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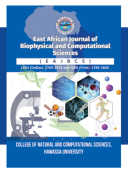

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ARTICLE

Assessment of Microbial Contamination in Beef from Abattoir to Retail Meat Outlets in Shone Administrative Town, Hadiya Zone, Southern Ethiopia

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Abstract

This study investigated microbial contamination along the beef production chain in Shone Administrative Town, Hadiya Zone, Southern Ethiopia. It assessed the contamination pathways from abattoirs to butcher shops. A total of 9 carcass samples from the abattoir and 30 meat samples from 10 butcher shops were analyzed for aerobic mesophilic bacterial count (AMBC), total coliform count (TCC), fecal coliform count (FCC), Staphylococcus aureus, Salmonella, and Shigella. At the abattoir, Sample 2 exhibited the highest AMBC (6.56±0.02 log CFU/ml), while Sample 1 recorded the highest TCC, FCC, and Salmonella levels. Sample 3 had the greatest loads of S. aureus and Shigella. The lowest microbial loads varied across samples, with Sample 2 showing the lowest TCC, FCC, and S. aureus. Among butcher shops, Butchers 10 and 5 showed the highest AMBC and TCC values, respectively, whereas Butcher 9 recorded the highest FCC and S. aureuscounts. Salmonella and Shigella were most prevalent in samples from Butcher 2. In contrast, Butcher 2 had the lowest AMBC, and Butcher 6 recorded the lowest TCC, FCC, and S. aureuslevels. Notably, Salmonella and Shigella were absent in samples from Butcher 3. Observational assessments further revealed poor hygiene practices during meat processing, handling, and transportation, posing significant food safety risks. The detection of pathogenic organisms such as Salmonella, Shigella, FCC, and S. aureusindicates substantial potential for foodborne infections and intoxications. In conclusion, the study underscores the urgent need to strengthen hygienic practices throughout the beef supply chain to safeguard public health in the region.

Keywords: Abattoir; butcher; Beef; contamination; hygiene; intoxication

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1 Introduction

Ethiopia is home to the largest livestock population in Africa. According to the 2021 Agricultural Sample Survey, there are around 70.3 million cattle, 42.9 million sheep, and 52.5 million goats (Legese et al., 2023). Livestock production is a vital part of the national economy, making up nearly 45% of agricultural GDP and about 18.7% of the total national GDP. In 2021, cattle production alone through meat, milk, hides, draft power, and other products brought in an estimated USD 8.52 billion (Li et al., 2023).

Beef is a crucial component of the Ethiopian diet, offering high-quality protein and essential micronutrients like vitamins A and B, which can be scarce in plant-based diets. The demand for meat is on the rise, fueled by population growth, increasing incomes, urbanization, and changing dietary habits. However, despite this growing appetite, significant food safety issues continue to challenge the meat production and marketing chain (Duguma & Janssens, 2020).

Various studies from different regions in Ethiopia have highlighted concerning levels of microbial contamination in raw beef. For example, a 2023 study in Assosa Town (Benishangul-Gumuz region) found high aerobic mesophilic bacterial counts (averaging 5.04 log10cfu/g) and elevated levels of *Staphylococcus aureus* (3.84 log10cfu/g) in slaughterhouses and butcher shops (Legese et al., 2023). In Hawassa, (Kenaw et al., 2024) reported high total plate counts, Enterobacteriaceae, and staphylococci on meat and contact surfaces, largely due to inadequate disinfection practices and the common exposure of meat to flies.

Similarly, a study conducted in three cities of the Tigray region found frequent contamination of raw cattle meat with zoonotic pathogens like Escherichia coli, *Salmonella* spp., *Staphylococcus aureus*, and Campylobacter spp., which pose serious public health risks (Reda et al., 2025). In a study carried out in the slaughterhouses of Bishoftu, researchers found that beef carcasses were contaminated with *Salmonella* and E. coli O157, highlighting serious issues with hygiene practices in these facilities (Gutema et al., 2021).

The findings also revealed that ongoing problems like poor sanitation, inadequate hygiene in both slaughterhouses and retail spaces, and lax enforcement of food safety regulations are compromising meat quality and public health in Ethiopia. This is particularly concerning in towns like Shone, where beef is sourced from both abattoirs and butcheries, making it crucial to evaluate the sanitary conditions throughout the meat production and distribution process.

2 Materials and Methods

2.1 Description of the Study Area

This study was carried out in Shone Administrative Town, located in the Hadiya Zone of Central Ethiopia (Figure 1). It is one of the eleven towns in the Hadiya Zone, part of the Central Ethiopian Regional state. Geographically, Shone is the farthest town from the zonal capital, Hosanna. It is found approximately 345 km south of Addis Ababa on the main road to Arba Minch, and97 km Southeast of Hosanna, and 17 km south of Durame.

Shone serves as the administrative center for both the town and the East Badawacho Woreda. It is situated at $7°8'21''$N latitude and $37°57'0''$E longitude, with an altitude of 1700 m above sea level. The town covers a total area of $35.32\,km^2$ and falls within the *woinadega* (mid-altitude) climatic zone. The local economy mainly depends on trade and related activities. According to the Central Statistical Agency (CSA) (2013), Shone has a population of 49,747, with 24,377 males and 25,370 females, and women make up about 51 % of the total.

Although there are slaughterhouses in the town that serve the locals, there are differences in the operational standards and degree of hygiene. Meat from sheep, goats, and cattle is frequently consumed by locals; consumption patterns are determined by both cultural and economic considerations. The community has uneven waste management procedures, and it frequently disposes of organic waste including animal byproducts inappropriately. The municipality generally has hygienic issues, which could affect the quality and safety of meat products.

2.2 Study Design

A cross-sectional study design was used, employing purposive sampling technique to collect meat samples. The samples were gathered from the Shone Administrative Town abattoir and ten retail meat outlets. Three replicate samples were collected from each location (abattoir and meat shops) to ensure data reliability and consistency. Laboratory analyses were conducted on selected microorganisms. These included aerobic mesophilic bacterial counts (AMBC), total coliform counts (TCC), faecal coliforms (FCC), *Staphylococcus aureus*, *Salmonella*, and *Shigella*.

To assess hygiene and sanitation practices, structured questionnaires were administered in English, Amharic, and Hadiyyisa. These were complemented by direct observations of the hygienic conditions and practices among workers in both abattoirs and meat shops. The questionnaires evaluated the knowledge and awareness of meat handlers regarding contamination risks along the beef production chain from the abattoir to retail outlets.

