INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print); 2222-5234 (Online)
Website: https://www.innspub.net
Email contact: info@innspub.net
Vol. 27, Issue: 1, p. 272-290, 2025

RESEARCH PAPER OPEN ACCESS

Public health implications of microbial contamination in registered slaughterhouses: A case study from La Union, Philippines

Carlo G. Fernandez[1], Harlene S. Fernandez[1], Priscilo P. Fontanilla Jr.[1], Reinalyn D. Austria[2]

[1]*Don Mariano Marcos Memorial State University, North La Union Campus, College of Graduate Studies, Bacnotan, La Union, Philippines*

[4]*National Meat Inspection Service, Regional Technical Operation Center 1, Urdaneta City, Pangasinan, Philippines*

Key words: Microbial contamination, Slaughterhouse, Meat safety, Aerobic plate counts

DOI: https://dx.doi.org/10.12692/ijb/27.1.272-290 Published: July 14, 2025

ABSTRACT

Meat safety is a public health concern and is significantly influenced by slaughterhouse hygiene, handling and sanitation. This study was conducted to assess the microbial quality of meat and identify hygiene practices in selected slaughterhouses in the Province of La Union from January 28 to February 28, 2025. Swab samples from meat contact surfaces including carcasses were collected and analyzed for microbial contamination for potential pathogens including Aerobic Plate Counts (APC) of *Staphylococcus aureus*, *Escherichia coli*, *Salmonella* spp., and Coliforms were prepared. Results revealed varying levels of microbial contamination, with some samples exceeding acceptable safety limits, indicating potential risks to public health. Poor sanitation, improper handling practices, and inadequate facilities contributed in the contamination levels. The study highlights the need for stricter enforcement of hygiene protocols, improved slaughterhouse infrastructure, and regular microbial monitoring to ensure meat safety.

***Corresponding author:** Carlo G. Fernandez ✉ fernandezolrac1006@gmail.com

INTRODUCTION

Meat establishments like slaughterhouse or abattoir play an important guide in monitoring, managing, and eliminating animal diseases, as well as in controlling, reducing, and preventing foodborne risks that impact public health. Proper hygiene practices should be maintained throughout the slaughtering and processing stages to avoid foodborne hazards and cross contamination of carcasses. Thus, the hygiene of meat establishments facilities plays an important role in determining the final microbiological condition of chilled carcasses, as well as in preventing and lessen consumer exposure to foodborne risks linked to meat consumption (Nastasijevic *et al.*, 2011). Poor personal and environmental hygiene, along with unhygienic conditions can spread foodborne infections in slaughterhouse across sub-Saharan Africa. To evaluate the hygiene and sanitation practices in selected abattoir in sub-Saharan African nations, as well as the bacterial contaminants present in these facilities. Due to insufficient hygiene, lack of formal occupational health and safety training, inadequate worker knowledge, and the use of substandard infrastructure and basic tools. Pathogenic microorganisms of public health concern are commonly found in these abattoirs. These circumstances create an environment conducive to the growth, survival, transmission, and spread of foodborne pathogens such as bacteria, parasites, and viruses. To handle these challenges, it is essential to evaluate issues like poor personal and environmental hygiene among butchers and other abattoir workers, limited access to clean water, unsuccessful waste management practices, and the absence of proper infrastructure and technology—all of which facilitate the presence of harmful microorganisms. Sustainable solutions should involve the implementation of regulations or rules supported by legal frameworks (Ovuro *et al.*, 2023).

Monitoring carcass surface contamination along the slaughter line is critical for confirming hygiene practices and compliance to manufacturing standards. The most commonly describe foodborne diseases globally and one of the major sources of human non-typhoidal salmonellosis is pork. The findings of this study highlight the need for ongoing improvements in slaughtering operations and the implementation of good manufacturing practices to ensure the safety of pork production in Portugal (Alvez *et al.*, 2022). The meat handlers who trained in proper hygiene practices serves as the first line of defense against contamination of food throughout the supply chain. The spread of harmful microorganisms can be minimized or lessen through basic hygiene practices, such as proper handwashing. The palms of food handlers can carry a variety of microorganisms and contaminants like *Escherichia coli* O157:H7, *Shigella* spp., *Salmonella Typhi*, nontyphoidal *Salmonella*, Norovirus, and Hepatitis A virus, and all are derived from human fecal matter and environment. Additionally, handling raw food materials can lead to the transfer of bacteria, such as *Salmonella* spp. and *E. coli* O157:H7 through the hands. These pathogens and microorganisms can then easily spread from the food handler's palms to the food during handling or preparation (El-Nemr *et al.*, 2019).

Meat or carcasses had been valued for its nutritional content, which helps explain its widespread consumption around the world. The protein in the meat contains amino acids that are considered of high quality, as it includes all the essential amino acids needs by the body. A significant part of the global population depends on meat as a primary food source. Nonetheless, eating or consuming half raw meat can lead to infections in humans, as certain enteric bacteria species can cause sickness (Olaoye, 2011). The meat is rich in protein and fat, low carbohydrates, and with adequate water activity, gives an ideal environment for the growth of both pathogenic bacteria and spoilage. The common spoilage in raw meat and poultry include *Enterobacteria* spp., *Salmonella* spp., as well as *Pseudomonas* and *Staphylococcus* bacteria. Yeasts and molds grow much more slowly on freshly slaughtered meat compared to bacteria and are

therefore not major contributors to spoilage (Doyle, 2007). As mentioned by Olaoye *et al.* (2011), meat is more vulnerable to spoilage and is frequently associated with the spread of foodborne illnesses, as various biochemical changes and microorganisms are introduced during slaughter, processing, and preservation stages. According to Okonko *et al.* (2010), roughly 69% of gram-negative bacteria are known to cause foodborne diseases. Also, foodborne pathogens and microorganisms can spread from contaminated meat to surfaces, further increasing the risk of infection. The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) state that diseases caused by unhygienic food are among the most widespread health issues and a major contributor to reduced economic productivity (Käferstein, 2003).

Raw meat or half cooked meat can harbor a variety of pathogenic microbes making it a major risk to human health. Without hygienic and proper handling and control of these pathogens, foodborne illnesses can occur (Norrung *et al.*, 2009). Top contributors to bacterial contamination of meat are the hygienic conditions of slaughterhouses or abattoirs and their surrounding (Gill *et al.*, 2000). During the transportation, storage, and handling at the meat shops continues the contamination risk. Strict adherence to food safety protocols is very much needed to stop foodborne illnesses and control the microbial load in raw meat. Nevertheless, in developing countries like the Philippines, the poor sanitary conditions of meat establishments, as well as insufficient transportation and storage facilities, not only lead to contamination but also promote the growth of both spoilage and pathogenic bacteria in meat (Ahmad *et al.*, 2013). The meat industry produces large amount of high-strength byproducts and waste from slaughterhouses, which, if untreated, can cause significant impact on the environment in China. These waste products are rich in protein and lipids, which could be successfully used for energy and nutrient recovery (Wang *et al.*, 2024).

With all the animal products like meat, fish, and fishery products often described as high-risk commodities due to their potential for harboring pathogens, natural toxins, and other contaminants, food security is a complicated issue (Yousuf *et al.*, 2008). Depending on the quantity of contaminated food consumed and the individual's exposure to the pathogens, foodborne diseases, caused by consuming of different harmful bacteria, toxins, and microbial cells, differ in severity (Clarence *et al.*, 2009). Foodborne contamination contributes significantly to healthcare burdens in the industrialized nations, (Adak *et al.*, 2005). According to Pereira *et al.* (2024) slaughterhouse and abattoirs activities is an alert to environmental and public health issues due to the large volume of effluents produced. As mentioned by Kebede *et al.* (2023), in abattoirs, the majority of respondents (87.5%) concur that there were some challenges in achieving slaughtering in the working environment. Food borne infections and diseases is a vital international health problem with consequent economic depletion is a major cause of illness and death worldwide (Adak *et al.*, 2005). Recognizing this, the World Health Organization (WHO) developed its Global Strategy for Food Safety (Adak *et al.*, 2005). In the developing world, food-borne contamination leads to the death of many children and the resulting diarrheal disease can have long-term impact on children's growth as development (Adak *et al.*, 2005).

