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RESEARCH ARTICLE

Impact of the Evisceration Process on the Hygiene Standards of Carcasses within Slaughterhouses

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ABSTRACT

Red meat is a vital component of a balanced diet due to its rich nutritional content, particularly its high-quality proteins. However, it can also serve as a conducive environment for the proliferation of numerous bacteria. To assess the level of hygiene and microbial contamination in red meat, a comprehensive study was conducted, both before and after the evisceration stage at a slaughterhouse. This study involved meticulous swabbing of three bovine carcasses, five sheep carcasses, and two goat carcasses, focusing on three specific anatomical regions: the shoulder, flank, and thigh. The swabbing method used was the standard microbiological procedure of wet swabbing. The primary objective of this investigation was to quantify and categorize two critical surface microbiota: the total aerobic mesophilic flora and coliforms. The collected samples underwent thorough phenotypic characterization using established microbiological techniques. It is essential to note that the distribution of microbial populations on the surfaces of bovine, sheep, and goat carcasses displayed significant non-uniformity. This irregular pattern reflects the complex interplay of environmental factors and microbial interactions during the meat production process. Before the evisceration stage, the average coliform counts were approximately 3.87 log10 CFU/cm^2 for bovine carcasses, 3.65 log10 CFU/cm^2 for sheep carcasses, and 3.43 log10 CFU/cm^2 for goat carcasses. However, after the evisceration stage, these counts increased, reaching 4.97 log10 CFU/cm^2 for bovine, 3.98 log10 CFU/cm^2 for sheep, and 4.26 log10 CFU/cm^2 for goats. Regarding the total aerobic mesophilic flora, microbial quantification before evisceration showed counts of 4.09 log10 CFU/cm^2 for bovine carcasses, 4.05 log10 CFU/cm^2 for sheep carcasses, and 3.65 log10 CFU/cm^2 for goat carcasses. After evisceration, these counts notably rose to 4.44 log10 CFU/cm^2 for bovine, 4.52 log10 CFU/cm^2 for sheep, and 5.09 log10 CFU/cm^2 for goats. It is crucial to emphasize that the recorded microbial counts exceeded acceptable contamination thresholds, indicating a level of concern higher than what has been reported in similar studies in the microbiological literature. This increase in contamination levels suggests potential lapses in hygiene protocols during meat processing stages.

INTRODUCTION

Red meat is renowned for its integral role in balanced diets, primarily due to its rich nutritional composition, notably its high-quality proteins. However, the nutrient-rich milieu that red meat offers can also serve as an inviting habitat for the proliferation of an array of bacteria, a phenomenon substantiated by extensive research in the field (Mescle et al., 1996; Guiraud, 1998; Fosse et al., 2006). Such studies underscore the imperative of maintaining stringent hygiene standards throughout the meat processing chain to mitigate potential microbial contamination risks.

Within this intricate web of meat production, the slaughterhouse represents the pivotal initial node. Paradoxically, it is here, where the journey from livestock to consumer commences, that significant challenges concerning meat contamination emerge. Pertinently, it has been reported that a substantial portion, ranging from 80% to 90%, of the microflora encountered in meat ultimately consumed by the public results from contamination events unfolding within the confines of these very slaughterhouses (Biss, 1998; Fosse and Margas, 2004; Dieye, 2011).

The potential for contamination of meat carcasses materializes at multiple junctures during the complex slaughtering and processing stages. These points of vulnerability encompass the phases of bleeding, evisceration, equipment manipulation, and human interaction. Of particular concern, the evisceration stage presents an environment ripe for bacterial dissemination across the surfaces of carcasses, a phenomenon substantiated by previous investigations (Collobert et al., 2002; El-Hadef et al., 2005; Bhandare et al., 2007). This concern becomes even more pronounced when the contaminants include pathogenic bacteria known to cause foodborne illnesses. Remarkably, such contaminations often evade detection during routine health inspections, necessitating the adoption of alternative and more rigorous control measures (FAO, 2006; Cartier, 2007; Bensid, 2018).

In response to these pressing concerns, the central objective of our experimental study is to conduct a comprehensive evaluation of hygiene levels and surface contamination across various types of carcasses, encompassing bovine, sheep, and goats, within the controlled environment of a slaughterhouse. Our assessment extends across both pre-evisceration and post-evisceration phases. To this end, we employ meticulous bacteriological examinations of carcass surfaces, guided by rigorous scientific protocols and methodologies.