2.3 Sample Size Determination for Questionnaires Administration

During this study, respondents were selected from all retail meat outlets and abattoir workers of Shone administrative town for participating in the study following systematic random sampling technique by using the following simple formulae (Yamane, 1967).

$$n = \frac{N}{1 + N(e)^2} \tag{1}$$

Where n= is the sample size N= is the population size and e =is the level of precision. Using the above formulae, out of 43 workers of meat shops and abattoir of the study town (Godoliyas=4, Abaroso=3, Firehiwot=3, Meskel=4, Abenezer=2, Mini=4, Lichcha=3, Luci=3, Arenchbaxo =3, Fkadusiga bet=4

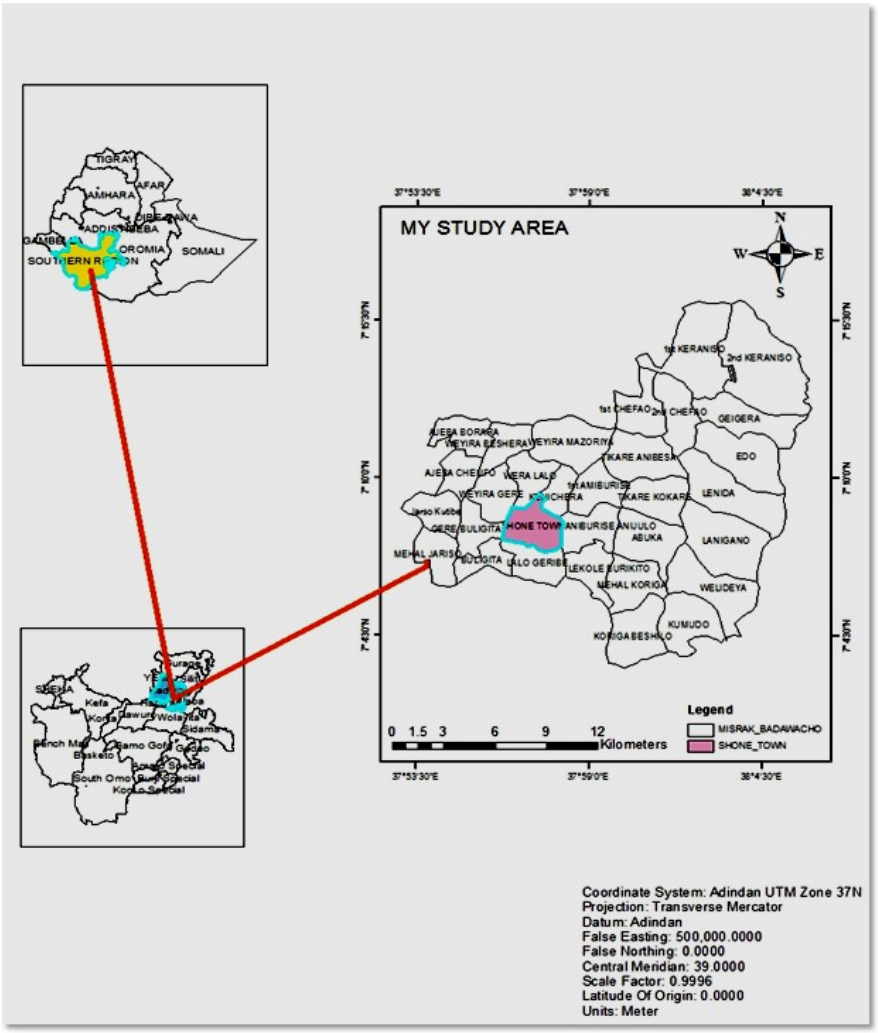

Figure 1: Location map of Shone administrative town (Source: Ethio. GIS)

and abattoir=10),38 respondents were selected. Therefore, N=43 and p=.5

$$n = \frac{N}{1 + N(e)^2(2)}$$

$= \frac{43}{1+43(.05)^2} = 38$ are sample size To keep proportionality of population among each, Palercolmorin formulae was used as cited by William Jams (1977). That means

$$Ps = \frac{nx}{N} \quad (3)$$

Where ps=proportional allocation to size X=number of populations in each retail meat outlets and abattoir N =total sample size N=total number of populations in all retail meat outlets and abattoir According to the above formulae proportionality number for each meat shop were Godoliyas = 3.61≈3, Abaroso = 2.71≈3, Firehiwot =2.71≈3, Meskel =3.61≈3, Abenezer = 1.8≈2, Licha =2.71≈3, Lucy =2.71≈3, Arenich baxo =2.71≈3, Fikadusiga bet=3.61≈3,Mini=3.61≈3 and abattoir=9.04≈9.Totally, 38 respondents, 9 from abattoir and 29 from butchers, were selected for interviews.

2.4 Data Collection Instruments

To support this study, data were gathered using structured questionnaires, direct field observations guided by prepared checklists, and meat sampling from the abattoir and retail meat outlets in Shone Administrative Town, Hadiya Zone, Central Ethiopia Regional State.

2.4.1 Observation and Checklist

Direct visual inspections were conducted to identify possible sources of microbial contamination during beef processing and to assess hygiene practices in the abattoir and butcher shops. The observations were accompanied by a checklist covering critical elements for good hygienic handling. The checklist focused on the condition of animals before slaughter (supported by veterinary specialist), the state of slaughterhouse facilities, processing procedures, hygiene of personnel and equipment, and meat transportation methods.

2.4.2 Questionnaire Administration

Questionnaires were used to collect data on from where the cattle are bought, meat distribution practices, methods of transportation, and availability of meat storage facilities. They also addressed the frequency of worker health checks, overall hygienic standards of the abattoir and meat outlets, and access to clean and safe water. The questionnaires were available in English, Amharic, and Hadiyyisa to ensure clarity and accessibility.

2.4.3 Media Preparation

All microbiological media used in this study were prepared according to the manufacturer's guidelines to maintain consistency and accuracy in laboratory testing.

2.4.4 Meat Sample Collection for Laboratory Analysis

For microbial examination, raw meat samples were aseptically collected by purposive sampling technique both from beef carcasses at the abattoir and from hanging displays in ten retail butcher shops. From 39 samples, 13samples in one round (10 from retail outlets and 3 from butcheries), each sample weighing 25 grams(according to ISO Standards: ISO 6887-2:2017), were placed in sterile containers with ice packs and immediately transported to the Veterinary Microbiology Laboratory at Hawassa University. All samples were processed within three hours of collection.

