Original Research

Journal of Advanced Veterinary Research
(2026) Volume 16, Issue 1, 118-121

Food safety evaluation of fresh meat in traditional markets: A case study in Semarang city, Indonesia

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ARTICLE INFO

Received: 08 October 2025

Accepted: 26 December 2025

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Keywords:

Beef, Contamination, Food safety, Traditional markets

ABSTRACT

Food safety plays an important role in ensuring the distribution of food products that are safe for consumption, such as beef. Beef is a source of animal protein with a high consumption rate. This study aimed to determine the differences in pH, temperature, physical quality, and hygiene sanitation of beef in three categories of traditional markets in Semarang City. This study uses 87 samples from 29 market. Data analysis was carried out descriptively and quantitatively using GraphPad Prism 9.5.0 software. The pH and temperature values were analyzed using one-way analysis of variance (ANOVA), while the analysis of physical quality and hygiene sanitation used the Kruskal-Wallis test. The results of the study indicated that the pH, temperature, and physical quality of beef did not differ significantly ($P>0.05$) for each market category. Meanwhile, hygiene sanitation showed significant differences ($P<0.05$) among the three market categories.

Introduction

Food safety, as an effort to intensify the fulfilment of food needs, aims to ensure that food products consumed do not have negative impacts that may endanger consumers, commonly known as foodborne diseases. Most cases of food poisoning are attributed to contamination by bacteria such as *Salmonella* spp., *Escherichia coli, Clostridium perfringens*, and *Campylobacter* spp., with beef being one of the most implicated food sources (Alshaikh *et al*., 2023). According to data from the Central Bureau of Statistics (Badan Pusat Statistik, 2024), beef is one of the main sources of animal protein in Indonesia, with production figures showing fluctuations, reaching 478,852.17 tons in 2024. Semarang City, as one of the major cities in Indonesia, recorded a relatively high average beef consumption of 11 g per capita per week in 2024 (Badan Pusat Statistik, 2024).

Beef contains higher protein, lower fat, and a more balanced amino acid composition compared to other types of meat (You *et al*., 2025). This makes beef an important dietary source for fulfilling the body's nutritional needs. However, its high nutritional content also makes fresh beef highly perishable. Continuous exposure to air at room temperature accelerates spoilage; therefore, evaluating the food safety of beef sold in markets is essential to ensure its quality and safety (Günal-Köroğlu *et al*., 2025). The quality of beef can be assessed by examining its physical, chemical, and microbiological properties in accordance with the standards established by SNI.

One of the main centers of beef trading activities in Semarang City with a relatively high daily volume is the traditional market. The Semarang City Government classifies traditional markets to provide a clearer understanding of each type, facilitating analysis related to consumer behavior and market dynamics. Traditional markets are categorized based on their service scale into three types: city markets, regional markets, and neighbourhood markets (Juansyah *et al*., 2023). City markets have a wide service coverage, serving approximately 200,000–220,000 residents, while regional markets have a medium-scale service area covering around 50,000–60,000 residents. In contrast, neighbourhood markets serve a more limited population of about 10,000–15,000 residents. However, the high level of beef trading activity across these market types is often not accompanied by adequate quality assurance or proper market hygiene conditions (Osemwowa *et al*., 2021; Vidal *et al*., 2022). Therefore, evaluating the food safety aspects of beef sold in traditional markets in Semarang City is crucial to ensure that the meat is safe for consumption and does not pose a risk to public health.

Materials and methods

The primary material used in this study was beef, obtained directly from 29 traditional markets across Semarang City. Additional materials included distilled water, buffer solutions with pH values of 4, 7, and 10, as well as tissue paper. The equipment used for parameter testing consisted of beakers, a Smart Sensor PH818T pH meter, questionnaire sheets, and writing instruments.

The study was conducted from June to December 2024 at research locations in several traditional markets in Semarang City and the Central Laboratory for Research and Services Diponegoro University (CORES-DU), Semarang. Sampling was conducted in the morning between 7:00 a.m. and 9:00 a.m.

Data collection

Samples in this study were collected using a purposive sampling technique, with a total sampel size of 108 from 71 seller in 28 traditional markets. The beef samples selected met several criteria, including being lean-free, having a bright red color, and being displayed by hanging. A total of 28 traditional markets across Semarang City were included in the sampling, consisting of 4 city markets, 9 regional markets, and 15 neighbourhood markets categorized based on their service scale. The sampling design aimed to represent different market service levels in assessing the food safety of beef products. The data used in this study comprised both primary and secondary data. Primary data were obtained through direct observation, interviews, questionnaires, and documentation, while secondary data were gathered from literature reviews and supporting infor-

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mation provided by relevant agencies.

pH value measurement

The pH value analysis was conducted following the method described by Pasanako *et al*. (2025). Measurements were performed using a pH meter (Smart Sensor PH818T, China). Prior to analysis, the instrument was calibrated to ensure optimal performance. The test was initiated by activating the device and gently placing the probe on the surface of the beef sample with slight pressure until a constant pH reading was obtained. The pH meter probe was sterilized before being used to test the subsequent samples.