By elucidating the intricate dynamics of microbial contamination within the slaughterhouse environment, our research endeavors to enrich the scientific understanding of these critical processes. Moreover, the insights gained hold the promise of not only advancing the field of food safety but also contributing to the development of enhanced meat processing practices. Ultimately, this scientific pursuit seeks to safeguard public health by reducing the risks associated with microbial contamination in meat products, ensuring the continued availability of safe and nutritious red meat for consumers worldwide.

LITRATURE REVIEW

Red meat, a nutritional cornerstone, celebrated for its nutrient richness, especially its high-quality protein content, stands as an indispensable constituent of the human diet. However, the nutrient-dense milieu inherent to red meat also serves as a fertile habitat for a diverse array of microorganisms, presenting profound implications for food safety and public health.

Microbial Contamination in Slaughterhouses Slaughterhouses, acting as the inaugural point in the meat production continuum, bear a monumental responsibility in upholding food safety. A substantial body of scientific evidence consistently underscores slaughterhouses as epicenters for microbial contamination (Parsons et al., 2005; Rani et al., 2017). These studies have elucidated the profound influence of slaughterhouse environments on the microbial landscape of meat products intended for human consumption. Notably, Gill et al. (1998) illuminated that a significant proportion, ranging from 80% to 90%, of the microbial biota encountered in meat earmarked for consumption can be attributed to contamination events transpiring within these sanctuaries of meat processing.

Evisceration and Contamination Risks Of particular biological significance is the evisceration process, wherein the strategic removal of internal organs from carcasses unveils a critical juncture rife with elevated microbial contamination risks (Chenoll et al., 2007; Wardhana et al., 2019). These studies cogently articulate that evisceration serves as a conduit for bacterial dissemination across carcass surfaces, accentuating its central role in the ecological dynamics of meat hygiene. Microbial communities undergo intricate shifts during this process, driven by factors such as temperature, moisture, and the intrinsic microbial diversity of the slaughterhouse environment.

Foodborne Pathogens and Public Health Of paramount biological concern is the insinuation of foodborne pathogens during slaughter and processing, an issue with direct ramifications for public health. Well-documented pathogens such as Salmonella and Escherichia coli command the spotlight due to their propensity to incite severe foodborne illnesses (CDC, 2016; EFSA, 2018). These pathogens, exhibiting intricate molecular strategies, have evolved to adapt and persist within the complex ecosystem of slaughterhouses, rendering them particularly challenging to control. Startlingly, these stealthy pathogens frequently evade detection during routine health inspections, necessitating the institution of advanced control strategies deeply rooted in the biological realm (Delgado et al., 2001).

The Need for Comprehensive Assessment Given the intricate interplay of evisceration and its far-reaching consequences on carcass hygiene, a judicious biological inquiry into microbial contamination patterns pre- and post-evisceration becomes imperative. While extant research has yielded invaluable insights into specific facets of meat hygiene and processing (Bakhtiary et al., 2016; Kanval et al., 2024; Parsons et al., 2005), a comprehensive biologically-informed examination of microbial dynamics in this context remains an urgent and multifaceted scientific pursuit. Cutting-edge techniques such as metagenomics and transcriptomics hold promise in unraveling the intricate genetic and functional diversity of microbial communities within the slaughterhouse ecosystem.

Conclusion In summation, while red meat stands as an indisputable nutritional powerhouse, its amenability to microbial contamination necessitates the rigorous enforcement of food safety protocols. Slaughterhouses materialize as pivotal nodes in the meat production continuum, often serving as focal points for the initiation of microbial proliferation and the evolution of complex microbial communities. Evisceration, in particular, emerges as a salient stage bearing profound implications for microbial ecology and, especially, when foodborne pathogens come into play. This study seeks to confront these daunting biological challenges by orchestrating a meticulously orchestrated appraisal of carcass hygiene before and after evisceration, thereby contributing to the advancement of our scientific comprehension of meat processing hygiene and, consequentially, public health. Further investigations, driven by cutting-edge biological methodologies, will undoubtedly shed more light on the intricate interplay of microorganisms within this critical domain of food production.

