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Research Article

Evaluating Practices and Analysing the Impact of Loading, Transportation, and Storage on Frozen Lamb Quality in the Catering Industry

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ABSTRACT

Ensuring food safety and quality is critical in the frozen lamb industry. This study evaluates the impact of handling, transportation, and storage practices on the microbiological and chemical properties of frozen lamb in the UAE catering industry.

This research investigates the effects of handling, transportation, and storage on the microbiological and chemical properties of frozen lamb, aiming to evaluate the impact of handling phases (loading, transportation time, offloading, and storage time) on the quality and safety of the products and its relations to the food safety knowledge and adherence to procedures among catering staff during these stages. There are two phases in this study. In the first phase, three identical frozen lamb products, labelled A, B, and C, were transported to three different units with varying transportation times: 30 minutes for unit A, 45 minutes for unit B, and 90 minutes for unit C. Microbiological and chemical tests were conducted throughout the stages, from loading at the supplier's point to 30 days of storage. The tests included are Total Viable Count (TVC), *Escherichia coli* (*E. coli*), *Salmonella*, pH, fat content, and Total Volatile Basic Nitrogen (TVBN). In the second phase, a questionnaire was given to evaluate food safety knowledge of 586 catering staff in handling frozen lamb during these stages, divided into five sections: Loading, receiving, transportation, storage, thawing, and food safety responsibilities and awareness. Results revealed significant variations in TVC during transportation and storage, with product C showing a peak TVC of 8266 Colony-Forming Units (CFU)/g after 30 days. Significant differences in microbiological quality were observed across different transportation times ($p<0.001$). However, overall microbiological quality during handling stages showed no significant differences ($p>0.05$), indicating stable microbial control measures. Chemical parameters exhibited significant changes ($p<0.05$), highlighting the need for stringent control, especially during storage. The questionnaire showed significant associations between respondent's roles and their practices in temperature monitoring ($p<0.001$) and safe thawing methods ($p<0.001$). Although 94.7% received food safety training, it was found that regular microbial testing during storage needs improvement.

In conclusion, continuous training and strict adherence to food safety protocols are essential to maintain product integrity. The study highlights the critical role of temperature control and regular monitoring, providing insights for optimizing frozen lamb handling and storage, enhancing food safety in the UAE's catering industry.

Keywords: Frozen lamb; Microbiological properties; Chemical properties; Transportation; Catering industry; Food safety

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INTRODUCTION

In the United Arab Emirates (UAE), lamb is a staple food, and ensuring the integrity of frozen lamb products is important for maintaining both food safety and quality [1]. The primary challenges in handling, transporting, and storing frozen lamb namely temperature control, storage duration, and handling practices—play a critical role in preventing spoilage, contamination, and deterioration. These factors significantly affect the microbiological and chemical properties of frozen lamb [2]. Given the high consumption rate and the necessity for high standards in food safety, it is essential to evaluate current practices and identify areas for improvement. Freezing is a common method used in the lamb meat industry to extend the storage time and maintain a steady supply of seasonal meat throughout the year [3]. The freezing process preserves the quality of the meat and is the best preservation method available [4]. However, frozen meat quality can be affected during storage due to temperature fluctuations [5], long distances, and improper handling. These factors can lead to microbial growth and chemical changes, compromising the meat's quality and safety [6]. Temperature control is a critical factor in maintaining the quality of frozen lamb during storage and transportation [7]. Additionally, the knowledge and practices of catering staff regarding food safety protocols play a vital role in maintaining the quality of frozen lamb products. Ensuring that all personnel involved are well-trained and adhere to stringent food safety measures is fundamental to preventing foodborne illnesses and ensuring customer satisfaction. Despite the wealth of research conducted on food safety, the specific relationship between the food safety knowledge of staff and the quality of frozen lamb meat during storage and transportation remains underexplored. Previous studies have extensively evaluated the impact of various factors on the microbiological quality of frozen meats. For instance, studies have shown that temperature fluctuations during storage can lead to significant microbial growth, which in turn compromises the safety and quality of frozen meat products [8].

Research conducted by Fernandes et al., has demonstrated that not only do microorganisms affect the shelf life and sensory attributes of frozen meats, but they also pose serious health risks to consumers if not properly managed [9]. Their study highlighted the importance of maintaining consistent low temperatures during the freezing process to inhibit microbial proliferation. Similarly, Rovira et al., emphasized that the duration and stability of storage conditions are crucial in preserving the microbiological integrity of frozen lamb, noting that even minor temperature fluctuations can have deleterious effects [8].

Moreover, studies focusing on the transportation of frozen seafood have found that improper handling and transportation can lead to temperature abuse, resulting in a degradation of product quality and an increased risk of foodborne illnesses [10]. These findings underscore the critical need for comprehensive training programs that equip catering staff with the necessary skills to manage frozen products effectively.

Given these challenges, it is imperative to ensure that food handlers possess not only the theoretical knowledge of food safety but also the practical skills to apply this knowledge effectively in real-world scenarios. This study seeks to bridge the gap in the existing literature by evaluating how the food safety knowledge of catering staff influences the microbiological quality of frozen lamb during storage and transportation. By examining the interplay between staff knowledge and product quality, this research aims to provide actionable insights that can enhance food safety practices in the catering industry. Considering these aspects, the objective of this study was to evaluate the effects of loading, transportation, offloading, and storage on the quality of commercial imported frozen cut lamb. The study aims to fill the gap in research on the effect of these steps on frozen lamb characteristics and provide valuable information to the commercial industry. This evaluation will focus on the knowledge and comprehension of food safety measures among catering employees regarding the transportation, storage, and thawing of frozen lamb. By enhancing food safety knowledge among catering employees, high standards of food safety can be maintained, ensuring customer satisfaction. The study also aims to identify areas for improvement in current practices to further enhance food safety and quality standards in the UAE's catering industry.

MATERIALS AND METHODS

Sample preparation and storage

The frozen lamb products used in this study were sourced from an Australian company and imported into the UAE, where they were stored by our local supplier at -18°C. The carcass pieces were derived from a whole carcass. Three identical frozen lamb products, labelled A, B, and C, were prepared and stored under controlled conditions.

Each product weighed approximately 20 kg and was cut into 6 uniform pieces, each approximately 10 cm × 5 cm × 3 cm. These pieces were individually wrapped and packed into cartons designed with dimensions of 564 × 360 × 200 mm. The lamb products were packed in Auto Irradiation (AI) bags made from polyethylene, providing an excellent barrier against moisture and contaminants. The packaging type was Individual Wrap (IW), ensuring the products remained fresh and uncontaminated throughout the storage period (Figure 1).