2.4.5 Preparation of Samples

Each meat sample was finely minced using a sanitized cutting blade, for each sample to prevent cross-contamination. A 10-gram portion from each sample was aseptically weighed using an analytical balance and mixed with 90 mL of sterile normal saline solution. The mixture was homogenized in a sterile beaker using a vortex mixer for two minutes. For serial dilution, seven sterile test tubes were used each filled with 9 mL of saline. One milliliter of the homogenized sample was added to the first tube and mixed thoroughly. Then, 1 mL from the first tube was transferred to the second, and this process was repeated through the seventh tube to achieve a seven-fold serial dilution (from 10^{1} to 10^{1}). One milliliter was discarded from the final dilution to ensure equal volume across tubes (Beijerinck, 1889).

2.4.6 Bacteriological Isolation and Identification

Distinct colonies that appeared on nutrient agar were examined for cultural characteristics such as shape, size, color, and texture. Gram staining and a series of standard biochemical tests were performed, following established procedures (Oyeleke & Manga, 2008). Isolates were identified based on their morphological and biochemical features including catalase, oxidase, coagulase, citrate utilization, methyl red reaction, motility, glucose fermentation, and lactose fermentation tests and compared with standard reference organisms using Bergey's Manual of Determinative Bacteriology (Buchanan & Gibbons, 1974).

2.4.7 Bacteriological Isolation

For primary isolation, bacterial growth on solid media was observed, and representative colonies were selected based on differences in size, shape, and color. These colonies were then sub-cultured onto nutrient agar and labeled for further identification.

2.5 Media for Primary Isolation and Enumeration of Bacteria

2.5.1 Aerobic Mesophilic Bacterial Count (AMBC)

Aerobic mesophilic bacteria were enumerated using the pour plate method on Plate Count Agar (PCA). From appropriately diluted samples, 0.1 mL of suspension was transferred into sterile Petri dishes containing pre-poured PCA. The plates were gently swirled in both directions to mix the inoculum evenly with the agar, then allowed to solidify for 15 minutes. They were then inverted and incubated at 35°C for 48 hours. After incubation, plates with 30–300 colonies were selected and counted using a colony counter, and CFU/mL was calculated using the formula: Colonies/Volume plated in mL) x Dilution Factor. Results were recorded as AMBC (American Public Health Association (APHA), 2017).

2.6 Enumeration of *Staphylococcus aureus*

To enumerate *Staphylococcus aureus*, the pour plate method was applied using Mannitol salt agar (MSA).Before inoculation, the storability of the media was tested by incubation of the sterile media in an autoclave for 24 hrs at 370C.Then, from each appropriate dilution, 0.1 mL was inoculated into sterile Petri dishes containing MSA. After gently swirling the plates and allowing them to solidify for 15 minutes, they were incubated at 37°C for 24 hours. Yellow-colored colonies were counted as S. *aureus*using a colony counter and the CFU/mL is calculated as shown above. Representative colonies were further sub-cultured on nutrient agar for confirmatory biochemical tests.

2.7 Enumeration of Total and Fecal Coliforms

To determine total and fecal coliform counts, 0.1 mL of each sample dilution was transferred into sterile Petri dishes containing 20 mL of MacConkey agar which was tested for its sterility before inoculation. The plates were left to solidify at room temperature for 15 minutes. Inoculated plates were incubated at 37°C for total coliforms and at 44°C for fecal coliforms for 24 hours. After incubation, plates with 30–300 colonies were selected, and red colonies were counted using a colony counter and the CFU/mL was calculated using the formula: Colonies / Volume plated in mL) x Dilution Factor. Selected colonies were sub-cultured on nutrient agar for further biochemical identification (Bhandare et al., 2007).

2.8 Detection of *Salmonella* and *Shigella* Species

To detect *Salmonella* and *Shigella*, 0.1 mL of diluted sample was poured into Petri dishes containing 20 mL of *Salmonella-Shigella* Agar (SSA). After the medium solidified, plates were incubated at 37°C for 48 hours. Black-centered colonies were identified as *Salmonella*, while colorless colonies indicated *Shigella*. Colonies were counted using a colony counter, and representative samples were sub-cultured onto nutrient agar for confirmatory tests (Cappuccino & Welsh, 2017).

Biochemical Tests for Identification of Bacterial Genera in Beef All tests were performed using pure bacterial cultures to ensure accuracy. Following staining procedures, various biochemical assays were conducted to support identification. Specific tests were selected based on the suspected bacterial types:

2.8.1 Gram Staining

Gram staining was used to differentiate Gram-positive from Gram-negative bacteria. A discrete colony was mixed with a drop of water on a clean slide, heat-fixed, and air-dried. The slide was treated sequentially with crystal violet (1 minute), Gram's iodine (1 minute), decolorizer (15 seconds), and safranin (1 minute), with gentle rinsing between steps. After drying, the sample was examined under an oil immersion microscope. Blue or purple cells indicated Gram-positive bacteria, while pink cells indicated Gram-negative bacteria (Bartholomew & Mittwer, 1952).

2.8.2 Catalase Test

A loopful of a 24-hour bacterial culture was placed on a clean slide, and a drop of 3% hydrogen peroxide was added. Immediate bubbling indicated a positive catalase reaction (Chester, 1979).

2.8.3 Coagulase Test

Using a sterile loop, a colony was mixed with a drop of rabbit plasma on a glass slide. Formation of white clumps within one minute indicated a positive coagulase result (Sperber & Tatini, 1975).

2.8.4 Oxidase Test

A piece of filter paper was moistened with freshly prepared 1% tetramethyl-p-phenylenediaminedihydrochloride. The test colony was streaked onto the paper. No color change after 15 seconds indicated a negative oxidase result (MacFaddin, 2000).

2.8.5 Citrate Utilization Test

Simmons citrate agar slants were inoculated with the test isolate and incubated at 37°C for 24 hours. A blue color on the slant surface indicated citrate utilization and a positive result (Forbes et al., 2007).

2.8.6 Methyl Red (MR) Test

MR-VP broth was inoculated with the test organism and incubated at 35°C for 48 hours. After incubation, five drops of methyl red reagent were added. Development of a stable red color indicated a positive result due to acid production and lowered pH (Madigan et al., 2024).

2.8.7 Glucose Fermentation Test

Phenol red glucose broth was inoculated with the test isolate and incubated at 37°C for 24 hours. A color change from red to yellow indicated acid production and a positive glucose fermentation result (MacFaddin, 2000).

2.8.8 Lactose Fermentation Test

Phenol red lactose broth was similarly inoculated and incubated at 37°C for 24 hours. Yellow coloration indicated lactose fermentation; no change indicated a negative result (MacFaddin, 2000).