MATERIALS AND METHODS

Sample collection

A total of 60 samples, comprising 20 from the flank, 20 from the thigh, and 20 from the shoulder, were obtained using a non-destructive approach involving sterile swabs saturated with physiological saline water. Sampling occurred at three distinct anatomical sites (shoulder, thigh, and flank) both before and after the evisceration process. During sampling, a defined surface area of 100 cm^2 was swabbed vigorously for a minimum of 20 seconds, employing vertical, horizontal, and diagonal strokes to capture any resident bacteria. The collected samples were subsequently transferred into 250 ml containers filled with physiological water.

Culture media

The enumeration of total mesophilic aerobic flora was conducted using the Plate Count Agar (PCA) medium, followed by incubation at 37°C for 72 hours. Coliform bacteria were enumerated using nutrient MacConkey and

EMB after incubation at 30°C for 72 hours.

Stock solution and decimal dilutions

The preparation of the stock solution and subsequent decimal dilutions adhered to the French standard NF V-057-2 and ISO 21528-2. Enumeration of total mesophilic aerobic flora followed the ISO 4833 standard method, while fecal coliform enumeration adhered to the NF V08-017 standard method.

RESULTS AND DISCUSSIONS

The microbiological analysis of our collected sample on various culture media clearly reveals signs of contamination. Microbiological colony morphology pertains to the visual attributes of microbial colonies that develop on different culture media. When examining these colonies on agar plates. These traits play a crucial role in the initial identification of microorganisms and can be affected by factors such as temperature, incubation duration, and the specific nutrients available in the growth medium.

Initial growth on nutrient agar   *E. coli* on EMB agar   Klebseilla on EMB agar

Figure 1: Colony morphology of E.coli and Klebseilla bacteria on different media

Moreover, the results of the enumeration have painted a concerning picture of the hygienic conditions within the Souk-Ahras slaughterhouse. It is evident that the quality of the ten examined carcasses does not align with the established legislative standards. Instead, they display contamination rates that are far from acceptable, particularly concerning the presence of very high microbial loads of Total Mesophilic Aerobic Flora and Total Coliforms, especially after the evisceration process.

Looking specifically at bovine carcasses, it's notable that the mean Total Coliform loads measured 3.87 log10 CFU / cm2 before evisceration and 4.97 log10 CFU / cm2 after evisceration. The Total Mesophilic Aerobic Flora showed a similar trend, with levels of 4.09 log10 CFU / cm2 before evisceration and 4.44 log10 CFU / cm2 after evisceration (Tab1, Fig2). This trend of increasing contamination post-evisceration is consistent across various carcass types.

Table 1: Average of the overall contamination of bovine carcass

Flore (log UFC/cm^2)	Sampling sites						Average	Average
	Before evisceration			After evisceration			before evisceration	after evisceration
	Thigh	Flank	Shoulder	Thigh	Flank	Shoulder		
TAMF	4.05	3.66	4.58	4.75	4.46	4.11	4.09	4.44
Coliforms	3.46	3.47	4.7	5.02	4.81	5.09	3.87	4.97

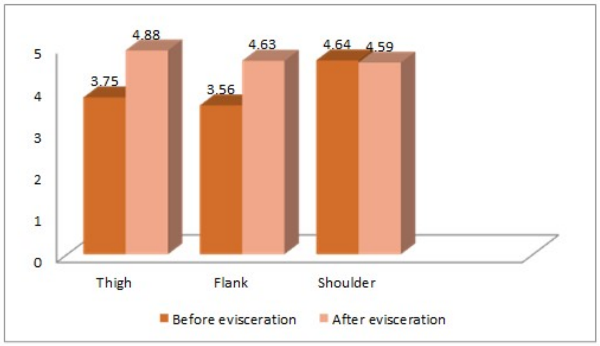

Figure 2: Average contamination of different regions of bovine carcass

For sheep carcasses, the mean Total Coliform loads were 3.65 log10 CFU / cm2 before evisceration and 3.98 log10 CFU / cm2 after evisceration. The Total Mesophilic Aerobic Flora was also affected, rising from 4.05 log10 CFU / cm2 before evisceration to 4.52 log10 CFU / cm2 after evisceration (Tab2, Fig3).