Sampling method

For this study, three distinct stages were conducted to comprehensively evaluate the impact of handling, transportation, and storage on the quality of frozen lamb (Figure 2). Three product groups labelled as product A, B, and C, were selected for this study. These Products were transported from the wholesaler's unit, located at Dubai warehouses area, to three different kitchen units: Unit A, unit B, and unit C. The transportation durations were 30 minutes for product A, 45 minutes for product B, and 90 minutes for product C, respectively. During transportation, the temperatures of the frozen lamb products were maintained at -18°C using Temperature Monitoring Devise (TMD) brand name (Ebro) samples were collected at three critical points: During loading at the wholesaler's unit, after transportation at the respective kitchen units, and during storage at intervals of 10, 20, and 30 days after arrival. The samples were subjected to microbiological and chemical analyses to assess their quality. Microbiological analysis included TVC, *E. coli*, and *Salmonella* detection. Chemical analysis involved measuring pH, fat content, colour, and TVBN. These analyses were conducted to monitor any changes in the microbiological and chemical properties of the frozen lamb throughout the handling, transportation, and storage stages.

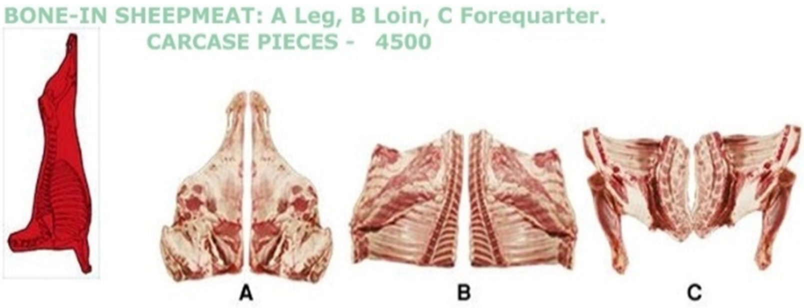

Figure 1: Bone-in pre-cut frozen lamb image. **Note:** A: Leg; B: Loin and C: Forequarter.

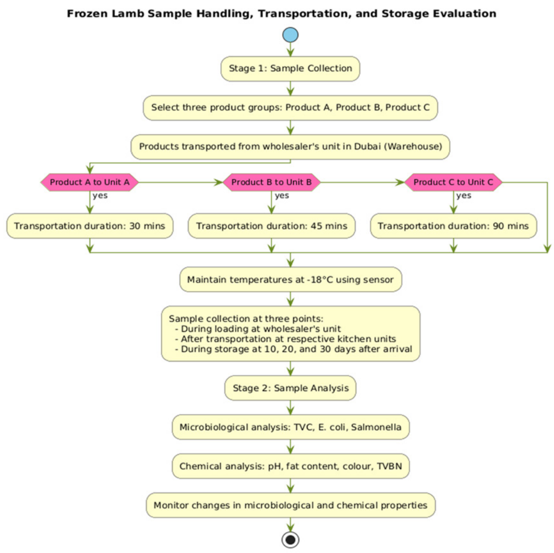

Figure 2: Flow process of sampling method of frozen lamb.

Chemical analysis

pH analysis: To determine the pH of the prepacked frozen lamb, a digital pH meter (Hanna Instruments, Smithfield, USA) was used. The pH meter was first calibrated using standard buffer solutions at pH 4.0, 7.0, and 10.0 to ensure accurate readings. Subsequently, samples of the frozen lamb from all three units (loading, transportation, offloading, and storage periods) were collected and homogenized with distilled water in a ratio of 1:10 (w/v). For each stage, three duplicate samples were taken, and the pH of the resulting homogenate was measured. The average of these three measurements was recorded to provide a more reliable pH value. This procedure allowed for the monitoring and assessment of any potential changes in pH levels during the various stages of handling and storage of the frozen lamb, including throughout the 30-day storage period.

Fat content analysis: The fat content of the lamb samples was determined using the Soxhlet extraction method with petroleum ether as the solvent. A fat extractor (Soxtec™ 2050) was employed for this purpose. Approximately 5 grams of each lamb sample were placed in a thimble and subjected to solvent extraction using 200 ml of petroleum ether (Sigma-Aldrich, USA). The extraction process was carried out for 6 hours. For each stage of the study (throughout the 30-day storage period at the three units-A, B, and C), three duplicate samples were analyzed. After extraction, the solvent was evaporated, and the extracted fat was weighed. The fat content was calculated as a percentage of the initial sample weight, and the average of the three measurements was recorded to ensure accuracy.

Colour analysis: The color values (L^*, a^*, b^*) of the frozen lamb were measured using a colorimeter (CM 508-d, Hunter MiniScan TMXE). The colorimeter was first calibrated using a white reference standard to ensure accurate color measurements. The colorimeter probe was then placed on the surface of the frozen lamb samples to obtain precise color values (L^*, a^*, b^*) [11]. For each stage of the study (various stages during the 30-day storage period), three duplicate samples were analyzed. The average of the three measurements was recorded to accurately track any changes in color throughout the different handling and storage phases.

TVBN analysis: The TVB-N content of the lamb samples was determined using a standard micro diffusion method [12]. Samples were homogenized with Tri-Chloroacetic Acid (TCA) using a laboratory homogenizer. The homogenate was centrifuged at 3000 rpm for 10 minutes, and the supernatant was collected. Nessler's reagent was then added to the supernatant, and the absorbance was measured at a wavelength of 410 nm using an Ultraviolet-Visible (UV-Vis) spectrophotometer (Model Shimadzue). The TVB-N content was calculated using a standard curve prepared with known concentrations of ammonium chloride. For each stage of the study (throughout the 30-day storage period) at the three units (A, B and C), three duplicate samples were analysed, and the average of the three measurements was recorded to ensure accurate assessment of TVB-N levels.