2.8.9 Motility Test

Using a sterile straight wire, the test organism was inoculated into the center of a semisolid agar tube. After 24 hours of incubation

at 37°C, diffused turbidity around the stab line indicated motility, while growth confined to the stab line indicated a non-motile organism (Mitchell & Kogure, 2006).

2.9 Data Quality Control and Laboratory Safety

To ensure the reliability and validity of the research, all laboratory procedures including sample collection, handling, and culturing were performed following standardized protocols. Universal biosafety measures were strictly observed in accordance with National Committee for Clinical Laboratory Standards(NCCLS) guidelines (2002), given the potential health risks associated with handling pathogenic bacteria. All inoculated culture materials including test tubes, Petri dishes, and slides were sterilized in an autoclave at 121°C for 15 minutes prior to disposal. To prevent data mix-up, all materials were clearly labeled with unique identification codes to maintain proper tracking throughout the study.

2.10 Statistical Analysis

Data were carefully recorded, organized, and analyzed using descriptive statistics. Bacterial counts were calculated to colony-forming units per milliliter (CFU/mL) and expressed as mean log10 values. To evaluate differences in meat quality across samples, one-way analysis of variance (ANOVA) was applied at a 5% significance level. All statistical analyses were conducted using SPSS software version 20.0.

3 Results

3.1 Evaluation of Microbial Loads in Abattoir

The results of aerobic mesophilic bacterial counts (AMBC) from carcass samples collected at the Shone abattoir are summarized in Table 1. The mean log10 CFU/mL values were 6.33 ± 0.13 for sample 1, 6.56 ± 0.02 for sample 2, and 6.50 ± 0.04 for sample 3, with the overall mean value of 6.46 ± 0.47 log10 CFU/mL. Among the samples, sample 2 showed the highest bacterial load, while sample 1 had the lowest. However, the statistical analysis revealed that there is no significant difference in AMBC levels among the three samples ($p = 0.261$), indicating similar levels of contamination.

For total coliform counts (TCC), the mean log10 CFU/mL values for samples 1, 2, and 3 were 6.45 ± 0.14, 4.10 ± 2.45, and 6.32 ± 0.07, respectively, with an overall mean of 5.62 ± 0.73. Sample 1 exhibited the highest TCC, while sample 2 recorded the lowest. Despite the apparent variation, the differences among samples were not statistically significant ($p = 0.473$), suggesting relatively uniform coliform presence across the abattoir carcasses.

Regarding faecal coliform counts (FCC), the mean values were 6.16 ± 0.14 for sample 1, 3.85 ± 2.34 for sample 2, and 6.03 ± 0.21 for sample 3, resulting in an overall mean of 5.34 ± 0.69 log10 CFU/mL. Sample 1 showed the highest level of faecal contamination, while sample 2 had the lowest. Nonetheless, these variations were not statistically significant ($p = 0.479$), indicating a comparable microbial load among the sampled carcasses.

The mean log10 CFU/mL count of *Staphylococcus aureus* from carcass samples collected at the Shone abattoir is presented in Table 1. Sample 3 had the highest bacterial load at 6.30 ± 0.14, followed by sample 1 at 5.60 ± 0.15, and sample 2 at the lowest with 3.66 ± 2.31. The overall mean was 5.18 ± 0.76 log10 CFU/mL. Although there were variations in bacterial load among the samples, the statistical analysis showed no significant difference ($p = 0.417$).

For *Salmonella*, the mean log10CFU/mL values were 3.04 ± 2.03 for sample 1, 1.03 ± 1.03 for sample 2, and 1.96 ± 1.96 for sample 3. The overall mean was 2.01 ± 0.04 $\log_{10}$ CFU/mL. While the highest count was observed in sample 1 and the lowest in sample 2, these differences were not statistically significant ($p = 0.717$), suggesting a relatively even distribution of *Salmonella* contamination across the samples.

Regarding *Shigella*, the recorded counts were 1.13 ± 1.13 for sample 1, 1.96 ± 1.96 for sample 2, and 3.14 ± 1.40 for sample 3, with an overall mean of 2.07 ± 0.09 log10CFU/mL. Sample 3 exhibited the highest load, while sample 1 had the lowest. However, statistical analysis revealed no significant difference among the samples ($p > 0.05$), indicating similar levels of *Shigella* contamination in the abattoir samples.

3.2 Evaluation of Microbial Loads in Retail Meat Outlets

Microbial analysis of beef samples collected from ten butcher shops in Shone Administrative Town revealed varying levels of contamination, as summarized in Table 2. The mean log10 CFU/mL for aerobic mesophilic bacterial counts (AMBC) ranged from 7.33 ± 0.16 in samples from butcher 2 to 7.86 ± 0.27 in samples from butcher 10. The overall mean was 7.62 ± 0.05. Although numerical differences were observed, statistical analysis showed no significant variation among the shops ($p = 0.788$). AMBC was the most commonly detected group, indicating a high level of general bacterial load across outlets.

For total coliform counts (TCC), the highest value was recorded in samples from butcher 5 (7.60 ± 0.15), while the lowest was from butcher 6 (4.90 ± 2.46). The overall mean log10CFU/mL was 6.67 ± 0.41. As with AMBC, there were no statistically significant differences between butcher shops ($p = 0.625$).

Faecal coliform counts (FCC) showed a similar pattern. The highest bacterial load was observed in samples from butcher 9 (7.33 ± 0.58), and the lowest in samples from butcher 6 (4.33 ± 2.18), with a total mean of 6.31 ± 0.40 log10CFU/mL. No significant variation was detected among the shops ($p > 0.05$).

Table 1: Mean ± S.EM $\log_{10}$ colony forming units (Mean $\log_{10}$ CFU/ml) of samples (n=3) Abattoir in Shone administrative town.

Abatttior	AMBC	TCC	FCC	*S. aures*	*Salmonella*	*Shigella*
Sample 1	6.33 ± 0.13	6.45 ± 0.14	6.16 ± 0.14	5.60 ± 0.15	3.06 ± 2.03	1.13 ± 1.13
Sample 2	6.56 ± 0.02	4.10 ± 2.45	3.85 ± 2.34	3.66 ± 2.31	1.03 ± 1.03	1.96 ± 1.96
Sample 3	6.50 ± 0.04	6.32 ± 0.07	6.03 ± 0.21	6.30 ± 0.14	1.96 ± 1.96	3.14 ± 1.40
Average	6.46 ± 0.47	5.62 ± 0.73	5.34 ± 0.69	5.18 ± 0.76	2.01 ± 0.04	2.75 ± 1.09
P-Value	0.261	0.473	0.479	0.417	0.717	0.720

Key: AMBC- aerobic mesophilic bacterial count, TCC- Total coliform count, FCC- fecal coliform count

Staphylococcus aureus counts were highest in samples from butcher 9 (7.56 ± 0.56) and lowest from butcher 6 (4.50 ± 2.25). The overall mean was 6.96 ± 0.26 log10CFU/mL. Despite the range of values, differences among samples were not statistically significant ($p > 0.05$).