Lagrimas *et al.* (2020) noted that *Trichinella* spp. one of the major prevalent food-borne zoonotic parasites worldwide, posing danger to human health, pig farming, and food safety. However, in the livestock production in the Philippines, there are still lacking researches. Immunoglobulin G (IgG) antibodies in the province of Bulacan and exploring the relationship between its presence and common animal husbandry practices. The study was done in selected abattoirs, where pigs were randomly chosen for sampling. Overall, the findings in Bulacan, Philippines shows that *Trichinella* spp. antibodies has a very low prevalence. The study highlights a valuable

early screening method for *Trichinella* in hogs, without the need to sacrifice animals for testing. These outcomes suggest the need for broader screening and further investigation of *Trichinella* spp. in pigs across other provinces in the Philippines. According to Auditors of Moroccan Court, the standards they required for slaughterhouses do not meet the basic conditions. Bacteriological results indicate a need to improve the available slaughter facilities and develop an appropriate slaughter process strategy to minimize the risk of carcass contamination (Muhammed *et al.*, 2022). The disinfection procedure was partly effective in reducing of microbial contamination of the environment, significantly reducing bacterial diversity and favoring some genera such as Psychrobacter and Weissella confuse (Sui *et al.*, 2023).

The predominant factors led to the contamination of beef meat and seriously compromise the quality of the meat products are poor personal hygiene along with low educational status, lack of training on food handling, personal and environmental hygiene, poor sanitation of the butcher shops and slaughterhouses, no veterinary laboratory, sterilization facilities, hot water service, and hazard analysis and critical control point (Codex Alimentarius Commission, 2020). According to Chelea *et al.*, 2019 training on Good Manufacturing Practices and implementation of HACCP principles is an urgent need for the slaughterhouse personnel. To control the food-borne illnesses and to keep the microbial load of raw meat in check, the food safety requirements should be followed strictly in accordance with HACCP (Hazard analysis critical control point), but in developing countries like Pakistan, the abattoir environment, its sanitary level, and transportation and storage conditions because it can not only contaminate but also enhance the growth of different types of spoilage as well as pathogenic bacteria in meat. (Ahmad *et al.*, 2013). As reported by Reta *et al.*, 2023 chickens are the main reservoirs of Salmonella and the slaughterhouse is the sites for cross-contamination of pathogens. Regardless of the sample weight, time of contact, and amount of inoculum, cross-contamination were occurred.

In accordance with Aenedo *et al.* (2019) cross-contamination during the transportation and slaughter process is very important but Campylobacter spp. infected flocks may be a source of these bacteria in the corresponding carcasses. The proliferation of bacteria, particularly Campylobacter, and the contamination of broiler carcasses by the bacteria found in the intestinal material during processing could lead to monitoring hygienic status (Khalefa and Laban *et al.*, 2023). Cabral and Pansanhagen (2017) noted that it is imperative to enforce sanitary inspections in slaughterhouses and to apply good manufacture practices to assure the safety of the produced pork. The monitoring of critical points, slaughterhouse equipment, good slaughtering practices, and effective washing and disinfection are the keys to obtaining good microbiological results (Delhalle *et al.*, 2008). Equipment frequently comes into direct contact with the carcass is critical to thoroughly remove the microorganisms through accurate cleaning to prevent the spread of microbial contamination on the carcasses (Nakamura *et al.*, 2022). The major sources of gut AMR bacteria on slaughtered meat were cross contaminated during the slaughter process (Wu *et al.*, 2022). The spread of antimicrobial resistance (AMR) is an impending crisis highlighted by the emergence of multidrug-resistant (MDR) pathogenic foodborne bacteria, like MDR *Salmonella enterica* due to the misuse and overuse of antibiotics in agricultural and livestock industries Hence, quick, and accurate identification of AMR and resistance genes are of utmost importance to treat infections, monitor or safeguard food production, and trace the sources of AMR outbreaks. Conventional methods of antimicrobial susceptibility testing (AST) such as disk diffusion assays are relatively inexpensive but are labor-intensive, slow, and limited to phenotypic detection. Conversely, modern AST methods include DNA sequencing and polymerase chain reaction (PCR) sequencing that provide more accurate genotypic detection and more faster. This

study sought to detect resistance genes in *S. enterica* isolated from swine from Philippine slaughterhouses through various protocols of conventional and modern AST methods. Resistance to five antibiotic classes was examined. It was found that 50% (14/28) of the isolates were MDR, and resistance to tetracycline was found in all isolates. The most common genes detected from the isolates were tet(A) (39.3%), followed by tet(C) (28.6%), and tet(E) (25%). Also, 25% (7/28) and 25% (7/28) of isolates were resistant to one and two antibiotic classes, respectively. PCR methods were used only for detection of tetracycline resistance genes, as a model for molecular investigation. The results of this study demonstrated the growing prevalence of MDR in the agricultural industry and the necessity for improvement of its detection (Pagoso *et al.*, 2024). Sui *et al.*, 2023 emphasizes the importance of disinfection in the slaughterhouses and scientific suggestions for implementing effective disinfection. Improper slaughterhouse waste disposal may contaminate the environment with infective forms of parasites and pathogens (Besana *et al.*, 2020). Sabiniano (2015) recommended that control measures be implemented to reduce the risk, such as chilling of carcass to 7°C, loading the carcass in refrigerated vans, and application of proper cooking time and temperature on the pork belly.

According to the section 12 of the National Meat Inspection Code of the Philippines (R.A. 9296) (2005), the local government units should endeavor to improve meat facilities in order to comply with the national standards. Furthermore, these unaccredited slaughterhouses may increase the consumers' exposure to pathogens due to non-compliance to the meat hygiene program (Maranan *et al.*, 2008). According to Manalo and Gabriel (2020), the microbial populations of pork and chicken meats both increase during storage for 12 hours at ambient temperature, while pH and %Titratable Acidity of the meats are not significantly affected by this storage. Abattoir hygiene has an important impact on final microbiological status of chilled carcass, as well as prevention and minimization of consumers exposure to foodborne hazards associated with meat consumption (Nastasijevic *et al.*, 2022). It is the core objective of this study to determine the public health implications of microbial contamination in registered slaughterhouses in La Union, Philippines.

MATERIALS AND METHODS

Research design

For this study, the researcher used the gold standard method as described by Official Methods of Analysis or as stated in the Bacteriological Analytical Manual (BAM) for Aerobic Plate Count (APC) by Larry Maturin and James T. Peeler (January 2001). The Observational Study Design, particularly a cross-sectional method where the data were gathered in a single time point. Three samples were taken from each meat contact surfaces and meat parts from the four locally registered slaughterhouses.

Sources of data

Materials

The materials used in the collection of swab samples were prepared before the collection process. Sampling materials for personnel includes head cap, mask, sterile gloves, hand soap, laboratory gown and rubber boots while sampling materials for the carcass and facilities were Transport Medium (Buffered Peptone Water in tubes), sanitizing solution - 70% alcohol, cotton swab/sponge, tissue paper, cooler/ice box, forceps, coolant packs, scissors/knife, sterile cotton, sampling kit box, labelling, plastic bags and labelling tape.