Microbiological analysis

TVC analysis: The TVC test was performed to determine the total number of viable bacteria in the lamb samples, following USFDA/BAM chapter 3 guidelines [13]. Samples of 500 grams were taken from each of the three products and kept in sterilized bags. These were transported in an ice box to the laboratory. From each product, 25 grams were added to 225 ml of diluted buffer peptone water in sterilized bags and homogenized using a stomacher. Plate Count Agar (PCA) was used, which was allowed to melt at 37°C. Then, 1 ml of the sample was added to 15 ml of melted PCA agar medium, mixed well, and poured into a sterile Petri dish to solidify. Five dilutions (up to 105) were prepared for each sample. The Petri dishes were incubated at 37°C for 48 hours. Positive and negative controls were also tested. Colonies were counted manually using a magnifying glass, and results were recorded as $\log_{10}$ values. For accuracy, three duplicate samples were tested at each stage, and the average count was calculated. The meat samples were classified based on the UAE 10106 microbiological standard.

***E. coli* analysis:** The isolation, identification, and enumeration of *E. coli* were carried out following International Organisation for Standardisation (ISO) 6649-2-2001 guidelines [14]. Briefly, 25 grams from each product were added to 225 ml of diluted buffer peptone water in sterilized bags and homogenized to prepare a 10-1 dilution. Serial 10-fold dilutions up to 10-5 were prepared, and 0.1 ml from each dilution was inoculated and spread on TBX agar, which was then poured into Petri dishes. The plates were incubated at 44.5°C, and bacterial colonies were counted after 24 hours. The presence of *E. coli* was indicated by blue colonies on the dishes. For accuracy, three duplicate samples were tested at each stage, and the average count was calculated. No positive samples were found; hence, confirmation was not carried out.

***Salmonella* analysis:** The isolation, identification, and enumeration of *Salmonella* were conducted following ISO 6579-1:2017+A1:2020 guidelines [15]. Samples of 25 grams were added to 225 ml of diluted buffer peptone water, homogenized in a sterilized bag, and incubated at 37°C for 24 hours. Subsequently, 1 ml of the mixture was added to 9 ml of Rappaport-Vassiliadis Soya peptone broth (RVS broth) and incubated at 44.5°C for 24 hours. A loopful was streaked onto Xylose Lysine Desoxycholate (XLD) agar and Brilliant Green Agar (BGA), followed by incubation at 37°C for 24 hours. For accuracy, three duplicate samples were tested at each stage, and the average result was calculated. No positive samples were detected; therefore, confirmation tests were not performed.

Questionnaire method

Study design, sampling, and area: A cross-sectional survey was conducted to evaluate food safety knowledge and practices among catering staff involved in handling frozen lamb in the UAE. The study focused on various stages of the handling process, including loading, transportation, offloading, and storage. The study protocol was approved by Human Research Ethics Committee (HREC), University Sains Malaysia (USM) (JEPeM) under JEPeM Code: USM/JEPeM/PP/23100748.

Eligibility criteria: The study included catering staff from various catering companies across the UAE who were directly involved in the handling, transportation, or storage of frozen lamb. Respondents who were unavailable or unwilling to participate were excluded from the study.

Sampling method: A purposive sampling method was employed, targeting catering staff from various catering companies across the UAE. The sample size for each group of employees was calculated using the following formula.

$$n = \frac{z2 \cdot p \cdot (1-p)}{\text{e}2} / (1 \frac{z2 \cdot p \cdot (1-p)}{\text{e}2.N})$$

Where,

- n is the required sample size
- z is the Z-score corresponding to the desired confidence level (1.96 for 95% confidence level)
- p is the estimated proportion of the population that has a particular characteristic (0.5 for maximum variability, yielding the maximum sample size)
- e is the margin of error (0.05)
- N is the population size

Using this formula, a total sample size of 628 respondents was determined. The sample included 144 managers, 187 chefs, 154 cooks, 114 logistic staff, and 30 individuals with various designations. The inclusion criteria required participants to be involved in the handling, transportation, or storage of frozen lamb. The respondents were chosen based on their availability and willingness to participate in the study (Table 1).

Table 1: Showed the estimated sample size for each category of employees.

Category	Population	Estimated sample size
Managers	200	114
Chefs	350	187
Cooks	250	155
Logistics	100	144
Others	100	30
Total	1000	630

Study area: The study was conducted in multiple catering units located in different regions of the UAE. The selected units represented a diverse range of catering environments, ensuring a comprehensive understanding of the current practices and challenges faced in handling frozen lamb.

Research instrument: Data collection was carried out using a structured questionnaire, which comprised both closed-ended and multiple-choice questions. The questionnaire was designed to assess the knowledge and practices related to food safety during the handling of frozen lamb. The questions were divided into four sections: General information, transportation and offloading, storage, thawing, and food safety responsibility and awareness.

Data collection: Data collection was carried out using a structured questionnaire created using Microsoft Forms. The questionnaire was distributed to catering staff through email and company WhatsApp groups to ensure flexibility and accessibility. The anticipated time commitment for each participant was approximately 20 minutes. The questionnaire was pretested and validated before use. It consisted of closed-ended, demographic questions and multiple-choice questions which divided into four sections: General information, transportation and offloading, storage, thawing, and food safety responsibility and awareness. The questions were designed to assess the knowledge and practices related to food safety during the handling of frozen lamb.

Statistical analysis: The collected data were analysed using Statistical Package for the Social Sciences (SPSS) software version 23. Descriptive statistics were used to summarize the demographic characteristics and responses to the questionnaire. Inferential statistics, including Chi-square tests, one-way Analysis of Variance (ANOVA), and regression tests, were employed to identify significant differences and correlations among the variables. The statistical significance was set at a 95% confidence level ($p \leq 0.05$), with an alpha level of 0.05 (Figure 3).