Table 2: Average overall contamination of sheep carcass

Flore (log UFC/cm^2)	Sampling sites						Average before evisceration	Average after éviscération
	Before evisceration			After evisceration				
	Thigh	Flank	Shoulder	Thigh	Flank	Shoulder		
TAMF	4.52	4.08	3.57	4.51	4.36	4.71	4.05	4.52
Coliforms	3.87	3.82	3.26	4.20	3.65	4.09	3.65	3.98

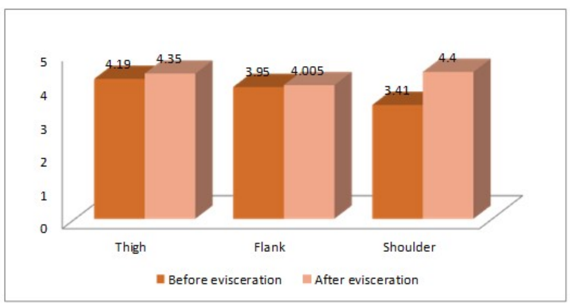

Figure 3: Average contamination of different regions of sheep carcass

In the case of goat carcasses, the situation is equally concerning. The mean Total Coliform loads before evisceration were 3.43 log10 CFU / cm2, spiking to 4.26 log10 CFU / cm2 after evisceration. Total Mesophilic Aerobic Flora followed a similar pattern, increasing from 3.65 log10 CFU / cm2 before evisceration to 5.09 log10 CFU / cm2 after evisceration (Tab3, Fig4).

Table 3: Average overall contamination of goat carcass

Flore (log UFC/cm^2)	Sampling sites						Average before evisceration	Average after evisceration
	Before evisceration			After evisceration				
	Thigh	Flank	Shoulder	Thigh	Flank	Shoulder		
TAMF	3.22	5.14	2.61	4.72	6.26	4.3	3.65	5.09
Coliformes	3.21	4	3.09	3.62	4.99	4.19	3.43	4.26

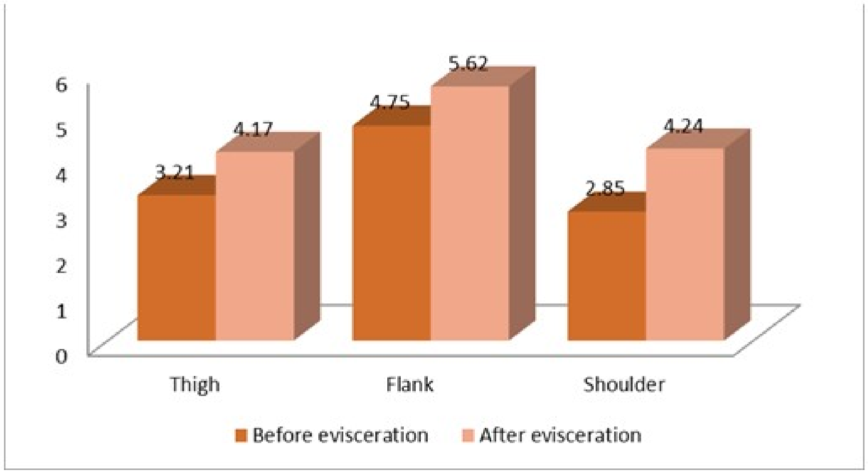

Figure 4: Average contamination of different regions of goat carcass

The consistently high levels of Total Coliforms observed across all carcass types, both before and after evisceration, are particularly troubling. These coliform bacteria are known to be abundant in feces, making their presence a significant factor in carcass contamination. Studies have underscored this association (Collobert et al., 2002; El-Hadef et al., 2005; Bhandare et al., 2007).

Another noteworthy observation is that the thigh region consistently exhibits higher microbial loads than other parts of the carcass. Before evisceration, the thigh averages 4.57 log CFU / cm^2, rising to 5.62 log CFU / cm^2 after evisceration. The flank and shoulder regions also show contamination patterns, emphasizing the need for vigilance during processing.

Surface contamination of carcasses can be attributed to multiple factors, including the initial state of the animals themselves, where soiled skin can be a source of contamination. Furthermore, the handling and hygiene practices during evisceration and processing play a pivotal role. The state of the slaughterhouse environment, including cleanliness and flooring, contributes significantly to this issue.