Site selection and characterization

The study was conducted in selected locally registered slaughterhouses in La Union. These sites were purposively selected based on several criteria, including the presence of operational and locally registered slaughterhouses, accessibility, willingness of the local government units and slaughterhouse personnel to participate, and their representativeness in terms of slaughterhouse practices and capacities within the province. Prior

to data collection, each slaughterhouse was visited and assessed to gather preliminary information on their physical layout, sanitation practices, type of animals slaughtered, average slaughter volume, and hygiene protocols. Coordination was made with the Local Chief Executive by submitting a request letter which facilitated the conduct of the study and ensured compliance with ethical and safety standards.

Collection of samples

Samples were collected from four locally registered slaughterhouses located in 4 locally registered slaughterhouses in La Union. The sampling was categorized into three sources: Equipment, Butchers, and Pork Carcass. A. Equipment: Composite swab samples were collected from commonly used slaughterhouse equipment such as splitting saws or axes, butchers' knives, scalding vats, and meat hooks. These swabs were taken prior to the start of slaughtering operations to assess the baseline level of contamination on the surfaces of equipment. B. Butchers: Swab samples were also collected from the hands of slaughterhouse personnel before the slaughtering process began. This aimed in evaluating the hygienic status of the butchers' hands and the potential for cross-contamination. C. Pork carcass: Swab samples were taken from different parts of the pork carcass — specifically the ham, belly, and jowls — immediately after the slaughtering process. This was conducted to determine the level of microbial contamination on the meat surfaces post-processing. D. Sample storage and transport: Swab samples were stored in a cooler with ice or ice-gel pack at 4°C (39.2°F) and immediately transported to the laboratory for analysis

Sample analysis

The analysis of microbial contamination in the broiler meat samples included the identification and enumeration of five key microorganisms: Aerobic Plate Count (APC), *Staphylococcus aureus*, *Escherichia coli*, *Salmonella* spp., and coliform bacteria (Table 1).

Table 1. Microbial contamination scale for aerobic plate count, S*taphylococcus aureus, Escherichia coli,* coliform

Range (CFU / cm^2)	Interpretation	Description
<10	Excellent	Indicates very low microbial contamination.
10-10,000	Acceptable	Suggest good hygiene issues that requires improvement in cleaning and handling procedures.
10,001 – 100,000	Moderate risk	Potential hygiene issues that require improvement in cleaning and handling procedures.
100,001 – 1,000,000	High risk	Indicate serious contamination.
>1,000,001 or TNTC	Critical risk	Extremely high bacterial load.

The Aerobic Plate Count test was conducted to determine the overall bacterial load present in the meat. This test involved plating diluted meat samples onto nutrient agar and incubating them at 45° for 48 hours. The number of colony-forming units (CFUs) was then counted to assess general hygiene conditions; higher counts indicate possible spoilage and poor handling practices. *Staphylococcus aureus* was analyzed as an indicator of contamination from human sources, such as improper handling or poor personal hygiene. The samples were cultured on bacterial media like Baird-Parker agar, and characteristic colonies were confirmed through further biochemical tests. *Escherichia coli*, a strong indicator of fecal contamination, was tested by enriching samples and plating them on *E. coli*-specific media. Colonies exhibiting a metallic sheen on EMB agar were counted and confirmed. Detection of E. coli indicates lapses in sanitation or cross-contamination from unclean surfaces or equipment. For *Salmonella* spp., a multi-step process was used, starting with pre-enrichment in a non-selective broth, followed by selective enrichment and plating on *Salmonella*-selective agars such as Xylose Lysine Deoxycholate. Any presence of *Salmonella* is considered a critical health risk, requiring immediate corrective action as

it can cause severe foodborne illnesses. Lastly, Coliform bacteria were assessed as general indicators of environmental hygiene and sanitation. Meat samples were plated on coliform-selective media like Violet Red Bile Agar, and the resulting colonies were counted.

Data gathered and analysis

Aerobic plate count

This was executed on total plate count agar. The medium was autoclaved and maintained at 46°C. Samples were serially diluted and an aliquot of 1 ml of each of serial dilution will be transferred to the petri dishes (4-inch diameter) and molten agar (15-20 ml) were poured on it. Plates were gently swirled to uniformly mix the sample and incubated at 37°C for 24 hours. *Staphylococcus aureus* enumeration. Baird Parker agar (Oxoid, England), a selective medium for the isolation and counting of coagulase positive staphylococci was used for the enumeration of *Staphylococcus aureus* as described by (Bhandare *et al.*, 2007). *Escherichia coli* enumeration. This was enumerated on Eosin methylene blue agar by plating an appropriate dilution on plates followed by aerobic incubation at 37°C for 24hrs. After incubation E. coli were counted as colonies with distinct metallic sheen (Bhandare *et al.*, 2007). *Salmonella* isolation and identification. This was established by pre-enrichment of meat sample in lactose broth followed by enrichment in tetra-thionate broth and final detection on Bismuth sulphite agar, XLD and *Salmonella-Shigella* agar as recommended by WHO procedures. Coliforms. Enumeration was done on a standard colony counter. Picking out of individual colonies for interpretation was done. Data were analyzed using the Descriptive - Quantitative Analysis where values obtained from the samples in each slaughterhouse/municipality were presented and discussed.

RESULTS AND DISCUSSION

Occurrence of common food-borne pathogen in local slaughterhouse

Table 2 presents the occurrence of common foodborne pathogens - *Escherichia coli*, *Staphylococcus aureus*, *Salmonella* sp., and Coliform bacteria—in meat samples collected from four locally registered slaughterhouses in the Province of La Union. Each pathogen was marked as either present (+) or absent (-) based on laboratory analysis.

Table 2. Occurrence of common food-borne pathogen in local slaughterhouse (Meat contact surfaces and carcass)

Locally registered slaughterhouses	Pathogens			
	E. coli	*S. aureus*	*Salmonella* sp.	Coliform
A	+	+	-	+
B	+	+	+	+
C	+	+	_	+
D	+	+	-	+

Legend: positive (+) negative (-)

According to the results, Escherichia coli and Coliform bacteria were detected in all four slaughterhouses, indicating a consistent presence of fecal contamination. *Salmonella* sp. was only present in the Slaughterhouse B the highest number of detected pathogens (all four), while the other three locations - Slaughterhouse A, C, and D. Slaughterhouse B—each had three pathogens present. This implied that the presence of multiple pathogens in the slaughterhouses suggests insufficient hygiene and sanitation during slaughtering and meat handling. The universal presence of *E. coli* and Coliforms is a strong indicator of poor cleaning practices and potential contamination from fecal matter. The detection of *Staphylococcus aureus*—commonly linked to improper handling by personnel—further reflects the need for stricter hygiene protocols. Slaughterhouse B detection of *Salmonella* sp. highlights a serious concern for public health due to its potential to cause severe foodborne illness outbreaks. Given these findings, the four locally registered slaughterhouses may consider the comprehensive sanitation and safety management plan aimed at minimizing or eliminating the presence of these pathogens. Such a plan could include regular staff training, improved facility sanitation, stricter compliance with meat safety standards, and routine microbial testing. These findings are supported by Bhandari *et al.* (2018),

who reported high levels of microbial contamination in urban slaughterhouses lacking proper sanitary control. Furthermore, Grace *et al.* (2015) emphasized that the risk of zoonotic disease transmission increases in facilities with poor hygiene practices, underscoring the need for improved slaughterhouse management to protect public health.

Aerobic plate count (APC)

Table 3 presents the Aerobic Plate Count (CFU/cm²) of various meat contact surfaces and meat parts from four locally registered slaughterhouses in La Union. The meat contact surfaces include the bolo, butcher's knife, scalding vat, meat hook, and butcher's hand, while the meat parts tested are pork ham, pork belly, and pork jowls.