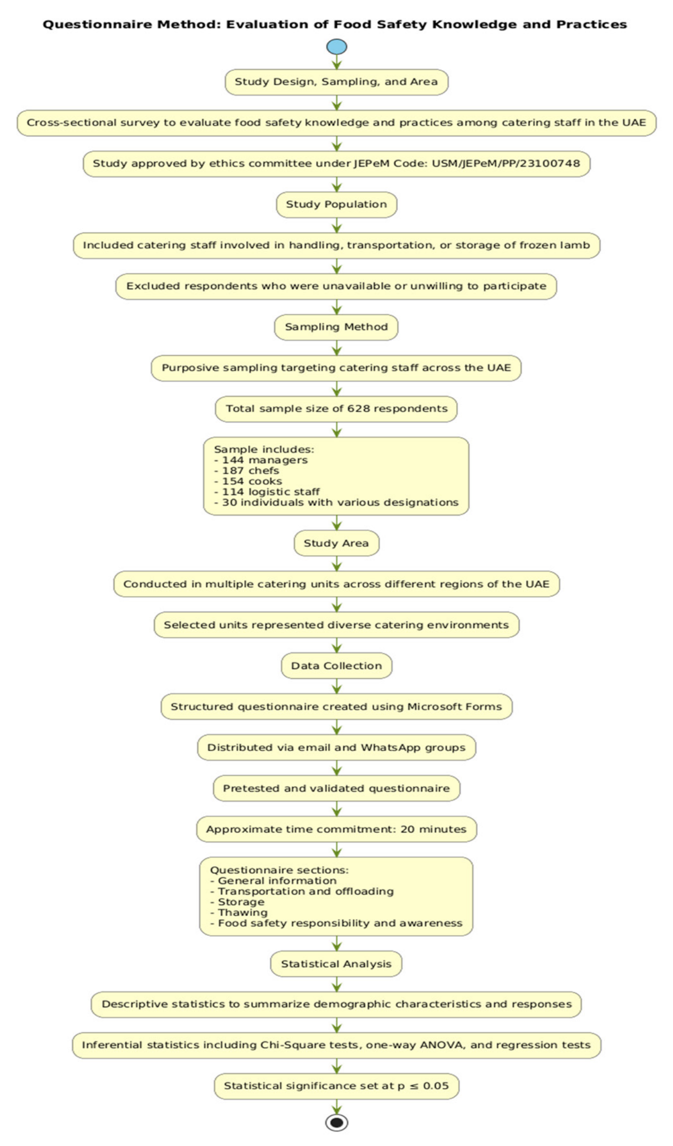

Figure 3: Flow diagram of the questionnaire method for evaluating food safety knowledge and practices among catering staff.

RESULTS

Results of Microbiological and chemical analysis

TVC: The TVC was significantly affected by transportation and storage conditions. For product A, the initial TVC was 400 CFU/g, which increased to 600 CFU/g post transportation and 1200 CFU/g after 30 days of storage. Product B showed significant microbial growth, starting with 3700 CFU/g, increasing to 5000 CFU/g post-transportation, and reaching 7000 CFU/g after 30 days of storage. Product C exhibited the highest microbial increase, starting at 510 CFU/g, rising to 3000 CFU/g post-transportation, and peaking at 8266 CFU/g after 30 days of storage ($p<0.001$). These results indicate a significant impact of transportation and storage on microbial growth. No *E. coli* or *Salmonella* were detected in any of the products at any stage, indicating good initial handling practices and effective microbial control during transportation and storage (Figure 4).

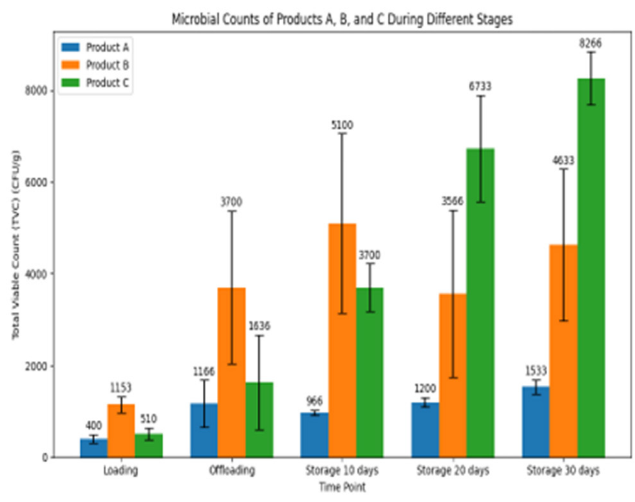

Figure 4: TVC count for the three product during different stages.

Chemical analysis

pH measurement: The pH values of the frozen lamb products were monitored throughout the study. For product A, the pH value increased slightly from 5.29 during loading to 5.8 after 30 days of storage. Product B showed a more considerable increase in pH, from 5.37 during loading to 6.75 after 30 days of storage. Product C's pH value remained relatively stable, starting at 6.01 during loading and reaching 6.5 after 30 days of storage ($p=0.274$). Previous studies have reported similar results, that the pH was signifcantly infuenced by the time of frozen storage [16]. Also, an increase in pH with frozen storage time was found by Kim et al. [17]. These variations in muscle pH may result from differences in proportions of red and white fiber types and the extent or rate of glycolysis, and microbial activity due to the thawing technique [18] (Figure 5).

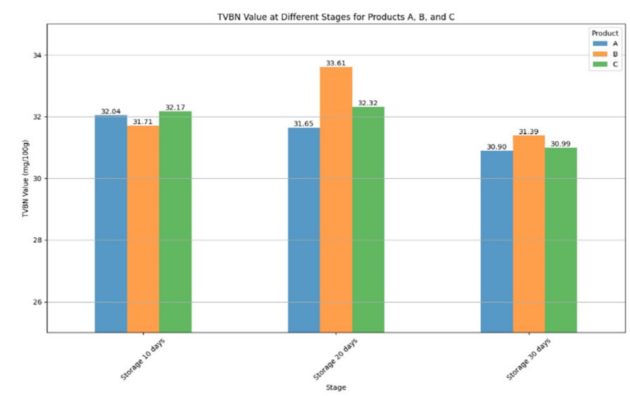

Figure 5: pH values of three products at different stages.

Fat content: The fat content of the frozen lamb products exhibited minor fluctuations during storage. For product A, the fat content started at 17.01% after 10 days and slightly decreased to 16.87% after 30 days. Product B fat content began at 17.28% after 10 days and decreased to 16.01% after 30 days. Product C fat content decreased from 17.21% at 10 days to 16.00% after 30 days. These changes suggest a marginal reduction in fat content over time, likely due to the storage conditions ($p<0.05$) (Figure 6A).

TVBN: TVBN levels were used to assess the protein degradation and freshness of the lamb products. For product A, TVBN levels showed a decreasing trend from 32.04 mg/100 g at 10 days to 30.90 mg/100 g after 30 days. Product B exhibited fluctuations in TVBN levels, with the highest value of 33.61 mg/100 g recorded at 20 days, before decreasing to 31.39 mg/100 g after 30 days. Product C showed a gradual decrease in TVBN levels from 36.0 mg/100 g at 10 days to 34.5 mg/100 g after 30 days. The TVBN values indicate that the frozen lamb remained within acceptable freshness limits throughout the storage period ($p<0.05$) (Figure 6B).