For *Salmonella*, the contamination levels ranged from 6.40 ± 0.26 in samples from butcher 2 to undetectable levels (0.00 ± 0.00) in samples from butcher 3. The mean log10CFU/mL across all samples was 3.16 ± 0.59. Again, no significant differences were noted ($p > 0.05$). Lastly, *Shigella* counts were highest in samples from butcher 2 (6.86 ± 0.03) and absent in samples from butcher 3. The total mean was 2.07 ± 0.09 log10CFU/mL, with no statistically significant variation among the outlets ($p > 0.05$).

3.3 Social Characteristics of Abattoir and Retail Meat Outlet Respondents

3.3.1 Age and Sex Distribution

Table 3 summarizes the age and sex distribution of the respondents involved in the study. A total of 38 individuals participated, all of whom were male. Among them, 9 were abattoir workers and 29 were employed in retail meat outlets.Of the abattoir workers, 4 respondents (44.4%) were aged between 18 and 30 years, while the remaining 5 (55.6%) were between 31 and 40 years. Among retail meat outlet workers, 16 individuals (55.2%) fell within the 18–30 age group, 11 (37.9%) were between 31 and 40 years, and 2 respondents (6.9%) were below the age of 18.

3.3.2 Educational Background and Training of Abattoir and Butchery Workers

Table 4 summarizes the education levels and training received by workers in abattoirs and retail meat outlets in Shone Administration town. Among the nine abattoir workers interviewed, 66.7% (6workers)had completed primary school, while33.3% (3 workers)had attended high school. Notably, all abattoir workers received annual training. In contrast, the study interviewedtwenty-nine butchery shop workers. Of these, 27.6% (8 workers)were illiterate,41.4% (12 workers)had completed primary school, and31% (9 workers)had reached high school level. However, 62% (18 workers)reported that they hadnot received any trainingrelated to hygienic meat handling or sanitation in the butcher's environment, while38% (11 workers)indicated they received such training annually.

3.3.3 Work Experience of Abattoir and Retail Meat Outlet Workers

According to Table 5, 66.7% (6 workers) in the abattoirs had less than five years of work experience, while the remaining 33.3% (3 workers) had between five and ten years of experience. Among the 29 workers in retail meat outlets, 48.3% (14 workers) had less than five years of experience, 31% (9 workers) had five to ten years, and 20.7% (6 workers) had between eleven and twenty years of experience.

3.4 Practices Contributing to Microbial Contamination of Beef in Abattoirs and Retail Meat Outlets

3.4.1 Meat Handling and Hygienic Practices of Abattoir and Retail Meat Outlet Workers

Table 6 presents the findings on hygiene practices among workers in abattoirs and retail meat outlets. All nine abattoir workers interviewed reported washing their hands before entering the deboning room. However, 77.8% (7 workers) used cold water and soap, while 22.2% (2 workers) used only water. Additionally, 33.3% (3 workers) had untrimmed fingernails and were considered unhygienic. Although all abattoir workers wore aprons consistently, none used hair nets. When asked about apron cleaning habits, 22.2% (2 workers) cleaned their aprons daily, 22.2% twice a week, and 55.6% only once a week.

Regarding hand washing after using the toilet, 55.6% (5 workers) always did so, while 44.4% (4 workers) did so only sometimes. Notably, 77.8% of workers used only water, not soap, for this purpose. Among the 29 retail meat outlet workers interviewed, all stated, they washed their hands before starting work. Of these, 72.4% (21 workers) used cold water and soap, while 27.6% (8 workers) used water alone. The same proportions (72.4% and

Table 2: Mean $\pm$ S.E M $\log_{10}$ colony forming units (Mean $\log_{10}$ CFU/ml) of Butchers in Shone administrative town.

Butchers	**AMPC**	**TCC**	**FCC**	***S. aures***	**Slmonella**	***Shigella***
Butcher 1	7.66 ± 0.14	7.30 ± 0.15	6.93 ± 0.38	7.26 ± 0.54	4.46 ± 2.23	4.60 ± 2.30
Butcher 2	7.33 ± 0.16	7.40 ± 0.11	6.73 ± 0.24	7.03 ± 0.37	6.40 ± 0.26	6.86 ± 0.03
Butcher 3	7.56 ± 0.17	7.50 ± 0.15	7.16 ± 0.08	7.50 ± 0.56	0.00 ± 0.00	0.00 ± 0.00
Butcher 4	7.53 ± 0.12	4.93 ± 2.46	4.83 ± 2.41	7.30 ± 0.20	4.03 ± 2.02	4.36 ± 2.19
Butcher 5	7.53 ± 0.08	7.60 ± 0.15	7.10 ± 0.15	7.13 ± 0.21	1.86 ± 1.86	1.23 ± 1.23
Butcher 6	7.76 ± 0.37	4.90 ± 2.46	4.33 ± 2.18	4.50 ± 2.25	4.00 ± 2.04	4.26 ± 2.15
Butcher 7	7.60 ± 0.15	4.93 ± 2.48	4.46 ± 2.25	6.96 ± 0.21	2.46 ± 2.46	2.40 ± 2.40
Butcher 8	7.66 ± 0.08	7.24 ± 0.26	7.03 ± 0.21	7.16 ± 0.31	2.03 ± 2.03	4.20 ± 2.10
Butcher 9	7.70 ± 0.11	7.56 ± 0.16	7.33 ± 0.58	7.56 ± 0.56	2.13 ± 2.13	2.23 ± 2.23
Butcher 10	7.86 ± 0.27	7.33 ± 0.08	7.20 ± 0.01	7.23 ± 0.18	4.20 ± 2.10	6.50 ± 0.43
Average	7.62 ± 0.05	6.67 ± 0.41	6.31 ± 0.40	6.96 ± 0.26	3.16 ± 0.59	3.60 ± 0.60
P-value	0.788	0.625	0.515	0.335	0.542	0.208

Key: AMBC- aerobic mesophilic bacterial count, TCC- Total coliform count, FCC- fecal coliform count

Table 3: Age and Sex distribution of abattoir and retail meat outlet respondents

Variables		Abattoir workers (n=9)		Retail meat outlets worker(n=29)	
		Frequency	%	Frequency	%
Age	Below 18	0	0.0	2	6.9
	18-30	4	44.4	16	55.2
	31-40	5	55.6	11	37.9
Sex	Male	9	100.0	29	100.0
	Female	0	0.0	0	0.0

Table 4: Frequency distribution of abattoir and retail meat outlet workers according to educational status and Received training.