Laboratory analysis reveals a range of microbial contamination levels across the sampled sites. In Slaughterhouse A, most surfaces such as the bolo, meat hook, pork ham and belly were in the excellent range (<10 CFU/cm²). Butcher's knives and pork jowls were in moderate risk and scalding vat (1,890,000 CFU/cm²) showed critical risk levels, requiring urgent corrective measures (see Appendix B). In Slaughterhouse B, multiple contact surfaces such as the meat hook (690,000 CFU/cm²), butcher's hand (810,000 CFU/cm²), butcher's knife, scalding vat and pork carcass displayed Too Numerous To Count, indicating high risk to critical risk. In Slaughterhouse C, only butcher's knives displayed moderate risk and the rest showed critical risk levels exceeding 1,000,000 CFU/cm². Meanwhile, Slaughterhouse D had mostly acceptable to moderate counts; however, several samples including the pork jowls (330,000 CFU/cm²) and pork ham (840,000 CFU/cm²) indicate high risk, necessitating improvement in sanitation protocols.

Table 3. Aerobic plate count of different equipment, meat contact surfaces and pork carcass in four locally registered slaughterhouse in the Province of La Union

Locally registered slaughterhouse	Aerobic plate count (CFU/cm2) <10(CFU/cm2) <10⁶							
	Bolo	Butcher's Knife	Scalding Vat	Meat Hook	Butcher's Hand	Pork Ham	Pork Belly	Pork Jowls
A	<10	10000	1890000	<10	90000	<10	<10	10000
	<10	220000	<10	3000	70000	<10	<10	<10
	<10	20000	<10	<10	<10	<10	<10	280000
B	<10	TNTC	TNTC	690000	810000	TNTC	<10	1360000
	<10	<10	<10	<10	<10	TNTC	120000	TNTC
	100000	<10	TNTC	<10	TNTC	1660000	TNTC	TNTC
C	310000	10000	90000	80000	150000	10000	350000	TNTC
	<10	80000	10000	<10	10000	TNTC	170000	TNTC
	10000	90000	700000	1180000	20000	TNTC	TNTC	TNTC
D	<10	10000	TNTC	<10	<10	30000	70000	<10
	10000	1100000	40000	<10	<10	840000	70000	330000
	<10	TNTC	<10	<10	<10	210000	130000	260000

Legend: <10 (excellent), 10-10,000 (acceptable), 10,001 -100,000 (moderate risk), 100,001-1,000,000 (high risk), >1,000,001 – TNTC (critical risk)

These findings implied that while some slaughterhouses maintain good hygienic practices on specific surfaces, others demonstrate lapses that could pose serious food safety threats. Critical contamination levels, especially on surfaces like scalding vats and butcher's hands, suggest ineffective cleaning or handling practices that could lead to foodborne illnesses. The presence of high bacterial counts on meat parts such as pork jowls and belly, which are often directly consumed or processed, underscores the need for reinforced hygiene training, proper equipment sanitation, and stricter monitoring. According to the Food and Agriculture Organization (2019), aerobic plate counts exceeding 100,000 CFU/cm² on meat surfaces typically denote non-compliance with

hygiene standards and require immediate corrective action. Similarly, Jay *et al.* (2005) emphasized that contamination from improperly sanitized tools and surfaces could introduce pathogens into meat products, elevating public health risks. Regular monitoring and Good Manufacturing Practices (GMP) are therefore critical to ensuring safe and hygienic meat handling in slaughterhouses.

Staphylococcus aureus

The bolo, butcher's knives, butcher's hand, pork belly and pork jowls across all location fell within the excellent to acceptable category. However, the scalding vat and meat hook of Slaughterhouse C, scalding vat of S, alaughterhouse D and pork ham of Slaughterhouse B recorded Too Numerous To Count indicating critical risk. The results implied that some meat contact surfaces are effectively cleaned, while other surfaces, especially the scalding vat, require more stringent sanitation practices. The high counts in pork ham of Slaughterhouse B, indicate potential cross-contamination during handling. These findings are consistent with established food safety guidelines of the Food and Drug Administration (FDA) and the World Health Organization (WHO) emphasized the importance of controlling bacterial contamination in food production to prevent foodborne diseases (FDA, 2012; WHO, 2015). Modern Food Microbiology by Jay, Loessner, and Golden (2005), provide detailed information on food microbiology, including the significance of aerobic plate counts and *Staphylococcus aureus* contamination, reinforcing the need for stringent hygiene practices in slaughterhouses (Table 4).

Table 4. The aerobic plate count of *Staphylococcus aureus* (CFU/cm²) on various meat contact surfaces in slaughterhouses located in four locally registered slaughterhouses in La Union

Locally registered slaughterhouse	Aerobic plate count of *Staphylococcus aureus* (CFU/cm²) <1000							
	Bolo	Butcher's Knife	Scalding Vat	Meat Hook	Butcher's Hand	Pork Ham	Pork Belly	Pork Jowls
A	<10	<10	TNTC	<10	<10	<10	<10	<10
	<10	1000	<10	<10	<10	<10	<10	<10
	<10	<10	<10	<10	<10	<10	<10	<10
B	<10	<10	<10	<10	<10	<10	<10	10000
	<10	<10	<10	<10	<10	TNTC	<10	4000
	<10	<10	<10	<10	<10	9000	<10	5000
C	<10	<10	44000	3000	1000	1000	4000	<10
	<10	1000	19000	<10	2000	<10	14000	<10
	<10	3000	TNTC	TNTC	<10	6000	<10	<10
D	<10	<10	<10	<10	3000	<10	<10	<10
	<10	<10	TNTC	<10	<10	11000	<10	1000
	<10	<10	<10	<10	<10	<10	8000	<10

Legend: <10 (excellent), 10-10,000 (acceptable), 10,001 -100,000 (moderate risk) 100,001-1,000,000 (high risk) >1,000,001 – TNTC (critical risk)

Escherichia coli

Table 5 presents the Aerobic Plate Count (APC) of Escherichia coli (CFU/cm²) obtained from various meat contact surfaces in four locally registered slaughterhouses in the Province of La Union.

The results implied that all meat contact surfaces of the four locally registered slaughterhouse displayed excellent result and pork carcass showed acceptable result except for pork belly of Slaughterhouse D (21,000 CFU/ cm²) indicating moderate risk requires greater attention. These findings are consistent with established food safety guidelines of the Food and Drug Administration (FDA) and the World Health Organization (WHO) emphasize the importance of controlling bacterial contamination in food production to prevent foodborne diseases (FDA, 2012; WHO, 2015). Textbooks on food microbiology,

such as Modern Food Microbiology by Jay, Loessner, and Golden (2005), provide detailed information on food microbiology, including the significance of aerobic plate counts and Escherichia coli contamination, reinforcing the need for stringent hygiene practices in slaughterhouses. Furthermore, the DA Administrative Order No. 19 and the National Meat Inspection Service (NMIS) guidelines within the Philippines highlight the importance of adhering to proper sanitation to ensure meat safety within the local context. (DA, retrieved 2024; NMIS, retrieved 2024).

***Salmonella* sp.**

Table 6 presents the aerobic plate count of Salmonella sp. from various meat contact surfaces in locally registered slaughterhouses in La Union.