In summary, this study exposes a troubling reality within the Souk Ahras slaughterhouse. The consistently high levels of coliforms and total mesophilic aerobic flora on all carcasses sampled reflect poor hygiene and inadequate slaughtering practices throughout the entire process. Contributing factors, such as overcrowding, unclean animals, subpar facility conditions, and inadequate staff practices, collectively result in unacceptable contamination levels. Urgent action and comprehensive reform are needed to ensure the safety and quality of meat produced in this facility.

Theoretical implications of the study

Theoretical implications of the study on the impact of the evisceration process on the hygiene standards of carcasses within slaughterhouses can be significant for both the field of food science and microbiology.

Hygiene protocols in meat processing: The study's findings suggest potential lapses in hygiene protocols during the meat processing stages. This implies that existing protocols may not be adequate in preventing microbial contamination. Theoretical implications include the need for reevaluation and potential enhancement of hygiene standards in slaughterhouses.

Microbial ecology in food processing: The study highlights the complex interplay of environmental factors and microbial interactions during meat production. This has theoretical implications for understanding microbial ecology in food processing environments. Researchers may explore the dynamics of microbial communities and how they respond to different processing stages.

Acceptable contamination thresholds: The study notes that the recorded microbial counts exceeded acceptable contamination thresholds. This raises theoretical questions about the adequacy of these thresholds. Future research could delve into establishing more precise contamination limits based on the type of meat, processing methods, and intended use of the final product.

Food Safety Regulations: The findings may have implications for food safety regulations. If contamination levels are consistently found to be above acceptable limits after evisceration, it could prompt regulatory bodies to review and potentially revise food safety standards related to meat processing.

Microbiological risk assessment: The study's results can contribute to the field of microbiological risk assessment. Researchers may use this data to model and predict contamination risks at different stages of meat processing, helping to inform safety measures and interventions.

Comparative microbiology: Comparative studies involving different animal species (bovine, sheep, and goats) provide theoretical insights into the variations in microbial contamination patterns. Understanding these differences can inform future research on species-specific hygiene practices and potential sources of contamination.

Foodborne illness prevention: Theoretical implications extend to the prevention of foodborne illnesses. Understanding where and how contamination occurs during meat processing can aid in designing targeted interventions to reduce the risk of foodborne diseases associated with meat consumption.

Quality control: The study's findings highlight the importance of rigorous quality control measures in slaughterhouses. Theoretical implications include the development of improved quality control frameworks that address microbial contamination concerns more effectively.

In conclusion, this study's theoretical implications are broad and encompass various aspects of food science, microbiology, food safety, and quality control. It highlights the need for ongoing research and the potential for revising and enhancing practices and regulations to ensure the safety of meat products for consumers.

Practical implication of the study

The practical implications of the study on the impact of the evisceration process on the hygiene standards of carcasses within slaughterhouses have direct relevance to the meat processing industry, food safety practices, and public health.

Improved Hygiene Protocols: The most immediate practical implication is the need for enhanced hygiene protocols within slaughterhouses. Meat processing facilities should review and update their procedures to minimize the risk of microbial contamination during the evisceration process. This may involve stricter sanitation practices, more rigorous training for personnel, and the use of disinfectants or antimicrobial treatments.

Quality assurance: Meat processing companies should implement robust quality assurance programs that monitor microbial contamination levels at various stages of processing. Regular testing and monitoring can help identify potential issues early and allow for corrective actions.

Species-specific protocols: The study examined different animal species (bovine, sheep, and goats) and found variations in contamination patterns. Practical implications include the development of species-specific hygiene protocols tailored to the unique characteristics of each animal type to minimize contamination risks.

*Education and training:*Training and education programs for slaughterhouse workers should emphasize the importance of hygiene and sanitation practices. Workers should be aware of the potential risks associated with contamination and understand their role in maintaining food safety.

Regular audits and inspections: Regulatory agencies and meat processing companies should conduct regular audits and inspections to ensure compliance with hygiene standards. These audits can help identify areas where improvements are needed and enforce adherence to best practices.

Technology and automation: Practical implications also include the adoption of technology and automation where feasible. Automated systems can reduce the risk of contamination associated with manual handling and processing. For example, automated evisceration equipment may reduce the potential for cross-contamination.