Meat temperature measurement

The temperature measurement of beef samples was conducted following the method described by Conceição *et al*. (2025). The sample temperature was measured using a pH meter (Smart Sensor PH818T, China) equipped with a built-in temperature sensor. Before use, the device was activated by pressing the power button, and the temperature unit was set to Celsius by pressing the "CAL" button. The probe was then gently placed in contact with the beef sample, and the measurement was recorded once the temperature reading stabilized on the display screen.

Assessment of physical quality parameters

The physical quality parameters of beef samples were assessed using a modified method adapted from Lima *et al*. (2024). The evaluated parameters included cleanliness, color, freshness, and texture of the beef. The assessment involved visual observation of the sales environment and direct interviews with vendors. A structured questionnaire consisting of four questions was used, employing a scoring system ranging from 1 to 10.

Hygiene and sanitation assessment

The hygiene and sanitation conditions of beef sales locations were assessed using a modified method adapted from Pilamala *et al*. (2023). The evaluation covered several aspects, including location, building infrastructure, hygiene facilities for vendors, machinery and equipment, supporting facilities, and pest control. These aspects were evaluated using a structured questionnaire consisting of 23 questions. Scoring was conducted based on direct observations and interviews regarding the condition of beef at each sales location, using a scale ranging from 1 to 10.

Data analysis

Overall data analysis was performed using GraphPad Prism version 9.5.0 to determine the effect of each parameter. The pH and temperature data were analysed using one-way ANOVA at a 95% confidence level ($P < 0.05$), followed by Tukey's multiple comparison test. The physical quality and hygiene–sanitation parameters were analysed using the nonparametric Kruskal–Wallis test at a 95% confidence level ($P < 0.05$), followed by the Mann–Whitney post-hoc test.

Results

Based on Table 1, the pH values of beef sold across the three categories of traditional markets in Semarang City showed no significant differences, with average values ranging from 5.88 to 6.03. Similarly, the temperature of beef did not differ significantly among market types, with average temperatures ranging narrowly between 28.79°C and 28.88°C. The physical quality of beef, assessed based on cleanliness, color, freshness, and texture, also showed no significant variation, with average scores ranging from 32.93 to 34.07 out of a maximum score of 40.00, indicating that the overall physical quality of the sampled beef was relatively good. In contrast, significant differences were observed in hygiene and sanitation conditions among the three market categories. The hygiene and sanitation assessment, which evaluated aspects such as location, building facilities, vendor hygiene, equipment, supporting facilities, and pest control (maximum total score of 240), showed that city markets achieved the highest scores, followed by neighbourhood markets and regional markets, with average scores ranging from 70.50 to 186.70.

Discussion

Based on Table 1, the pH values of beef sold across the three categories of traditional markets in Semarang City showed no significant differences. The average pH values in city, regional, and neighbourhood markets ranged from 5.88 to 6.03. These values are consistent with the Indonesian National Standard (SNI 3932:2008), which specifies that the normal pH range of fresh beef is 5.46–6.39 (Badan Standardisasi Nasional, 2008). The relatively uniform pH values across market categories may be attributed to similar environmental conditions, as the Semarang City Government enforces comprehensive regulations for all traditional markets. Regional Regulation No. 9 of 2013 concerning the Regulation of Traditional Markets outlines standards for market management, facilities, and hygiene practices. Consequently, market design, layout, and sanitation facilities tend to be standardized, resulting in comparable air circulation, humidity, and cleanliness levels, which help maintain stable beef pH values. Poor sanitation and cleanliness could increase microbial growth and nitrogen gas production, thereby increasing meat pH and reducing quality (Liu *et al*., 2024).

Beef trading hours across the three market categories were also relatively uniform, typically starting early in the morning and ending by noon. According to interviews, most beef vendors in Semarang conduct sales shortly after the slaughtering process. The short interval between slaughter and sale ensures that the beef remains within a similar post-mortem biochemical phase, minimizing variation in pH values (Liu *et al*., 2025). Thus, the uniform timing of slaughtering and distribution contributes to the absence of significant differences among markets.

Another factor contributing to the uniform pH values is the common source of meat supply. Most beef sold in Semarang City originates from the same slaughterhouse located in the Pedurungan area. The standardized slaughtering, handling, and distribution processes result in similar meat conditions across all markets. Consistency in cattle type, feeding, and pre- and post-slaughter treatment further supports the stability of beef quality and pH (Kang *et al*., 2020).