Educational status		Abattoir workers (n=9)		Retail meat outlet workers (n=29)	
		Frequency	%	Frequency	%
Illiterates		0	0.0	8	27.6
Primary school Education		6	66.7	12	41.4
Secondary Education		3	33.3	9	31.0
Received training	Yes	9	100.0	11	38.0
	No	0	0.0	18	62.0

Table 5: Frequency distribution of respondents according to working experience in abattoir and retail meat outlets.

Work Experience (Years)	Abattoir workers (n=9)		Retail meat outlet workers (n=29)	
	Frequency	%	Frequency	(%)
0-4	6	66.7	14	48.3
5-10	3	33.3	9	31.0
11-20	0	0.0	6	20.7

27.6%) applied to the frequency of hand washing after toilet did so always, others only sometimes. None of the retail workers used gloves while handling meat.

Furthermore, 41.4% (12 workers) handled money while serving food. While 72.4% always wore aprons, 37.9% wore visibly dirty aprons, and 58.6% did not wear hair nets. In terms of transportation, all workers reported that meat was delivered to the shops using Bajaj vehicles, which were in poor hygienic condition. Finally, regarding health certification, 77.8% of abattoir workers and 79.3% of retail workers did not possess valid medical health certificates.

Table 6: Frequency distribution of Meat hand lining and Hygienic practices of abattoir and retail meat outlet workers.

Practices		Abattoir workers (n=9)		Retail meat outlet workers (n=29)	
		Frequency	%	Frequency	%
Washing hand before starting work	Yes	9	100	29	100
	No	0	0.0	0	0.0
Using water and soap		7	77.8	21	72.4
Using only water		2	22.2	8	27.6
Not cut nail		3	33.3	0	0.0
Use apron	Always	9	100	21	72.4
	Some times	0	0.0	8	27.6
Cleaning of apron	Every day	2	22.2	8	27.6
	Twice a week	2	22.2	10	34.5
	Once a week	5	55.6	11	37.9
Hair net	Used	0	0.0	12	41.4
	Not used	9	100	17	58.6
Handling money while serving meat		0	0.0	12	41.4
Washing hand after toilet	Always	5	55.6	21	72.4
	Some times	4	44.4	8	27.6
Presence of health certificate	Yes	2	22.2	6	20.7
	No	7	77.8	23	79.3

3.4.2 Hygienic Conditions of Abattoir and Retail Meat Outlet Facilities

Table 7 presents findings on hygiene practices at the abattoir and retail meat shops in Shone administrative town. Among the 9 abattoir workers interviewed, 88.9% (8 workers) reported that no daily cleaningoccurredafter slaughtering. The facility also lacked proper separation of slaughter stages such as skinning, evisceration, deboning, and meat delivery. Moreover, no rodent or insect control measures were in place, and essential sanitation tools like hot water, sterilizers, and retention rooms were absent. The lairage was poorly maintained, with accumulated cattle dung and feces-contaminated animals being slaughtered.

Additionally, 44.4% (4 workers) indicated that carcasses sometimes came into contact with the floor or the outer side of the skin/hide, increasing the risk of contamination. Out of 10 retail meat outlets inspected, 80% were found to have poor hygienic conditions, despite daily cleaning with water and soap. From 29 meat outlet workers surveyed, 41.3% (12 workers) stated that butchers did not practice daily personal hygiene.

Regarding leftover meat storage, 60% (6 out of 10) of the butchers did not use refrigerators, while 40% (4 outlets) had refrigerators in their shops. Metal hooks were commonly used in 80%of the outlets for hanging meat. All retail workers confirmed that they sold unchilled meat. For fly control, 70% of the shops used glass windows and cleaned daily, while the remaining 30% relied solely on glass windows.

4 Discussion

4.1 Microbial Load Assessment in Abattoir and Retail Meat Outlets

Aerobic mesophilic bacterial count (AMBC) is a widely accepted indicator of the general microbiological quality of meat and the hygienic conditions under which is processed. Elevated AMBC levels often reflect poor sanitation, cross-contamination, or inadequate handling practices during slaughter and retail.

In the current study, AMBC values in Shone town abattoir ranged from 6.33±0.13 to 6.56 ±0.02 log CFU/ml, with a mean of 6.46±0.47 log CFU/ml. The findingsare comparable to those reported by Ntanga (2013) in Tanzania (6.60±0.37 log CFU/ml), but higher than those observed by (Ahmad et al., 2013; Haileselassie et al., 2012; M. A. Nervy et al., 2011), indicating variability likely due to differences in hygiene protocols and facility management.

Retail butcher shops exhibited even higher AMBC levels, ranging from 7.33±0.16 to 7.86±0.27 log CFU/ml, with a mean of 7.62±0.05 log CFU/ml. These values exceed those reported by Gebeyehu Arse et al. (2013) and Melkamnesh and Mulugeta (2017), but are consistent with findings from Ntanga (2013) and Ahmad et al. (2013). The elevated bacterial loads in retail outlets may be due to contamination from handling tools, water, carcass transport, and environmental exposure. Although numerical differences were observed between abattoir and retail samples, statistical analysis revealed no significant difference ($p > 0.05$), and this is probable due to uniformly poor hygienic practices across the meat supply chain. This aligns with findings by Haileselassie et al. (2012), who emphasized the role of disorganized processing and inadequate personal hygiene in

Table 7: Frequencies distribution of abattoir and retail meat outlets facilities in Shone administrative town.

Practices		Responses (abattoir workers)		Responses (Retail meat outlet workers)	
		Frequency	%	Frequency	%
Daily cleanness of abattoir and butchers	Yes	1	11.1	17	57.7
	No	8	88.9	12	41.3
Daily cleanness of equipments	Yes	9	100.0	29	100.0
Water availability	Yes	9	100.0	29	100.0
	No	0	0	0	0
Contact of carcass with skin/hind or floor	Yes	4	44.4		
	No	5	55.6		
Refrigerator	Used			11	37.9
	Not used			18	62.1
Ways of flies control	Uses glass window only			8	27.6
	Glass window and clean daily			21	72.4

microbial contamination.

