreting them. First, the sample size of 10 sales sites is relatively small, which may limit the generalizability of the findings to the broader meat-selling sector in Ouagadougou or Burkina Faso. The study's focus on a single urban area also restricts its applicability to rural regions or other cities with different environmental or socioeconomic conditions. Also, the study did not account for seasonal variations or other temporal factors that could influence microbial contamination, such as changes in temperature, humidity, or meat supply. Environmental factors, such as the presence of open gutters near sales sites, were noted but not systematically analyzed; this may have further contributed to contamination. The lack of a detailed analysis of carcasses transportation conditions and duration of meat storage before selling, which could also impact meat safety, was another limitation.

## Conclusion

This work revealed that several preservation technologies are used by sellers to preserve frozen meat. Freezing is the most commonly used method but it is not well mastered. Study also revealed that vendors do not control temperature when using freezer. This can explain the fact that most of the meat analyzed was contaminated by thermotolerant coliforms, *E. coli*, *Bacillus cereus*, and *Staphylococcus aureus* with a few samples contaminated by *Salmonella/Shigella*. The absence of *Pseudomonas* sp. in the frozen meats' samples may be associated with the absence of initial contamination or with good handling of carcasses after slaughter. These results suggest that there is a need to adhere to good hygiene practices to help decrease the prevalence of these microbial pathogens in frozen meat. Furthermore, seasonality, sampling size, antibiotics susceptibility and virulence genes of targeted bacteria in various meat system selling should be taken into account in future studies to improve the findings of this study. This research provided a first line data for assessing microbiological quality of frozen meat in Central region of Burkina Faso.

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## Authors' contributions

Cissé H was responsible for conception and design of the study. Cissé H, Kouhounde SHS, Ouédraogo GA, Savadogo K and Badoum ES analyzed and interpreted the data. Cissé H, Ouédraogo GA and Savadogo K drafted the article. Kouhounde SHS, Badoum ES, Sawadogo A, Odetokun IA and Iboudo AJ revised the draft of the article critically for important intellectual content. Sawadogo A, Zongo C, Iboudo AJ and Savadogo A supervised, approved, and reviewed the final version of the manuscript. All authors approved the final version of the manuscript.

## Conflict of interests

The authors declared no competing interests.

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## References

**Abebe BA, Jones KW, Solomon J, Galvin K & P. E** 2020. Examining social equity in community-based conservation programs: A case study of controlled hunting programs in Bale Mountains, Ethiopia. *World development.* **135**: 105066.

**Abou-Kassem DE, et al.** 2025. Growth performance, carcass traits, meat composition, digestibility coefficients and caecal microbiota of growing rabbits fed diets supplemented with a herbal mixture. *Tropical animal health and production.* **57 (1)**: 22.

**Adzitey F, Wachiebine Sulleyman K & Serbeh Mensah S** 2018. Knowledge and practices of meat safety by meat sellers in the Kumasi Metropolis of Ghana. *Journal of food science and technology.* **7 (2)**: 34-41.

**African Development Fund** 2023. Part of the African Development Bank Group (AfDB), contributes to poverty reduction in its member countries by spurring sustainable economic development and social progress. https://www. interaction.org/ choose-to-invest-fy-2024/ development/african-development-fund

**Ali AF & Gujiba UK** 2024. Household wastewater management in sub-Saharan Africa: a review. *Discover water.* **4 (1)**: 6.

**Assefa A, et al.** 2023. Quantitative analysis of knowledge, attitude and practice of workers in chicken slaughter slabs toward food safety and hygiene in Ouagadougou, Burkina Faso. *Frontiers in sustainable food systems.* **6**: 1091209.

**Awuchi CG** 2023. HACCP, quality, and food safety management in food and agricultural systems. *Cogent food & agriculture.* **9 (1)**: 2176280.

**Bishnoi S, Jairath G, Rani M, Yadav S & Kumar P** 2025. Meat products enriched with micronutrients. In *Healthier Meat Products*, pp. 247-265. Springer.

**Bonkoungou I, et al.** 2013. Bacterial and viral etiology of childhood diarrhea in Ouagadougou, Burkina Faso. *BMC Pediatrics.* **13 (1)**: 1–6.

**Comi G & Iacumin L** 2025. Spoilage of meat and fish. In *The microbiological quality of food* (ed. A. Bevilacqua, M. Rosaria Corbo and M. Sinigaglia), pp. 221-248. Elsevier.

**Couture G** 2019. Lignes directrices et normes pour l'interprétation des résultats analytiques en microbiologie alimentaire.

**Food and Agriculture Organization** 2018. Food and agriculture organization of the United Nations. Rome.

**Gemeda BA, et al.** 2024. Food safety and hygiene knowledge, attitudes and practices in street restaurants selling chicken in Ouagadougou, Burkina Faso. *Frontiers in sustainable food systems.* **8**: 1448127.

**Ghali-Mohammed I, et al.** 2024. Food safety knowledge and attitudes among fish vendors in informal markets in Ilorin, Nigeria: a cross-sectional study. *Discover food.* **4 (161)**.

**Gufe C, et al.** 2025. A review on the occurrence of antibiotic-resistant bacteria found in abattoir effluent from resource-limited settings: The necessity of a robust One Health framework. *Sustainable environment.* **11 (1)**: 2464419.

**Gutema F, et al.** 2021. Assessment of hygienic practices in beef cattle slaughterhouses and retail shops in Bishoftu, Ethiopia: Implications for public health. *International journal of*



[ DOI: 10.18502/jnfs.v11i2.21434 ]

*environmental research and pblic health.* **18 (5)**.