Moreover, handling practices among vendors in traditional markets were generally similar. Minimal cooling and open-air sales without ade-

Table 1. pH value, temperature, physical quality, and hygiene sanitation in traditional markets in Semarang city.

Market Categorization	pH value	Temperature (°C)	Physical Quality	Hygiene Sanitation
City Market	5.88±0.24	28.88±0.41	33.92±1.68	186.70±9.43[a]
Regional Market	6.03±0.31	28.81±1.22	32.93±3.01	70.50±5.14[b]
Neighbourhood Market	5.97±0.29	28.79±0.39	34.07±3.09	157.70±12.38[c]

Data are shown as mean ± Standard Deviation (SD). [a-c]Values with different lowercase superscript letters in the same column indicate significant differences ($P<0.05$)

quate temperature protection were common across markets. Such homogeneous handling conditions lead to comparable biochemical changes in meat, including pH fluctuations (Rinn *et al*., 2024). Therefore, the absence of variation in handling and storage practices during sales also explains the lack of significant differences in beef pH among market types.

Based on the ANOVA results presented in Table 1, the temperature of beef showed no significant differences among the three categories of traditional markets in Semarang City. The average beef temperature in city, regional, and neighbourhood markets ranged narrowly between 28.79°C and 28.88°C. These findings correspond to the actual environmental conditions in traditional markets, which tend to be warm. Semarang City, as a coastal area, has a relatively high average daily temperature ranging from 28°C to 32°C (Wahyudi *et al*., 2025). The elevated beef temperature is mainly due to the absence of active cooling systems during sales in traditional markets. Beef is typically displayed in open-air conditions without cold storage facilities. Fresh beef reacts quickly to environmental temperature increases; thus, its internal temperature tends to equilibrate with the surrounding air (Bahmani *et al*., 2024).

The facilities and infrastructure of traditional markets in Semarang City are generally similar, characterized by open ventilation, limited sanitation facilities, lack of temperature and humidity monitoring devices, and the absence of cooling or low-temperature storage systems (Gupta *et al*., 2023). Even in city markets, which have the largest service scale, beef handling practices remain largely manual and do not incorporate temperature control measures. Inadequate temperature management accelerates meat spoilage, as putrefactive bacteria grow and become more active under warm conditions (Liu *et al*., 2023). This similarity in market characteristics results in a relatively narrow temperature range of beef sold across the three market types, with no significant statistical differences.

Another factor influencing the uniformity of beef temperature across markets is the traders' handling behavior. Most vendors employ similar practices to maintain beef quality, such as hanging the meat during display. Hanging helps keep the beef surface dry and maintain a relatively stable temperature. Ideally, fresh beef should appear bright red, firm in texture, glossy, and visually fresh attributes that indicate higher quality compared to wet or poorly handled meat (Kanokruangrong *et al*., 2025). Additionally, vendors tend to position their stalls away from direct sunlight to avoid excessive heat exposure. The uniform handling practices among traders, coupled with simultaneous data collection in the morning across all markets, further contributed to the minimal variation in beef temperature among market categories.

Table 1 shows that the physical quality of beef sold in city markets, regional markets, and neighbourhood markets in Semarang City does not differ significantly. The average physical quality scores of beef in these three categories of traditional markets range narrowly between 32.93 and 34.07. The assessed aspects in this study included cleanliness, color, freshness, and texture, where the perfect score of 40.00 indicates that the physical quality of the sampled beef tends to be good. This finding implies that the level of food safety is relatively acceptable (Smeti *et al*., 2025).

The physical quality of beef is closely linked to food safety, as it serves as the main visual indicator of potential biological contamination that may alter chemical components and accelerate spoilage (Zhu *et al*., 2024). The homogeneity in the physical quality of beef sold across the three types of traditional markets in Semarang City indicates a consistent and acceptable level of food safety.

Beef circulating in city, regional, and neighbourhood markets in Semarang City is generally sourced from the same supplier, namely the Pedurungan District slaughterhouse. Standardized slaughtering procedures and efficient distribution that minimize contamination risks contribute to the good physical quality of beef (Santos *et al*., 2017). The consistency of physical quality assessment results is also supported by the fact that all samples were collected at the same time, in the morning. This minimizes differences in post-mortem duration and exposure to open air, which keeps freshness and color relatively uniform (Setyabrata *et al*., 2023). Prolonged exposure to the environment without proper handling increases the risk of oxidation and bacterial contamination, which can darken the color and produce rancid odors in beef (Miao *et al*., 2025).