The data indicates that majority of samples across all slaughterhouses tested negative for *Salmonella* sp., indicating effective sanitation practices. However, Slaughterhouse B exhibited positive results for *Salmonella* sp. in several samples: pork ham, pork belly, and pork jowls. This suggests potential contamination issues specific to Slaughterhouse B particularly in the handling and processing of these pork products. The consistency of negative results in other slaughterhouses and on other surfaces underscores the importance of stringent hygiene protocols. The presence of Salmonella sp. in pork ham, pork belly, and pork jowls in Slaughterhouse B poses a significant food safety risk. *Salmonella* is a pathogenic bacterium that can cause foodborne illness, leading to symptoms like diarrhea, fever, and abdominal cramps. The positive results indicate potential fecal contamination or cross-contamination during the processing of pork in Slaughterhouse B. These findings are consistent with the Food and Drug Administration (FDA) and the World Health Organization (WHO) that emphasized the importance of controlling bacterial contamination, particularly *Salmonella* sp., in food production to prevent foodborne diseases (FDA, 2012; WHO, 2015). Modern Food Microbiology by Jay, Loessner, and Golden (2005), provide detailed information on food microbiology, including the significance of *Salmonella* sp. contamination, reinforcing the need for stringent hygiene practices in slaughterhouses. Furthermore, the DA Administrative Order No. 19 and the National Meat Inspection Service (NMIS) guidelines within the Philippines highlight the importance of adhering to proper sanitation to ensure meat safety within the local context (DA, retrieved 2024; NMIS, retrieved 2024).

Table 5. Aerobic plate count of *Escherichia coli* of different equipment, meat contact surfaces and pork carcass in four locally registered slaughterhouse in the Province of La Union

Locally registered slaughterhouse	Aerobic plate count of *Escherichia coli* (CFU/ cm²) <500							
	Bolo	Butcher's Knife	Scalding Vat	Meat Hook	Butcher's Hand	Pork Ham	Pork Belly	Pork Jowls
A	<10	<10	<10	<10	<10	5000	<10	<10
	<10	<10	<10	<10	<10	<10	<10	<10
	<10	<10	<10	<10	<10	1000	<10	<10
B	<10	<10	<10	<10	<10	<10	<10	<10
	<10	<10	<10	<10	<10	1000	1000	1000
	<10	<10	<10	<10	<10	2000	<10	<10
C	<10	<10	<10	<10	<10	2000	5000	<10
	<10	<10	<10	<10	<10	<10	1000	<10
	<10	<10	<10	<10	<10	<10	<10	<10
D	<10	<10	<10	<10	<10	<10	8000	<10
	<10	<10	<10	<10	<10	<10	21000	7000
	<10	<10	<10	<10	<10	1000	<10	<10

Legend: <10 (excellent), 10-10,000 (acceptable), 10,001 -100,000 (moderate risk), 100,001-1,000,000 (high risk), >1,000,001 – TNTC (critical risk)

Table 6. Aerobic plate count of *Salmonella* sp. of different equipment, meat contact surfaces and pork carcass in four locally registered slaughterhouse in the Province of La Union

Locally registered slaughterhouse	Aerobic plate count of *Salmonella* sp. (Negative)							
	Bolo	Butcher's Knife	Scalding Vat	Meat Hook	Butcher's Hand	Pork Ham	Pork Belly	Pork Jowls
A	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
B	-	-	-	-	-	-	-	-
	-	-	-	-	-	+	+	+
	-	-	-	-	-	+	+	-
C	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
D	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-

Legend: positive (+) negative (-)

Table 7. Aerobic plate count of coliform of different equipment, meat contact surfaces and pork carcass in four locally registered slaughterhouse in the Province of La Union

Locally registered slaughterhouse	Aerobic plate count of coliform (CFU/ cm²) <500							
	Bolo	Butcher's Knife	Scalding Vat	Meat Hook	Butcher's Hand	Pork Ham	Pork Belly	Pork Jowls
A	<10	<10	<10	<10	<10	2000	2000	<10
	<10	14000	<10	<10	<10	<10	2000	<10
	<10	<10	<10	<10	<10	<10	<10	1000
B	<10	TNTC	<10	TNTC	<10	<10	<10	TNTC
	TNTC	<10	<10	<10	<10	TNTC	7000	TNTC
	36000	<10	<10	<10	<10	5000	49000	TNTC
C	TNTC	<10	<10	11000	10000	2000	1000	TNTC
	<10	<10	<10	<10	1000	TNTC	<10	TNTC
	<10	<10	<10	<10	<10	TNTC	TNTC	TNTC
D	<10	<10	<10	<10	12000	<10	5000	<10
	<10	TNTC	TNTC	<10	<10	1000	4000	19000
	<10	TNTC	<10	<10	<10	<10	4000	1000

Legend: <10 (excellent), 10-10,000 (acceptable), 10,001 -100,000 (moderate risk) 100,001-1,000,000 (high risk) >1,000,001 – TNTC (critical risk)

This finding necessitates an immediate review of sanitation and handling procedures in the slaughterhouse B to prevent further contamination and protect public health. The consistently negative results in the other slaughterhouses suggest that effective hygiene practices are achievable and should be replicated in Slaughterhouse B.

Coliform

Aerobic Plate Count of Coliform (CFU/cm²) across various meat contact surfaces in four locally registered slaughterhouses is presented in Table 7. The acceptable limit for coliform contamination is set at <500 CFU/cm².

The data reveals significant variations in coliform contamination across different surfaces and slaughterhouses. Notably, several samples, particularly from Slaughterhouse B, C and D, showed "Too Numerous To Count" (TNTC) results, indicating extremely high coliform counts or critical risk. Only slaughterhouse A meat contact surfaces and pork carcasses displayed excellent to acceptable category. The result implied that the presence of high coliform counts, particularly the TNTC results, indicates significant fecal contamination and poor sanitation practices. Coliforms are indicator organisms for fecal contamination, and their high levels suggest a high risk of pathogenic bacteria being present. This poses a serious threat to food

safety. The variations in coliform counts across different surfaces and slaughterhouses highlight the need for consistent and thorough cleaning and disinfection procedures. The TNTC results indicate that immediate corrective actions are necessary to prevent foodborne illness.

These findings are consistent with established food safety guidelines of the Food and Drug Administration (FDA) and the World Health Organization (WHO) that emphasize the importance of controlling bacterial contamination, particularly coliforms, in food production to prevent foodborne diseases (FDA, 2012; WHO, 2015). According to Loessner, and Golden (2005), reinforcing the need for stringent hygiene practices in slaughterhouses. Furthermore, the DA Administrative Order No. 19 and the National Meat Inspection Service (NMIS) guidelines within the Philippines highlight the importance of adhering to proper sanitation to ensure meat safety within the local context (DA, retrieved 2024; NMIS, retrieved 2024

Table 8. Hygiene compliance of slaughterhouses A and B

Equipment & Facility	A		B	
	Status	Remarks	Status	Remarks
Hand washing facility	C/NS		C/NS	
Hand dryer		Under negotiation		Under negotiation
Hand dip		Under negotiation		Under negotiation
Tool dip		Under negotiation		Under negotiation
Scalding vat	C/NS		C/NS	
Dehairing machine	C/NS		C/NS	
Electric stunner % restraining box	C/NS		C/NS	
Dehairing table	C/NS		C/NS	
Inspection table	C/NS		C/NS	
Bolo	C/NS		C/NS	
Butcher's knife	C/NS		C/NS	
Meat hook	C/NS		C/NS	
Slaughterhouse area	Status	Remarks	Status	Remarks
Chute area	C/NS		C/NS	
Shower & bath area	C/NS		C/NS	
Restraining area	C/NS		C/NS	
Sticking and bleeding area	C/NS		C/NS	
Scalding and dehairing area	C/NS		C/NS	
Evisceration area	C/NS		C/NS	
Carcass washing area	C/NS		C/NS	
Visceral washing area	C/NS		C/NS	
Branding area	C/NS		C/NS	
Weighing area	C/NS		C/NS	
Dispatch/Loading area	C/NS		C/NS	
Personnel hygiene & use of personal protective equipment (PPE)	Status	Remarks	Status	Remarks
1.Use of hairnet, face mask, boots, apron	x	inc PPE	x	inc PPE
2.Wash hand before going to work,	√		√	no provision of hand sanitizer
3.Keep nails trimmed and clean	√		√	
4.Workers do not smoke, eat, spit and scratch body during operation	√		√	
5. No sick or wounded worker is allowed to work	√		√	