Recent studies reinforce these concerns. For instance, Kebede and Getu (2023) reported AMBC values ranging from 2.75 to 7.52 log CFU/g in abattoirs and 2.49 to 5.16 log CFU/g in butcher shops in Assosa, Ethiopia, with over 40% of samples exceeding acceptable limits. Similarly, Jaja et al. (2018) found AMBC levels exceeding 6.0 log CFU/cm² in informal meat sectors in South Africa, highlighting the public health risks posed by inadequate sanitation.

Importantly, the AMBC values recorded in this study exceed the maximum acceptable limit of 6.00 log CFU/cm² set by the International Commission on Microbiological Specifications for Foods (International Commission on Microbiological Specifications for Foods (ICMSF), 1985). According to Food and Agriculture Organization (FAO) (2007), total viable counts above 5.0 log CFU/cm² indicate unacceptable hygiene and necessitate corrective actions throughout the meat production and distribution chain.

Total Coliform Counts (TCC)

Coliform bacteria are traditionally used as indicators of fecal contamination and potential presence of enteric pathogens. While some coliforms inhabit the human intestinal tract, many are environmental and not necessarily of sanitary concern (Greenberg & Hunt, 1985). However, high coliform counts in food products, particularly meat, are undesirable and suggest poor hygiene during processing.

In the current study, the highest mean log value of TCC in abattoir samples was 6.45 ±0.14 log CFU/ml, while the lowest was 4.10 ±2.45 log CFU/ml. The overall mean was 5.62 ±0.73 log CFU/ml. These values are lower than those reported by Ntanga (2013), who found a mean of 6.33 ±0.02 log CFU/ml, but higher than the 2.29 ±2.38 log CFU/ml reported by Chepkemoi (2016). The elevated TCC in this study may be duet o inadequate hygiene practices, such as all workers participating in multiple tasks without proper sanitation or sterilization of equipment.

No statistically significant differences were observed among carcass samples ($p > 0.05$), likely due to uniform handling practices and shared equipment. In retail meat outlets, TCC ranged from 4.90 ±2.46 to 7.60 ±0.15 log CFU/ml, with a mean of 6.66 ±0.41 log CFU/ml. These values exceed those reported by Gebeyehu Arse et al. (2013), Melkamnesh and Mulugeta (2017), and Natanga (2013), who found means of 5.55, 3.97, and 1.72 log CFU/ml, respectively. Such discrepancies may reflect differences in hygiene standards, equipment sanitation, and worker practices.

Recent studies continue to highlight the role of coliforms as indicators of meat hygiene. For instance, Kang et al. (2020) emphasized the need for improved detection methods to reduce false positives, while Koech (2024) linked high coliform counts to poor handling in Nairobi butcheries.

Fecal Coliform Counts (FCC)

Fecal coliforms are more specific indicators of fecal contamination and poor sanitary conditions. In this study, FCC in abattoir samples ranged from 3.85 ±2.34 to 6.16 ±0.14 log CFU/ml, with a mean of 5.34 ±0.69 log CFU/ml. These values are lower than those reported by Natanga (2013) but higher than those by Bhandare et al. (2009) and M. A. Nervy et al. (2011).

The high FCC levels may be due to processing activities conducted on the abattoir floor and the lack of separation between clean and dirty zones, leading to cross-contamination. In retail outlets, FCC ranged from 4.33 ±2.18 to 7.33 ±0.58 log CFU/ml, with a mean of 6.31 ±0.40 log CFU/ml. These values exceed the Food and Agriculture Organization (FAO) (2007) recommended limit of 3.0 log CFU/g, indicating unacceptable hygiene levels. Recent findings by Hanyinza et al. (2020) in Zambia and Metaferiya (2022) in Ethiopia support the conclusion that poor hygiene and handling practices significantly contribute to elevated FCC in meat.

***Staphylococcus aureus* Counts**

Staphylococcus aureus is a pathogenic bacterium commonly found on the skin and mucous membranes of humans and animals. It can cause foodborne illness when present in high

numbers. In this study, S. *aureus*counts in retail meat outlets ranged from 4.50 ±2.25 to 7.56 ±0.56 log CFU/ml, with a mean of 6.96 ±0.26 log CFU/ml. These values are higher than those reported by Ahmad et al. (2013), Gebeyehu Arse et al. (2013), and Twum (2015).

The high prevalence of S. *aureus*is likely due to poor personal hygiene among meat handlers and the use of unsterilized equipment. Human hands are a major source of cross-contamination in food handling environments (Kanko et al., 2023). In abattoir samples, S. *aureus*counts ranged from 3.66 ±2.31 to 6.30 ±0.14 log CFU/ml, with a mean of 5.18 ±0.76 log CFU/ml.

Recent studies by Pérez-Boto et al. (2023) and Mumed et al. (2023) confirm the persistence of S. *aureus*in meat processing environments and its resistance to common antibiotics, underscoring the need for improved hygiene and monitoring.

Salmonella Counts

This study revealed the presence of *Salmonella* in both abattoir and retail meat outlets in Shone town. Among ten butcher shops sampled, nine showed contamination, with the highest mean log count reaching 6.46 ±0.26 CFU/ml. In the abattoir, *Salmonella* was also detected, with mean log values ranging from 1.03 ±1.03 to 3.04 ±2.03 CFU/ml. Although microbial loads differed between the two sources, the variation was not statistically significant ($p > 0.05$), suggesting similar hygiene and meat handling practices across the sites.

The overall mean *Salmonella* counts were 3.16 ±0.59 CFU/ml in butcher shops and 2.01 ±0.04 CFU/ml in the abattoir. These findings align with Twum Ernest (2015), who reported 3.60 ±0.12 CFU/ml in East Ghana, but contrast with Gebeyehu Arse et al. (2013), who found no *Salmonella* in Adama Town, Ethiopia. The contamination likely stems from poor hygiene, including unclean equipment, exposure to flies, and cross-contamination from handlers factors also highlighted in recent studies (Etikudike et al., 2022; Hammuel & Briska, 2024).

Shigella Counts

Shigella was detected in all abattoir samples, with mean log values ranging from 1.13 ±1.13 to 3.14 ±1.40 CFU/ml. In butcher shops, all but one (Butcher 3) tested positive, with the highest count at 6.86 ±0.03 CFU/ml. No significant difference was observed between the abattoir and butcher shops ($p > 0.05$), again indicating uniformity in meat handling practices.

These results differ from Gebeyehu Arse et al. (2013), who reported no *Shigella* in Adama Town. The presence of *Shigella* in this study may be due to unhygienic practices such as the use of contaminated knives and cutting boards, poor personal hygiene, and inadequate sanitation findings echoed in recent literature (Hammuel & Briska, 2024; Rabins, 2021).