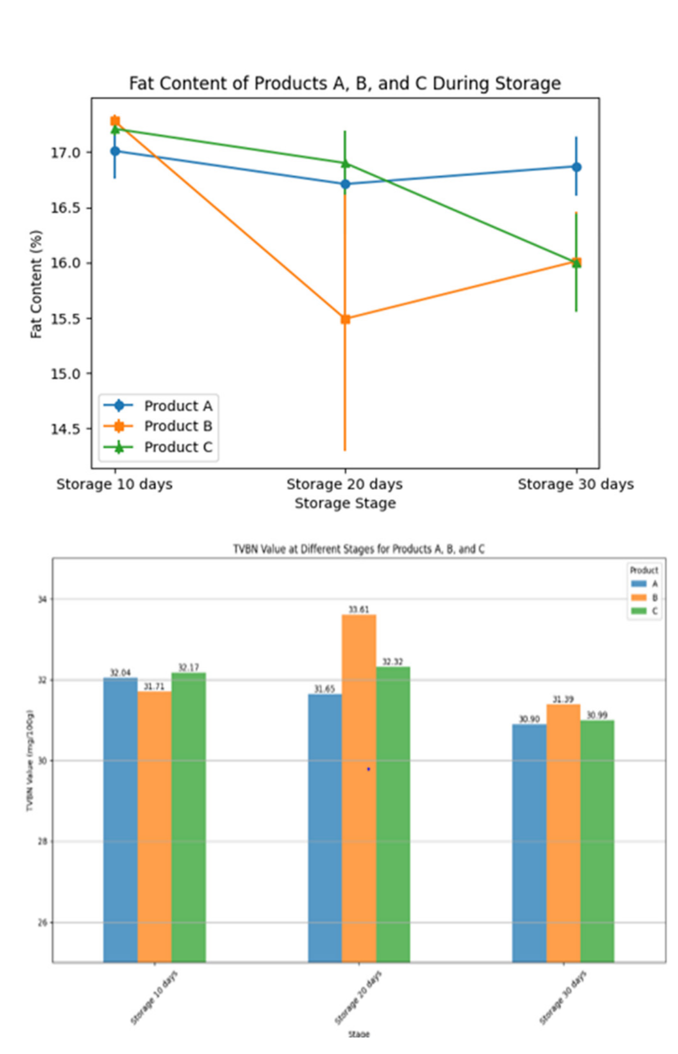

Figure 6: A: Fat content of product A, B, and C during storage and B: TVBN content of products A, B, and C during storage at different stages (10, 20, and 30 days).

Color measurement: The color values of the frozen lamb products remained relatively stable throughout the study. There were no significant changes in the L^*, a^*, and b^* values for all products, indicating that the storage conditions maintained the visual quality of the lamb ($p=0.971$) (Figure 7).

Questionnaire results

Demographic data: The study included 628 catering staff members, with a distribution of 84.9% male and 15.1% female respondents. The age distribution revealed that 8% of the respondents were 20-29 years old, 52% were s30-39 years old, and 27.10% were 40-49 years old. Educational qualifications varied, with 36.90% holding a degree 26.6% possessing a diploma most respondents (70%) had over 5 years of experience in the catering industry. Respondents: Chefs 187 (29.8%), cooks 154 (24.5%), storekeepers 113 (18%) and managers 144 (22.9%) (Figure 8).

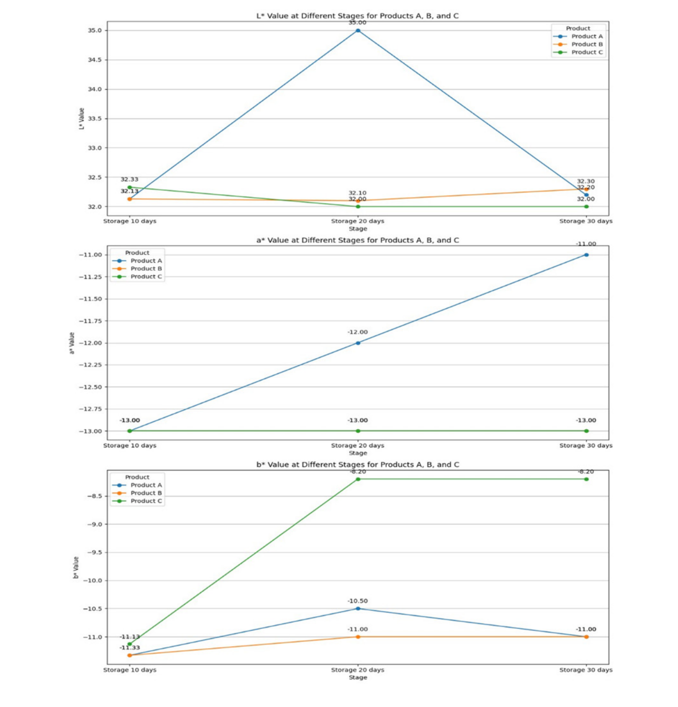

Figure 7: Color measurements (L^*, a^*, b^*) of Products A, B, and C during storage at different stages (10, 20, and 30 d).

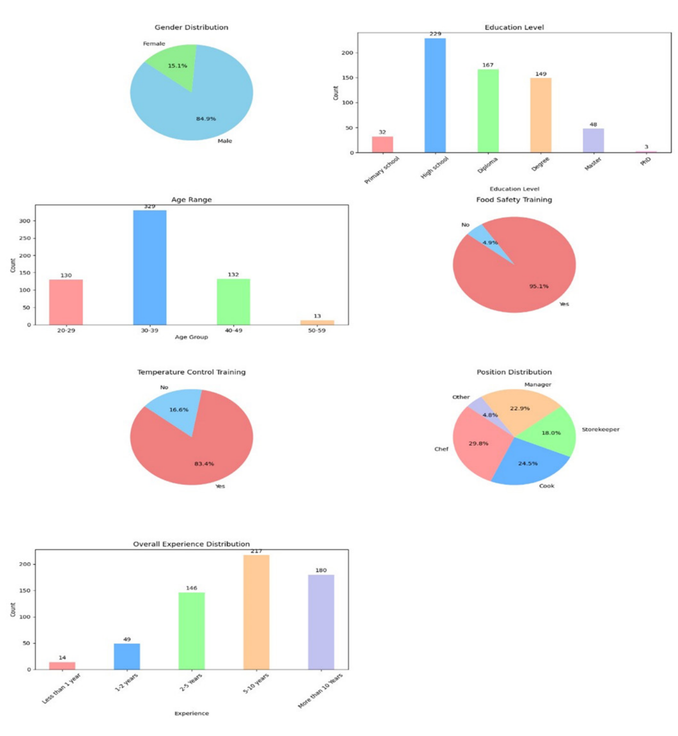

Figure 8: Demographic data of responders.