Traceability and recall plans: Meat processors should have robust traceability systems in place, allowing for the rapid identification and recall of contaminated products if necessary. This ensures that consumers are promptly informed and protected in the event of a food safety issue.

Consumer awareness: Practical implications extend to consumer education. Consumers should be aware of the potential risks associated with meat consumption and encouraged to follow proper cooking and food handling practices to mitigate these risks.
Regulatory considerations: Regulatory bodies may consider revising or strengthening food safety regulations based on the study's findings. This may involve setting more stringent microbial contamination limits or updating guidelines for meat processing facilities.
Public health impact: Ultimately, the practical implication of improving hygiene standards in slaughterhouses is a reduction in the risk of foodborne illnesses associated with meat consumption. This can have a positive impact on public health by lowering the incidence of foodborne diseases and associated healthcare costs.
In summary, the practical implications of this study underscore the importance of implementing measures to enhance hygiene standards in slaughterhouses. These measures not only contribute to the safety of meat products but also have broader implications for the food industry, public health, and consumer confidence in meat products.

CONCLUSION

The slaughterhouse, typically known for producing high-quality meat, paradoxically exposes raw meat to microbes. In a study at Souk Ahras, hygiene levels of cattle, sheep, and goat carcasses were assessed. Results showed all carcasses had unacceptable hygiene due to contamination from dirty animals, lack of fasting, and poor staff and tool hygiene, despite veterinarian inspections. Contaminated meat poses a serious public health risk, emphasizing the need for rigorous training and inspections in meat production and distribution.

Future research directions

The study on the impact of the evisceration process on the hygiene standards of carcasses within slaughterhouses opens up several avenues for future research.
Microbial characterization: Further research can delve deeper into the microbial communities present on carcasses at different processing stages. This could involve advanced microbiological techniques, including metagenomics and metatranscriptomics, to identify specific bacterial species and their metabolic activities.
Source tracking: Investigate the sources of microbial contamination in slaughterhouses. Understanding whether contamination originates from animals, equipment, personnel, or the environment can help in designing targeted interventions.
Effect of pre-slaughter factors: Examine how pre-slaughter factors such as animal health, stress levels, and transportation conditions impact microbial contamination. This research could inform animal handling practices to reduce contamination risk.
Hygiene intervention strategies: Research on the effectiveness of various hygiene intervention strategies, such as antimicrobial treatments, sanitation protocols, and equipment design, in reducing microbial contamination during evisceration and other processing stages.
Genomic analysis: Employ genomic analysis to study the genetic diversity and virulence factors of pathogenic bacteria found on carcasses. Understanding the genetic makeup of these microbes can aid in risk assessment.
Species-specific studies: Conduct species-specific studies to explore variations in contamination patterns and the effectiveness of hygiene practices across different types of livestock.
Microbiome management: Investigate how changes in the microbiome of the processing environment, including the use of probiotics or competitive exclusion strategies, can influence microbial contamination levels.
Antibiotic resistance: Assess the prevalence of antibiotic-resistant bacteria on carcasses and their potential for transmission to humans through meat consumption.
Consumer behavior and education: Research the impact of consumer education campaigns on food safety practices. Understand how consumer behavior and awareness can contribute to reducing foodborne illness risks.

Regulatory frameworks: Evaluate the effectiveness of existing food safety regulations and guidelines in ensuring the safety of meat products. Propose revisions or updates based on research findings.
Technological innovations: Investigate the feasibility and impact of implementing advanced technologies, such as robotics and artificial intelligence, in slaughterhouse operations to improve hygiene and reduce contamination risks.
Sustainability considerations: Examine the environmental sustainability of hygiene practices in slaughterhouses, including water usage, waste management, and energy consumption.
Cross-contamination studies: Study the potential for cross-contamination between different types of meat during processing and packaging and explore strategies to mitigate this risk.
International comparisons: Compare hygiene standards and practices in slaughterhouses across different countries to identify best practices and areas for improvement on a global scale.
Economic impact: Analyze the economic implications of implementing enhanced hygiene standards, considering factors such as cost-effectiveness, market competitiveness, and consumer demand for safer meat products.
Future research in these directions can contribute to the development of evidence-based best practices, enhanced food safety measures, and a deeper understanding of the complex dynamics of microbial contamination in meat processing. These efforts ultimately aim to improve the safety and quality of meat products for consumers.

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