Age and Sex Distribution

In the abattoir, 55.6% of workers were aged 31–40, while 44.4% were 18–30. In butcher shops, 55.6% were 18–30, 37.4% were 31–40, and 6.8% were under 18. All workers were male, consistent with findings by Adzitey et al. (2011), who noted that meat processing is typically dominated by young and middle-aged men due to the physical demands of the work.

Educational Status and Training

In the abattoir, 66.7% of workers had primary education and 33.3% had secondary education; all had received hygiene training. In contrast, 27.6% of butcher workers had no formal education, 41.4% had primary, and 31.0% had secondary education. These figures are lower than those reported in Nairobi and Tanzania (Chepkemoi, 2016; Ntanga, 2013), where higher educational attainment was observed. Low education levels may hinder comprehension and implementation of hygienic practices. Recent studies confirm that education and training significantly influence food safety behavior (AzekoAsati et al., 2024; Kassaw et al., 2024).

Work Experience

Most abattoir (66.7%) and butcher (48%) workers had less than five years of experience. This limited experience, coupled with low education and training, may reduce adherence to hygienic practices and limit peer learning. Similar concerns were raised by (Ashuro et al., 2023), who found that work experience significantly affects meat hygiene practices.

4.2 Practices Contributing to Microbial Contamination of Beef in Abattoirs and Retail Meat Outlets

Hygiene Practices of Workers

The study revealed several hygiene-related shortcomings among abattoir and retail meat outlet workers that contribute to microbial contamination of beef. Although all abattoir workers reported washing their hands before entering the deboning room, 22.2% used only water, and 77.8% did not use soap. Furthermore, only 55.6% consistently washed their hands after using the toilet, while 44.4% did so occasionally. Additionally, 33.3% of workers had untrimmed nails, posing further hygiene risks.

Despite all abattoir workers wearing aprons, most did not clean them daily, and none wore hairnets. These findings contrast with Natanga (2013), who reported that most abattoir workers in Morogoro, Tanzania, did not wear protective clothing. However, the lack of daily cleaning and absence of hairnets in the current study still presents significant contamination risks.

Retail meat outlet workers also demonstrated poor hygiene. While all washed their hands before work, 27.6% used only water, and only 27.6% consistently washed their hands after toilet use. None used gloves, and 41.4% handled money while serving meat, a known vector for microbial transmission (N. J. Nervy et al., 2011). These practices are inconsistent with findings from Chepkemoi (2016) and Little et al. (1999), who reported even lower hand washing rates in Kenya and the UK, respectively.

Meat was commonly transported in Bajaj vehicles, which were also used for other purposes, including transporting people and goods. This practice violates hygiene standards and increases the risk of contamination. Similar concerns were raised by Adzitey et al. (2011) in Ghana and Chepkemoi (2016) in Kenya.

A significant proportion of workers lacked medical health certification 77.8% in abattoirs and 79.3% in retail outlets raising concerns about their fitness to handle food. This is higher than the 15.4% reported by Haileselassie et al. (2013) in Mekelle, Ethiopia, but lower than rates in Nairobi and Isiolo, Kenya (Chepkemoi, 2016). Recent studies confirm that poor hygiene practices, inadequate protective clothing, and improper meat transportation significantly contribute to microbial contamination. For instance, Kebede and Getu (2023) found high levels of *Staphylococcus aureus* and *Salmonella* in meat samples from Ethiopian abattoirs and butcher shops, largely due to poor handling and environmental hygiene.

Hygienic Conditions of Abattoir and Retail Meat Outlet Facilities The Shone town abattoir is situated near residential areas, limiting its potential for expansion and exposing it to unauthorized access and vermin due to the absence of fencing. Observations revealed that 88.9% of abattoir workers reported no routine cleaning after slaughtering, and there was no clear separation between critical processes such as skinning, evisceration, deboning, and carcass delivery. All operations were conducted on a contaminated floor, increasing the risk of microbial contamination.

The facility lacked essential infrastructure, including septic tanks and designated waste disposal pits. Effluents were stored in a poorly maintained borehole with limited capacity, often overflowing and contaminating the surrounding environment. Solid wastes such as faeces, horns, and tissue scraps were discarded near the abattoir, creating foul odors and attracting pests like rodents, flies, and stray animals.

These findings align with previous studies. For instance, Adzitey et al. (2011) and Adeyemo et al. (2009) reported similar unhygienic practices in Ghana and Nigeria, respectively, where carcasses were processed on bare or unclean floors due to the absence of hoisting equipment. Akinro et al. (2009) highlighted the environmental hazards posed by effluent seepage into water sources. More recently, Yimana and Hassen (2024) emphasized that inadequate infrastructure, lack of trained personnel, and poor sanitation practices continue to compromise meat safety in Ethiopian abattoirs. Retail meat outlets in Shone town also exhibited poor hygienic conditions. Although 80% of shops reported daily cleaning with water and soap, most used unclean wooden chopping blocks and lacked refrigeration for leftover meat. Only 40% of outlets had refrigerators, and many mixed leftover meat with fresh cuts, increasing the risk of cross-contamination. Domestic flies were prevalent due to the practice of opening glass windows during sales, allowing insects to enter.

These observations are consistent with findings by Nurye and Demlie (2021), who reported high microbial loads in meat from butcher shops due to inadequate hygiene and poor infrastructure. Similarly, Ali et al. (2010) noted that cleaning once daily with detergent and water is insufficient to maintain sanitary conditions in meat retail environments.

Overall, the study underscores the urgent need for improved infrastructure, regular sanitation, proper waste management, and training of personnel to ensure meat safety from slaughter to retail.

5 Conclusion

This study found that meat from both abattoirs and retail outlets in Shone administrative town was contaminated with high levels of microorganisms, as indicated by elevated Aerobic Mesophilic Bacterial Count (AMBC), Total Coliform Count (TCC), Fecal Coliform Count (FCC), *Staphylococcus aureus*, *Salmonella*, and *Shigella*. The results suggest that both the abattoir and retail meat outlets failed to meet basic sanitation and hygiene standards.

The poor hygiene and sanitation practices observed at slaughterhouses and butcher shops likely contributed to the microbial contamination, posing a serious public health risk. The presence of these pathogens highlights the potential for food borne illnesses if contamination is not addressed.To protect public health, it is essential to promote proper meat handling and sanitation practices through education and enforcement of hygiene standards in abattoirs and butcheries.

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Data Availability Statement

All data supporting the findings of this study are included in the article. Requests for additional information can be directed to the corresponding author.

Declaration of Interest

The authors declare no conflicts of interest.

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