Knowledge of frozen lamb reception temperature: Ensuring that frozen lamb is received at the correct temperature is critical for maintaining food safety and quality. The survey asked respondents about the appropriate reception temperature for frozen lamb. The overwhelming majority of respondents (96.3%) demonstrated correct knowledge by selecting -18°C as the appropriate temperature for receiving frozen lamb (Table 2).

Position and frequency of temperature checking: The frequency of checking the temperature of transported frozen lamb varied significantly among different positions. The Chi-square statistic was 104.982 with 12 degrees of freedom, and the p-value was less than 0.001, indicating a statistically significant association between the position of responders and their frequency of temperature checks. Out of 628 unit managers, 510 (81.2%) checked the temperature during loading and offloading. Out of 187 chefs, 164 (87.7%) checked the temperature during loading and offloading. Cooks had a lower frequency, with 127 out of 154 (82.5%) checking during loading and offloading. Storekeepers and others showed varied practices with lower consistency. These findings highlight the importance of role-specific training to ensure uniformity in temperature monitoring practices across different positions (Table 3).

Key factors checked during receipt of frozen lamb: The association between the position of responders and their responses to key factors checked during the receipt of frozen lamb was significant, with a p-value of less than 0.001. Among chefs (n=112 out of n=134, 83.6%) selected "4 options", indicating comprehensive knowledge. Only storekeepers (n=28 out of n=112, 25.0%) selected "2 options", showing a gap in awareness. These discrepancies suggest the need for tailored training programs to ensure all staff are equally informed about critical checks during receipt.

Temperature monitoring and maintenance: Temperature monitoring and maintenance methods showed significant discrepancies between positions, with a Chi-square statistic of 60.375 and a p-value of less than 0.001. A significant portion of chefs (n=118 out of n=134, 88.1%) selected "4 options". In contrast, (n=28 out of n=112, 25.0%) selected "2 options". This indicates that while some positions adhere strictly to temperature monitoring protocols, others may require additional training to standardize these practices.

Safe thawing practices: There were significant differences in safe thawing practices based on position, with a p-value of less than 0.001. Most chefs (n=125 out of n=134, 93.3%) and cooks (n=104 out of n=117, 88.9%) preferred using a refrigerator. Other positions had more varied responses, indicating a need for targeted education on safe thawing methods.

Food safety training: Food safety training appeared to be uniformly distributed across positions, with no significant association (p-value <0.151). Training appears to be consistently provided, with 96.3% of chefs and 94.9% of cooks reporting having received training. However, the content and effectiveness of the training might still need assessment to ensure it meets the needs of all roles adequately.

In Table 4, association between questionnaire responses and position of responders. The Chi-square statistic and p-value indicate significant associations between the position of responders and their responses to key factors, temperature monitoring methods, and safe.

Table 2: The responder's percentage knowledge on frozen lamb reception temperature.

Temperature (°C)	Frequency	Percent
-18	605	96.30%
5	10	1.60%
-10	11	1.80%
25	2	0.30%
Total	628	100%
Total	1000	630

Table 3: Frequency of checking temperature of transported frozen lamb by position.

Position	Total responders	Checked during loading and offloading	Checked during loading only	Checked at regular intervals during transportation	Checked irregularly/ not consistently
Unit manager	628	510 (81.2%)	20	89	9
Chef	187	164 (87.7%)	5	17	1
Cook	154	127 (82.5%)	3	20	4
Storekeeper	113	86 (76.1%)	5	20	2
Others	30	16 (53.3%)	3	11	0

Table 4: Association between questionnaire responses and position of responders.

Variable	Frequency of checking temperature n (%)	Key factors checked during receipt n (%)	Temperature monitoring methods n (%)	Safe thawing practices n (%)	Food safety training n (%)	χ^2	p-value
Position of responders	-	-	-	-	-	-	-
Others	16 (53.3)	5 (16.7)	10 (33.3)	15 (50.0)	25 (83.3)	104.982	<0.001
Cook	127 (82.5)	40 (26.0)	100 (64.9)	104 (88.9)	146 (94.8)	60.375	<0.001
Chef	164 (87.7)	112 (83.6)	118 (88.1)	125 (93.3)	129 (96.3)	35.128	<0.001
Store Keeper	86 (76.1)	28 (25.0)	28 (25.0)	90 (78.3)	110 (98.2)	11.23	<0.001
Unit manager/ supervisor	510 (81.2)	95 (66.0)	89 (66.4)	520 (82.8)	611 (97.3)	2.69	0.151

Additional analysis based on age and experience: A significant association was found between age and the frequency of checking the temperature of transported frozen lamb, with a Chi-square statistic of 42.706, 9 degrees of freedom, and a p-value of less than 0.001. For example, 85.8% of respondents aged 30-39 checked the temperature during loading and off-loading, whereas only 77.9% of respondents aged 20-29 did the same.

Significant differences were also observed in measures to prevent temperature abuse during offloading, with a Chi-square statistic of 50.698, 12 degrees of freedom, and a p-value of less than 0.001. For instance, 75.9% of respondents aged 30-39 selected "5 options" compared to 55.8% of those aged 20-29.

In terms of ensuring the quality of pre-packed lamb during 30 day frozen storage, the p-value was less than 0.001, indicating a significant relationship between age and the measures taken. For example, 75.9% of respondents aged 30-39 selected "5 options", whereas only 69 out of 130 respondents aged 20-29 did the same.

Confidence in answering customer questions related to food was significantly associated with age, with a p-value of less than 0.001. The analysis showed that 99.4% of respondents aged 30-39 felt confident compared to 99.7% of those aged 20-29.

There was no significant association between age and compromising food safety procedures while handling frozen lamb, with a p-value of 0.18.

Communication of food safety measures to customers was significantly associated with age, with a p-value of 0.001. For example, 238 out of 329 respondents aged 30-39 selected three options compared to 81 out of 130 respondents aged 20-29.

Years of experience significantly influenced receiving food safety training, with a p-value of 0.019. Respondents with less than 1 year of experience were more likely to not have received training compared to other groups. Those with 1-2 years and 2-5 years of experience had higher likelihoods of having received training, indicating a high level of compliance with food safety training standards. Respondents with 5-10 years and more than 10 years of experience showed even higher likelihoods of having received training, reflecting the industry's commitment to ongoing education.