C – Clean, S – Sanitized, NS – Not Sanitized, √ - Conforms, X – Non-conforming

Hygiene compliance

Table 8 and 9 presented the hygiene compliance status of slaughterhouses in four municipalities of La Union. The checklist was categorized into three sections: Equipment and Facility, Slaughterhouse Area, and Personnel Hygiene and Use of Personal Protective Equipment (PPE). The hygiene assessment revealed notable gaps across the surveyed

slaughterhouses. In terms of equipment and facility availability, all four municipalities marked essential items such as hand dryers, tool dips, and scalding vats as "Under Negotiation," indicating that these resources were not yet procured or installed at the time of evaluation. Despite the presence of basic infrastructure, many of the listed areas were rated C/NS, implying that while these facilities existed, they were not regularly sanitized according to standard protocols. Moreover, sanitation practices seemed to be inconsistent across sites. For example, all slaughterhouse areas—such as the sticking and bleeding area, carcass washing area, and weighing area—were noted as present but not necessarily maintained in a sanitized condition. Personnel hygiene compliance varied. While all sites acknowledged the inclusion of PPE, remarks showed differences in completeness and consistency. Notably, Slaughterhouse B and C reported a lack of hand sanitizer provision, which is a basic requirement for hygiene maintenance. Nevertheless, most personnel were observed in practice with acceptable hygiene habits, such as maintaining trimmed nails, refraining from smoking or eating while working, and not allowing sick workers to participate in operations.

Table 9. Hygiene compliance of slaughterhouses C and D

Equipment & Facility	C		D	
	Status	Remarks	Status	Remarks
Hand washing facility	C/NS		C/NS	
Hand dryer		Under negotiation		Under negotiation
Hand dip		Under negotiation		Under negotiation
Tool dip		Under negotiation		Under negotiation
Scalding vat	C/NS		C/NS	
Dehairing machine	C/NS		C/NS	
Electric stunner % restraining box	C/NS		C/NS	
Dehairing table	C/NS		C/NS	
Inspection table	C/NS		C/NS	
Bolo	C/NS		C/NS	
Butcher's knife	C/NS		C/NS	
Meat hook	C/NS		C/NS	
Slaughterhouse area	Status	Remarks	Status	Remarks
Chute area	C/NS		C/NS	
Shower& bath area	C/NS		C/NS	
Restraining area	C/NS		C/NS	
Sticking and bleeding area	C/NS		C/NS	
Scalding and dehairing area	C/NS		C/NS	
Evisceration area	C/NS		C/NS	
Carcass washing area	C/NS		C/NS	
Visceral washing area	C/NS		C/NS	
Branding area	C/NS		C/NS	
Weighing area	C/NS		C/NS	
Dispatch/Loading area	C/NS		C/NS	
Personnel hygiene & use of personal protective equipment (PPE))	Status	Remarks	Status	Remarks
1.Use of hairnet, face mask, boots, apron	x	inc PPE	x	inc PPE
2.Wash hand before going to work,	x	No provision of hand sanitizer	x	No provision of hand sanitizer
3.Keep nails trimmed and clean	√		√	
4.Workers do not smoke, eat, spit and scratch body during operation	√		√	
5. No sick or wounded worker is allowed to work	√		√	

C – Clean, S – Sanitized, NS – Not Sanitized, √ - Conforms, X – Non-conforming

The findings imply several important issues that needed to be addressed to improve slaughterhouse hygiene in La Union. The absence of essential equipment such as hand dryers, hand and tool dip due to ongoing procurement negotiations suggested administrative or budgetary constraints that may

hinder the full implementation of sanitation standards. The consistent classification of critical slaughterhouse areas as "Not Sanitized" highlighted the urgent need for routine cleaning and disinfection to prevent microbial contamination and ensure food safety. Inadequate hygiene among personnel, particularly due to the unavailability of hand sanitizers and inconsistent PPE usage, posed additional risks. These gaps, if unaddressed, could compromise meat quality, endanger consumer health, and potentially violate national food safety regulations. The observed practices pointed to a need for stricter enforcement of hygiene protocols, better resource allocation, and increased awareness among slaughterhouse workers regarding proper sanitation and biosecurity measures.

The importance of hygiene and sanitation in slaughterhouses is well-supported by literature. According to the Food and Agriculture Organization (FAO, 2019), proper hygiene in meat production facilities is critical in reducing the risk of foodborne illnesses and ensuring the safety of meat products. Sanitation measures, including handwashing, regular cleaning of equipment, and use of PPE, are essential components of Good Hygienic Practices (GHP) in meat processing. As noted by Gracey and Collins (1992), inadequate hygiene in slaughterhouses not only affects the immediate quality of meat but also has long-term public health implications. Moreover, the Department of Agriculture's Administrative Order No. 5, Series of 2010, emphasizes the implementation of Standard Sanitation Operating Procedures (SSOPs) and the proper use of sanitation facilities and equipment in all accredited slaughterhouses in the Philippines. These references underscore the need for timely procurement of sanitation facilities and strict adherence to hygiene protocols to safeguard consumer health and maintain compliance with national and international standards.

Comprehensive plan

The Comprehensive Plan for the Improvement of Locally Registered Slaughterhouse Operation presents a strategic and integrated framework designed to enhance the safety, hygiene, and efficiency of meat processing in local slaughterhouses. The plan outlines critical interventions, including personnel training, provision of personal protective equipment (PPE), modernization of facilities, implementation of structured workflows, and strict sanitation and biosecurity protocols. With a total budget of ₱300,000, the plan allocates resources toward training, equipment, sanitation supplies, and staffing. These components are geared toward minimizing microbial contamination, ensuring regulatory compliance, and improving the overall quality of meat produced for local consumption.

The plan effectively addresses the root causes of microbial contamination in slaughterhouses—namely, poor hygiene practices, inadequate equipment, and limited staff training. By prioritizing regular training on Good Hygienic Slaughtering Practices (GHSP) and Good Manufacturing Practices (GMP), the plan enhances the competency of butchers and operators. The proposed upgrades to infrastructure, including hand and foot baths, tool dips, and handwashing stations, are evidence-based interventions that reduce cross-contamination risks. Additionally, assigning personnel to specific tasks and enforcing sanitation both inside and outside the facility demonstrate a holistic understanding of meat safety. Overall, the plan combines hardware (infrastructure and equipment) with software (knowledge and behavior change) for a comprehensive solution.

Implementing this plan is expected to yield significant improvements in public health, consumer safety, and community trust in local meat products. Enhanced sanitation and operational standards can reduce the incidence of foodborne illnesses, contribute to environmental protection, and improve the marketability of locally produced meat. Furthermore, offering incentives to personnel based on operational profit can lead to higher staff morale and increased accountability. On a broader scale, the successful implementation of this initiative can serve as a replicable model for other municipalities aiming to

upgrade their slaughterhouse facilities and align with national and international food safety standards.

The components of this plan are supported by established literature emphasizing the importance of hygienic practices and infrastructure in meat processing. According to Gracey *et al.* (2015) hygienic design and proper personnel training are crucial to preventing contamination in abattoirs. The Food and Agriculture Organization, (2001) also stresses the significance of workflow separation, personal hygiene, and biosecurity in reducing microbial hazards in meat processing facilities. In line with these recommendations, the World Health Organization, (2006) advocates for capacity building and sanitation infrastructure to improve food safety outcomes in developing regions. These references validate the strategies employed in the plan and reinforce the necessity of integrated interventions.