**Hapsari R & Tjandrawinata R** 2025. Nutritional composition and action mechanism of Channa striata meat in wound healing: A systematic review. *Narra journal.* **5 (3)**: e2903-e2903.

**Henny S, et al.** 2022. Factors affecting the knowledge and motivation of health cadres in stunting prevention among children in Indonesia. *Journal of multidisciplinary healthcare*. **15**: 1069-1082.

**Hissein AH, et al.** 2023. Production and microbial quality of "charmout", a dried meat produced in Chad. *American journal of food science and technology*. **11**: 1-7.

**Ilboudo J, Savadogo A, Samandoulougou S, Seydi M & AS T** 2016. Bacteriological quality of pork and beef carcasses produced at the Ouagadougou slaughterhouse, Burkina Faso. *Journal of industrial, sanitary and environmental microbiology*. **10 (1)**: 33-55.

**International Organization for Standardization** 2004. Food microbiology - Horizontal method for the enumeration of presumptive Bacillus cereus - Colony counting technique at 30°C.

**International Organization for Standardization** 2010. Meat and meat products - Presumptive Pseudomonas spp. enumeration.

**International Organization for Standardization** 2013. Microbiology of the food chain - Horizontal method for the enumeration of microorganisms - Part 2: Colony counting at 30 °C by the surface plating technique.

**International Organization for Standardization** 2017. Microbiology of the food chain- Preparation of test samples, initial suspension and decimal dilutions for microbiological examination- Part 1: General rules for the preparation of the initial suspension and decimal dilutions.

**International Organization for Standardization** 2021. Microbiology of the food chain - Horizontal method for the enumeration of coagulase-positive staphylococci (Staphylococcus aureus and other species) - Part 1: Method using Baird-Parker agar.

**Jouve X** 1995. Microbiological quality of food / control and criteria, control and criteria - National Coordination Centre for Studies and Research on Nutrition and Food, Commission for the Evaluation of Microbiological Quality of Food. In Polytechnica Sa, editor. 978th-2nd-84054th-040–3rd ed.

**Kabore D, et al.** 2018. Microbial quality of fresh and grilled beef sold at several outlets in Ouagadougou, Burkina Faso. *Natural and applied sciences.* **34**: 147–156.

**Lamuka P, Chepkemoi S, Abong G & Matofari J** 2015. Sanitation and hygiene meat handling practices in small and medium enterprise butcheries in Kenya - case study of nairobi and isiolo counties. *Internet journal of food safety*,. **15**: 64-74.

**Leroy F, et al.** 2023. The role of meat in the human diet: evolutionary aspects and nutritional value. *Animal frontiers.* **13 (2)**: 11-18.

**Lin Q, et al.** 2022. Protein digestibility of textured-wheat-protein (TWP)-based meat analogues:(I) Effects of fibrous structure. *Food hydrocolloids.* **130**: 107694.

**Louw C** 2023. Feasibility assessment of biogas-fuelled refrigeration to curb spoilage in food value chains in Sub-Saharan Africa.

**Manyi-Loh C & Lues R** 2023. A South African Perspective on the Microbiological and Chemical Quality of Meat: Plausible Public Health Implications. *Microorganisms.* **11**: 2484.

**Metallinos-Katsaras E & Beto J** 2025. Survey methodology for data collection and analysis in nutrition and dietetics research. *Journal of the Academy of Nutrition and Dietetics.* **125 (5)**: 615-629.

**Morelli G, Bastianello S, Catellani P & Ricci R** 2019. Raw meat-based diets for dogs: survey of owners' motivations, attitudes and practices. *BMC veterinary research.* **15 (1)**: 74.

**Muleta BG & Dida MF** 2025. Challenges and strategies to enhance meat quality in the Ethiopian livestock chain. *Discover animals.* **2 (1)**: 75.

**Odetokun IA, et al.** 2020. Occupational health and food safety risks in Ilorin, Northcentral Nigeria: A cross-sectional survey of



[ DOI: 10.18502/jnfs.v11i2.21434 ]

slaughterhouse workers. *Food protection trends,*. **40 (4)**: 241–250.

**Ogundele T, Ogundele O & Bello E** 2022. Knowledge and perception of mothers toward donor milk and human milk banking: Experience from two centers in southwest, Nigeria. *Nigerian journal of general practice*. **20 (1)**: 1–5.

**Ouédraogo I** 2022. Production technology and microbiological quality of kilichi produced in 5 localities of Burkina Faso. University Joseph KI-ZERBO: Burkina Faso.

**Paudyal N, et al.** 2017. Prevalence of foodborne pathogens in food from selected African countries - A meta-analysis. *International journal of food microbiology*. **249**: 35–43.

**Shaltout S & Shaltout F** 2024. Foodborne bacterial diseases due to consumption of meat, fish and poultry products. *Journal of thoracic disease and cardiothoracic surgery*. **5 (2)**: 2693-2156.

**Somda N, et al.** 2021. Diversity and antimicrobial drug resistance of non-typhoid Salmonella serotypes isolated in lettuce, irrigation water and clinical samples in Burkina Faso. *Journal of agriculture and food research*. **5**: 100167.

**Traoré O, et al.** 2014. Occurrence of Vibrio cholerae in fish and water from a reservoir and a neighboring channel in Ouagadougou, Burkina Faso. *Journal of infection in developing countries*. **10 (8)**: 1334-1338.

**Xu J, et al.** 2025. Meat preservation innovation: Ultrasonic pretreatment-driven quality improvement in vacuum-cooled chicken breast. *Food chemistry*. **493**: 145554.



[ DOI: 10.18502/jnfs.v11i2.21434 ]