The frequency of temperature checking showed significant variation by experience, with a p-value of 0.032. For instance, 89.6% of respondents with 5-10 years of experience checked the temperature during loading and offloading, compared to only 76.9% of those with less than 1 year of experience.

Ensuring the temperature of frozen lamb is consistent during transportation also showed significant differences based on experience, with a p-value of less than 0.001. For example, 61.1% of respondents with 5-10 years of experience selected "4 options", compared to only 18.2% of those with less than 1 year of experience.

Other important things to check for during the receipt of frozen lamb were significantly associated with experience, with a p-value of less than 0.001. For instance, 64.0% of respondents with 5-10 years of experience selected "4 options", while only 27.3% of those with less than 1 year of experience did the same.

Ensuring frozen lamb is stored safely was significantly influenced by experience, with a p-value of less than 0.001. For example, 75.8% of respondents with 5-10 years of experience selected "4 options", compared to 45.5% of those with less than 1 year of experience.

Methods for monitoring and maintaining storage temperature were significantly associated with experience, with a Chi-square statistic of 40.637, 12 degrees of freedom, and a p-value of less than 0.001. For instance, 81.0% of respondents with 5-10 years of experience selected "4 options", compared to only 54.5% of those with less than 1 year of experience.

Ensuring the quality of pre-packed lamb during 30-day frozen storage showed significant differences based on experience, with a Chi-square statistic of 46.886, 16 degrees of freedom, and a p-value of less than 0.001. For example, 80.0% of respondents with 5-10 years of experience selected "5 options", compared to 36.4% of those with less than 1 year of experience.

Significant associations were found for how respondents thaw frozen lamb, with a p-value of 0.022. For instance, 86.5% of respondents with 5-10 years of experience selected "using a refrigerator", compared to 63.6% of those with less than 1 year of experience.

Communication of food safety measures to customers was significantly associated with experience, with a p-value of less than 0.001. For example, 76.3% of respondents with 5-10 years of experience selected "3 options", compared to 46.2% of those with less than 1 year of experience.

In Table 5, association between age, experience, and various food safety practices. The table shows significant associations between age and experience with various food safety practices, temperature monitoring, and safe thawing practices, indicated by the Chi-Square.

Table 5: Association between age, experience, and various food safety practices.

Variable	Category	Frequency (%)	χ^2	p-value
Age and frequency of temperature checks	20-29	77.9		<0.001
	30-39	85.8	42.706	
	40-49	81.2		
	50+	80		
Measures to prevent temperature abuse	20-29	55.8		<0.001
	30-39	75.9	50.698	
	40-49	70.2		
	50+	72.4		
Ensuring quality during 30-day storage	20-29	69	42.746	<0.001
	30-39	75.9		
	40-49	73.2		
	50+	71.1		
Confidence in answering customer queries	20-29	99.7	47.086	<0.001
	30-39	99.4		
	40-49	98		
	50+	97.5		
Food safety procedures	20-29	65	6.047	0.18
	30-39	70.2		
	40-49	69.5		
	50+	72		
Communicating food safety measures	20-29	62.3	49.343	0.001
	30-39	72.3		
	40-49	68.5		
	50+	71.5		
Experience and food safety training	Less than 1 year	50	11.801	0.019
	1-2 years	60		
	2-5 years	75		
	5-10 years	85		
	More than 10 years	90		
Temperature check frequency	Less than 1 year	76.9	22.508	0.032
	1-2 years	82		
	2-5 years	85		
	5-10 years	89.6		
	More than 10 years	88.5		
Ensuring temperature consistency	Less than 1 year	45.5	52.049	<0.001
	1-2 years	58		
	2-5 years	70		
	5-10 years	75		
	More than 10 years	80		
Important checks during receipt	Less than 1 year	27.3	60.588	<0.001
	1-2 years	55		
	2-5 years	64		
	5-10 years	70		
	More than 10 years	74		
Safe storage of frozen lamb	Less than 1 year	45.5	26.612	< 0.001
	1-2 years	58		
	2-5 years	65		
	5-10 years	75.8		
	More than 10 years	80		

Monitoring storage temperature	Less than 1 year	54.5	46.666	< 0.001
	1-2 years	60		
	2-5 years	70		
	5-10 years	81		
	More than 10 years	85		
Quality during 30-day frozen storage	Less than 1 year	36.4	36.555	< 0.003
	1-2 years	50		
	2-5 years	65		
	5-10 years	80		
	More than 10 years	82		
Safe thawing practices	Less than 1 year	63.6	30.396	0.022
	1-2 years	70		
	2-5 years	78		
	5-10 years	86.5		
	More than 10 years	90		
Communicating food safety measures	Less than 1 year	46.2	37.123	<0.001
	1-2 years	55		
	2-5 years	70		
	5-10 years	76.3		
	More than 10 years	80		

DISCUSSION

The present study evaluated both the microbiological and chemical quality of frozen lamb products during different stages of handling, transportation, and storage, as well as surveyed the food safety knowledge and practices of staff involved in these processes. The findings provide comprehensive insights into the effectiveness of current practices and highlight areas that require stringent monitoring to maintain meat quality and safety. The one-way ANOVA conducted on the chemical parameters across various stages of handling and storage of frozen lamb products revealed significant differences ($p<0.05$), indicating a need for careful monitoring during storage. The analysis specifically pointed to changes in chemical stability that could potentially impact the safety and quality of the products. The F-value of 2.946, significant at $p<0.05$, underlines that these differences are statistically meaningful and not due to random variation (Table 6).

Table 6: One-way ANOVA results on chemical parameters.