CONCLUSION

The common food borne pathogens present in the four locally registered slaughterhouses were *Eschirichia coli*, *Staphylococcus aureus*, *Salmonella* sp., and Coliforms. Slaughterhouse B and C had the most frequent instances of high contamination, with "Too Numerous To Count" results in key areas like scalding vats and meat products. *Staphylococcus aureus* was present in several locations, with TNTC levels in scalding vats across all areas, indicating serious contamination. High levels of *E. coli* were found in pork jowls in slaughterhouse D, exceeding the safe limit. Coliform bacteria were widespread, with TNTC levels found on equipment and meat in slaughterhouse B and C. Some samples in slaughterhouse B also tested positive for Salmonella. The proliferation of microbial species in meat swabs from the slaughterhouses can be attributed to poor hygiene and sanitation practices, including the lack of hand dryers, hand dips, tool dips, and disinfectants. The absence of proper hand sanitation measures and incomplete use of personal protective equipment (PPE) increase the risk of bacterial contamination from workers and surfaces to the meat. Additionally, the unavailability of disinfectants and poorly maintained equipment create an environment where bacteria can thrive, leading to higher microbial loads. Without proper cleaning and sanitation protocols, cross-contamination becomes inevitable, compromising meat safety and quality.

To improve the operation of Locally Registered Slaughterhouses in La Union, a comprehensive plan should focus on enhancing sanitation practices, staff training, and equipment maintenance. This includes implementing strict cleaning protocols, regular microbial testing, and ensuring compliance with food safety regulations like Hazzard Analysis Critical and Control Points and Good Manufacturing Practices. Staff should receive continuous training on proper hygiene and meat handling, while the slaughterhouses should invest in modern, easy-to-clean equipment and temperature-controlled storage. Additionally, improved post-slaughter handling, including reduced direct meat contact and proper packaging, will minimize contamination. Ongoing audits, data-driven decision-making, and community engagement will ensure the slaughterhouses meet high hygiene and quality standards, reducing foodborne risks and boosting consumer confidence.

REFERENCES

Adak G, Meakin S, Yip H, Lopman B, O'Brien S. 2005. Disease risks from foods, England and Wales, 1996–2000. Emerging Infectious Diseases **11**(3), 365–372. https://doi.org/10.3201/eid1103.040191.

Adu-Gyamfi A, Torgby-Tetteh W, Appiah V. 2012. Microbiological quality of chicken sold in Accra and determination of D10-value of *E. coli*. Food and Nutrition Sciences **3**(5), 693–698. http://dx.doi.org/10.4236/fns.2012.35094.

Aenedo I, Fandos E. 2019. Prevalence of *Campylobacter* spp. in poultry in three Spanish farms, a slaughterhouse and a further processing plant. Foods **8**(3), 111. https://doi.org/10.3390/foods8030111.

Agu AP, Onah CK, Umeokonkwo CD, Nnbabu RC, Una A. 2021. Hygiene practices in abattoir and slaughter slab, determinants and assessment of abattoir and slaughter slab facilities in Abakaliki, Ebonyi State South-East Nigeria. African Health Sciences **21**(4), 1914–1923. https://doi.org/10.4314/ahs.v21i4.50.

Ahmad M, Sarwar A, Najeeb M, Nawaz M, Anjum A, Ali M, Mansur N. 2013. Assessment of microbial load of raw meat at abattoirs and retail outlets. The Journal of Animal & Plant Sciences **23**(3), 745–748. https://www.researchgate.net/publication/287524023.

Alvez M, Carvalho M, Ribeiro D, Barbosa J, Silveira L, Pista A, Pinto H, Saraiva C, Teixeira P, Esteves A. 2022. Hygiene indicators and *Salmonella* on surfaces of swine carcasses from two slaughterhouses in Northern Portugal. Journal of Food Protection **85**(11), 1566–1575. https://doi.org/10.4315/JFP-21-312.

Besana C, Paller V. 2020. Evaluation of selected slaughterhouses and parasites of slaughtered livestock in Cotabato Province, Mindanao, Philippines. Journal of Livestock Science **11**, 67–76. https://livestockscience.in/wp-content/uploads/slaughterhouse-philippines.pdf.

Bhandare S, Sherikar A, Paturkar A, Waskar V. 2007. A comparison of microbial contamination on sheep/goat carcasses in a modern Indian abattoir and traditional meat shops. Food Control **18**(7), 854–858. https://doi.org/10.1016/j.foodcont.2006.04.013.

Bhandari D, Terao M, Goto K. 2018. Assessment of microbial contamination in meat from urban slaughterhouses in developing countries. Journal of Food Protection **81**(9), 1451–1457. https://doi.org/10.4315/0362-028X.JFP-17-551.

Cabra C, Pansanhagen P. 2017. Contamination of carcasses and utensils in small swine slaughterhouses by *Salmonella* in the northwestern region of the State of Rio de Janeiro, Brazil. Journal of Food Protection **80**(7), 1128–1133. https://www.sciencedirect.com/science/article/pii/S0362028X22098027.

Chelea M, Luzy N, Anna Z, Marie N. 2019. Factors influencing *Salmonella* contamination and microbial load of beef carcass at the Yaoundé slaughterhouse, Cameroon. https://www.researchgate.net/publication/336849979.

Clarence SY, Obinna CN, Shalom NC. 2009. Assessment of bacteriological quality of ready to eat food (meat pie) in Benin City Metropolis, Nigeria. African Journal of Microbiology Research **3**(6), 390–395. https://www.researchgate.net/publication/202030919.

Codex Alimentarius Commission. 2005. Code of hygienic practice for meat (CAC/RCP 58-2005). FAO/WHO.

Codex Alimentarius Commission. 2020. General principles of food hygiene. CAC/RCP 1-1969.

Delhalle L, De Sadeleer L, Bollaerts K, Farnir K. 2018. Risk factors for *Salmonella* and hygiene indicators in the 10 largest Belgian pig slaughterhouses. Food Protection **71**(7), 1320–1329. https://doi.org/10.4315/0362-028x-71.7.1320.

Department of Agriculture. 2010. DA Administrative Order No. 19. Guidelines on good hygienic slaughtering practices for locally registered meat establishments (GHSP-LRMES). https://elibrary.judiciary.gov.ph/thebookshelf/showdocs/10/57297

Department of Agriculture. 2010. DA Administrative Order No. 5, Series of 2010. Guidelines on good manufacturing practices in slaughterhouses and meat establishments.

Doyle ME. 2007. Microbial food spoilage – losses and control strategies: A brief review of the literature. FRI Briefing. https://fri.wisc.edu/files/Briefs_File/2017-07.

El-Nemr I, Mushtaha M, Irungu P, Asim H, Tang P, Hasan M, Goktepe I. 2019. Assessment of food safety knowledge, self-reported practices, and microbiological hand hygiene levels of produce handlers in Qatar. Journal of Food Protection **82**(4), 561–569. https://doi.org/10.4315/0362-028X.JFP-18-191.

Ercolini D, Russo F, Torrieri E, Masi P, Villani F. 2006. Changes in the spoilage-related microbiota of beef during refrigerated storage under different packaging conditions. Applied and Environmental Microbiology **72**(7), 4663–4671.

Food and Agriculture Organization. 2001. Guidelines for slaughterhouse hygiene. Rome: FAO.

Food and Agriculture Organization. 2019. Good practices for the meat industry. FAO Animal Production and Health Manual.

Food and Agriculture Organization. 2019. Meat inspection and control in the slaughterhouse.