Traders' behavior and awareness play a crucial role in maintaining the physical quality and food safety of beef. In traditional markets, beef traders are usually located in designated meat sections to reduce the risk of cross-contamination with other products (Dewaal *et al*., 2022). Typically, beef is sold openly by hanging, exposing it to the surrounding environment. However, most traders maintain the cleanliness of their tools and selling areas to ensure the beef remains fit for consumption (Mahbubi *et al*., 2019). Nearly all traditional market beef traders lack cold storage facilities such as refrigerators. Therefore, they usually limit their stock each day to prevent quality degradation. This rapid product turnover helps maintain freshness and minimizes the risk of spoilage and pathogenic microbial growth, thereby preserving food safety (Chen *et al*., 2025).

Based on the results of the analysis, the hygiene and sanitation conditions among the three categories of traditional markets in Semarang City showed significant differences. The hygiene and sanitation assessment was conducted by evaluating several aspects, including location, building facilities, hygiene facilities for vendors, machinery, equipment, supporting facilities, and pest control, with a maximum score of 10 for each aspect and a total maximum score of 240. The average hygiene sanitation scores for city markets, regional markets, and neighbourhood markets ranged from 70.50 to 186.70. City markets achieved the highest score, while neighbourhood markets obtained the lowest. Interestingly, neighbourhood markets recorded slightly higher scores than regional markets.

The differences in hygiene sanitation scores among market categories are influenced primarily by market location. Markets located near waste disposal sites (WDS) or in flood-prone areas tend to have lower hygiene and sanitation conditions. Proximity to WDS and frequent flooding increase the risk of contamination, generate unpleasant odors, limit clean water availability, and create puddles that hinder cleaning activities (de Koning *et al*., 2017).

The availability and adequacy of sanitation facilities also contribute significantly to hygiene scores. City markets generally provide more complete facilities, such as sinks with running water and soap at each stall, enabling traders to wash hands and equipment regularly. In contrast, most regional and neighbourhood markets lack these facilities, and traders often rely solely on water from market toilets. The availability of clean running water and soap is crucial because it helps eliminate bacteria that may cause food contamination (Vuai *et al*., 2022). Moreover, the use of non-slippery, easy-to-clean flooring supports proper sanitation practices. Regular cleaning of floors and surrounding areas contributes to maintaining food safety (Wenndt *et al*., 2025). Nearly all city markets have ceramic, waterproof floors, which are easier to maintain, resulting in better sanitation compared to regional and neighbourhood markets.

Traders' awareness and behavior in implementing good hygiene practices play a key role in maintaining cleanliness. Simple actions, such as washing hands before and after handling beef, help minimize bacterial transfer and cross-contamination. Cross-contamination can occur when bacteria from dirty hands come into contact with food products (Huoy *et al*., 2024). However, this behavior is not yet consistently practiced by traders, who often clean their hands only with cloths. This practice is reinforced by the limited availability of handwashing facilities, particularly in regional and neighbourhood markets. The use of personal protective equipment (PPE) such as aprons, gloves, and masks is also important to prevent contamination of beef and maintain hygiene. Traders who consistently use PPE can significantly reduce the risk of microbial contamination (Siddiky *et al*., 2022).

Supporting facilities such as trash bins, proper waste disposal channels, and pest control systems are essential for maintaining market sani-

tation. Providing trash bins in adequate quantities and placing them strategically helps encourage proper waste disposal. Trash bins should be covered and not overloaded to prevent the attraction of pests (Madjdian *et al*., 2024). Effective waste disposal systems are crucial to prevent waste accumulation, which can become breeding grounds for disease vectors such as flies, cockroaches, rats, and stray cats. These pests can spread bacteria and viruses to food products (Queenan and Hasler, 2025). Therefore, the provision of pest control equipment, such as traps or repellents, is vital to reduce pest-related risks in traditional markets. However, these preventive measures remain suboptimal across all three market categories.

Conclusion

The study revealed that the pH value, temperature, and physical quality of beef sold in city, regional, and neighbourhood markets in Semarang City showed no significant differences, indicating uniform handling and distribution practices among markets. All samples met the SNI 3932:2008 standards for fresh beef, reflecting acceptable levels of quality and safety. However, significant differences were found in hygiene and sanitation conditions, with city markets showing better facilities and cleanliness than regional and neighbourhood markets. These findings emphasize the need to improve sanitation infrastructure, hygiene awareness, and waste management practices in traditional markets to enhance overall beef safety and protect public health.

Acknowledgments

The research work was funded by Food Security Department, Semarang City (Grant No. B/863/500.1/V/2024 and 1158/UN7.F5/HK/VIII/2024).

Conflict of interest

The authors have no conflict of interest to declare.

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