Food and Drug Administration. 2012. Bad bug book: Foodborne pathogenic microorganisms and natural toxins handbook. 2nd ed. U.S. FDA.

Gill CO, Bryant J, Brereton D. 2000. Microbiological conditions of sheep carcasses from conventional or inverted dressing processes. Journal of Food Protection **63**(9), 1291–1294.

Grace D, Mutua F, Ochungo P, Kruska R, Jones K, Brierly L. 2015. Mapping of poverty and likely zoonoses hotspots. ILRI Report to the UK Department for International Development. https://hdl.handle.net/10568/21161.

Gracey J, Collins D, Huey R. 2015. Gracey's meat hygiene. 11th ed. Wiley-Blackwell. https://vetbooks.ir/graceys-meat-hygiene-11th-edition/

Gracey J, Collins D. 1992. Meat hygiene. 9th ed. Bailliere Tindall.

Jay J, Loessner M, Golden D. 2005. Modern food microbiology. 7th ed. Springer Science & Business Media.

Käferstein FK. 2003. Actions to reverse the upward curve of foodborne illness. Food Control **14**(2), 101–109.

Kebede M, Getu A. 2023. Assessment of bacteriological quality and safety of raw meat at slaughterhouse and butchers' shop (retail outlets) in Assosa Town, Western Ethiopia. BMC Microbiology **23**(1), 403. https://doi.org/10.1186/s12866-023-03106-2.

Khalefa H, Laban E. 2023. Impact of microbial load of slaughterhouse environment on the degree of broiler chicken carcass contamination, with a focus on *Campylobacter* prevalence. Journal of Food Science and Engineering **9**, 266–275.

Lagrimas D, Gonzales R, Briones J. 2021. Low levels of *Trichinella* spp. antibodies detected in domestic pigs at selected slaughterhouses with farm-based exposure assessment in Bulacan, Philippines. Veterinary Parasitology **297**, September 2021. https://www.researchgate.net/publication/376377334.

Li M, Zhou X, Xu C, Zhu W. 2006. Changes of bacterial diversity and main flora in chilled pork during storage using PCR-DGGE. Food Microbiology **23**(7), 607–611. https://doi.org/10.1016/j.fm.2006.01.004.

Manalo M, Gabriel A. 2020. Changes in the physicochemical and microbiological properties of pork and chicken meats at ambient storage condition. Institute of Meat Hygiene and Technology **61**(1).

Maranan R, Paraso M, Alcantara A, Espaldo M, Alaira S, Sevilla C, Valdez C. 2008. Operations and waste management of slaughterhouses in the Province of Laguna. Journal of Environmental Science and Management **11**(2), 32–41.

Maturin L, Peeler J. 2001. Bacteriological analytical manual, Chapter 3: Aerobic plate count. FDA, U.S. Food and Drug Administration.

Mohammed AB, Errachidi I, Hemlali M, Sarhane B, Tantane A, Mohammed A, Belkadi B, Filali-Maltouf A. 2022. Knowledge, attitude, and practices (KAP) regarding meat safety and sanitation among carcass handlers operating and assessment of bacteriological quality of meat contact surfaces at the Marrakech slaughterhouse, Morocco. International Journal of Food Science **2022**, 4881494. https://doi.org/10.1155/2022/4881494

Mohammed N, Mulu D. 2021. Assessment of hygienic practices and microbial quality of meat at slaughterhouses and butcher's shops in West Hararghe Zone, Ethiopia. Abyssinia Journal of Science and Technology **6**(2), 32–41.

Nakamura A, Takahashi H, Kondo A, Koike F, Kuda T, Kimura B. 2022. Distribution of psychrophilic microorganisms in a beef slaughterhouse in Japan after cleaning. PLoS ONE **17**(8), e0268411. https://doi.org/10.1371/journal.pone.0268411

Nastasijevic I, Cabrol M, Glisic M. 2022. Abattoir hygiene: Present knowledge in food safety – a risk-based approach through the food chain. https://doi.org/10.1016/B978-0-12-819470-6.00002-0

National Meat Inspection Service. 2025. https://www.nmis.gov.ph/

Norrung B, Andersen JK, Buncic S. 2009. Main concerns of pathogenic microorganisms in meat. In: Toldrá F (ed.), Safety of Meat and Processed Meat, Food Microbiology and Food Safety Series. Springer, New York, pp. 3–29.

Olaoye OA. 2011. Meat: An overview of its composition, biochemical changes and associated microbial agents. International Food Research Journal **18**(3), 877–885.

Ovuro K, Izah S, Ogidi O, Imarhiagne O, Ogwu M. 2023. Slaughterhouse facilities in developing nations: sanitation and hygiene practices, microbial contaminants and sustainable management system. Food Science and Biotechnology **33**(3), 519–537. https://doi.org/10.1007/s10068-023-01406-x

Pagoso E, Grabiel A, Aldaba M, Rivera W. 2024. Identification of antimicrobial resistance in *Salmonella enterica* isolates from swine slaughterhouses in the Philippines through different antimicrobial susceptibility test protocols. Asia-Pacific Journal of Science and Technology. https://www.tci-thaijo.org/index.php/APST/index

Pereira DS, Karla A. 2024. A critical review on slaughterhouse wastewater: Treatment methods and reuse possibilities. Journal of Water Process Engineering **58**, 104819.

Reta G, Lopes S, Soraya N, De Aquino M, Tondo T. 2023. Quantification of *Salmonella* transfer in cross-contamination scenarios found in chicken slaughterhouses. Food Microbiology **116**, 104347. https://doi.org/10.1016/j.fm.2023.104347

Sabiniano J. 2015. Quantitative microbiological risk assessment of non-typhoidal *Salmonella* in pork belly under Philippine setting. Southeast Asian Regional Center for Graduate Study and Research in Agriculture. https://www.searca.org/pubs/abstracts-theses-dissertations/database/view

Shunli W, Zehui W, Lili W. 2024. Improving slaughterhouse byproducts utilization via anaerobic digestion, composting, and rendering. Renewable & Sustainable Energy Reviews **189**, 113881.

Sui L, Yi Z, Xiao X, Ma J, Huang H. 2023. Investigation of microbial communities across swine slaughter stages and disinfection efficacy assessment in a pig slaughterhouse. LWT - Food Science and Technology **187**, 115334.

Wang L, Liu N, Gao Y, Liu J, Huang X, Zhang Q, Li Y, Zhao J, Wang J, Zhao G. 2021. Surveillance and reduction control of *Escherichia coli* and diarrheagenic *E. coli* during the pig slaughtering process in China. Frontiers in Veterinary Science **8**, 735076. https://doi.org/10.3389/fvets.2021.735076

Wang S, Wei Z, Wang L. 2024. Improving slaughterhouse byproducts utilization via anaerobic digestion, composting, and rendering. Renewable and Sustainable Energy Reviews **189**, 113881. https://doi.org/10.1016/j.rser.2023.113881

World Health Organization. 2006. Five keys to safer food manual. Geneva: WHO Press.

World Health Organization. 2015. WHO estimates of the global burden of foodborne diseases: foodborne botulism, campylobacteriosis, and listeriosis. World Health Organization.

Wu X, Suksawat F, Angkititrakul S, Song C. 2022. A systematic review: The source of antimicrobial resistance pathogenic bacteria on slaughtered meat, cross-contamination or self-contamination? Thai Journal of Veterinary Medicine **52**(3). https://he01.tci-thaijo.org/index.php/tjvm/article/view/258351

Yousuf A, Ahmed M, Yeasmin S, Ahsan N, Rahmann M, Islam M. 2018. Prevalence of microbial load in shrimp, *Penaeus monodon* and prawn, *Macrobrachium rosenbergii* from Bangladesh. World Journal of Agricultural Sciences **4**(S), 852–855.