Product	Parameter	Storage duration (Days)	Value ± SD	p-value
Product A	pH	Loading	5.29 ± 0.083	
		Unloading	5.60 ± 0.173	
		Storage 10 days	5.60 ± 0.1	
		Storage 20 days	5.60 ± 0.1	
		Storage 30 days	5.80 ± 0.1	0.028
	Fat (%)	Storage 10 days	17.01 ± 0.25	
		Storage 20 days	16.71 ± 0.45	
		Storage 30 days	16.87 ± 0.27	0.05
	TVBN	Storage 10 days	32.04 ± 0.43 mg/100g	
		Storage 20 days	31.65 ± 0.45 mg/100g	
		Storage 30 days	30.90 ± 0.271 mg/100g	0.05
	L*	Storage 10 days	-32.33 ± 0.5	
		Storage 20 days	-32 ± 0.5	
		Storage 30 days	-32 ± 0.5	0.971
	a*	Storage 10 days	-13	
		Storage 20 days	-13	
		Storage 30 days	-13	0.971
	b*	Storage 10 days	-11.13 ± 0.5	
		Storage 20 days	-8.2 ± 0.5	
		Storage 30 days	-8.2 ± 0.5	0.971

	pH	Loading	5.37 ± 0.032	
		Unloading	6.49 ± 0.391	
		Storage 10 days	6.53 ± 0.197	
		Storage 20 days	5.95 ± 0.689	
		Storage 30 days	6.75 ± 0.069	0.028
	Fat (%)	Storage 10 days	17.28 ± 0.059	
		Storage 20 days	15.49 ± 1.196	
		Storage 30 days	16.01 ± 0.445	0.05
	TVBN	Storage 10 days	31.71 ± 0.717 mg/100g	
		Storage 20 days	33.61 ± 3.792 mg/100g	
Product B		Storage 30 days	31.39 ± 0.681 mg/100g	0.05
	L*	Storage 10 days	-32.13 ± 0.5	
		Storage 20 days	-32.1 ± 0.5	
		Storage 30 days	-32.3 ± 0.5	0.971
	a*	Storage 10 days	-13	
		Storage 20 days	-13	
		Storage 30 days	-13	0.971
	b*	Storage 10 days	-11.33 ± 0.5	
		Storage 20 days	-11 ± 0.5	
		Storage 30 days	-11 ± 0.5	0.971

	pH	Loading	6.01 ± 0.081	
		Unloading	6.46 ± 0.291	
		Storage 10 days	6.51 ± 0.197	
		Storage 20 days	6.28 ± 0.189	
		Storage 30 days	6.57 ± 0.169	0.028
	Fat (%)	Storage 10 days	17.21 ± 0.059	
		Storage 20 days	16.90 ± 0.289	
		Storage 30 days	16.00 ± 0.445	0.05
	TVBN	Storage 10 days	32.17 ± 0.717 mg/100g	
		Storage 20 days	32.32 ± 0.392 mg/100g	
Product C		Storage 30 days	30.99 ± 0.581 mg/100g	0.05
	L*	Storage 10 days	-32.13 ± 0.5	
		Storage 20 days	-35 ± 0.5	
		Storage 30 days	-32.2 ± 0.5	0.971
	a*	Storage 10 days	-13	
		Storage 20 days	-12	
		Storage 30 days	-11	0.971
	b*	Storage 10 days	-11.33 ± 0.5	
		Storage 20 days	-10.5 ± 0.5	
		Storage 30 days	-11 ± 0.5	0.971

For microbiological parameters, the one-way ANOVA for TVC across various handling and storage stages showed no significant differences (F=0.634, p>0.05). This indicates a stable microbial environment throughout the product's processing and storage lifecycle.

The significant chi-square results suggest that the transportation time has a statistically significant impact on the microbiological parameters of the frozen lamb products. Specifically, product A (30 minutes) shows low microbial growth, suggesting that shorter transportation time might be better for maintaining microbiological quality. Product B (45 minutes) had intermediate results, indicating moderate microbial growth. Product C (90 minutes) exhibited the highest microbial growth, emphasizing the need for better control during longer transportation times to prevent quality deterioration (Table 7).

Table 7: Chi-square test results for the impact of transportation time on microbiological parameters of frozen lamb product.

Product	Transportation time	TVC	p-value
Product A	30 minutes	Low	<0.001
Product B	45 minutes	Moderate	<0.001
Product C	90 minutes	High	<0.001

The second objective in this study investigated the demographic characteristics and food safety knowledge of respondents in the food industry, particularly focusing on how these factors influence the handling, transportation, and storage of frozen lamb. The majority of the respondents were male, with a significant proportion having completed high school or higher education. These demographics are reflective of the typical workforce within the food industry. The results indicate that the educational background of the respondents may play a crucial role in their understanding and implementation of food safety practices, similar to findings in studies conducted in other regions, where higher education levels were linked to better food safety knowledge and practices [19-21].

However, inconsistencies with other studies suggest that the type of training received and the practical application of this knowledge can vary widely, impacting the overall effectiveness of food safety protocols [22]. This highlights the need for targeted training programs that not only impart theoretical knowledge but also emphasize practical application, particularly in areas critical to preventing food borne illnesses and ensuring the microbiological and chemical safety of frozen lamb during storage and transportation.

Training and continuous education play pivotal roles in food safety [23,24]. The high percentage of respondents who received food safety training and specific training on temperature control during transportation underscores the industry's commitment to maintaining meat quality and safety. These findings are consistent with studies from [25,26] as they also emphasized the importance of regular training in enhancing food safety practices.

Regular temperature checks during loading, offloading, and transportation were well recognized by the majority of respondents, important for preventing quality deterioration [27].

Storage practices are another critical area where respondents demonstrated a high level of compliance. Regular microbial testing and awareness of best storage practices are essential for ensuring meat safety and quality [28]. This high adherence to recommended storage practices mirrors the results of studies conducted in Saudi Arabia and Ghana, indicating a robust understanding and implementation of food safety protocols among the respondents [20].

Thawing practices, particularly the use of refrigerators for thawing frozen lamb, were correctly identified by most respondents as the safest method. This is crucial for preventing food borne illnesses and ensuring safe food handling [29]. The significant proportion of respondents who received training on safe thawing practices further emphasizes the importance of continuous education in maintaining food safety standards [30]. These findings are consistent with study which also highlighted the necessity of proper thawing methods to prevent contamination.

Food safety awareness and responsibilities are highly prioritized by the respondents, with a significant majority considering food safety as "extremely important" and employing multiple methods to communicate food safety measures to customers. This high level of awareness and commitment is important for preventing food borne illnesses and ensuring customer trust. This observation aligns with findings from studies in Haiti and Ghana, which also found high levels of food safety awareness among food handlers [31].

The confidence in handling frozen lamb and the ability to address customer questions related to food safety, as demonstrated by the vast majority of respondents, highlights the effectiveness of training and the importance of knowledgeable staff in maintaining high food safety standards [32]. Similar results were observed in studies conducted in Ethiopia, where trained food handlers exhibited high confidence and competence in food safety practices [33].

The findings from the survey indicate a high level of knowledge and compliance with food safety practices among the respondents. The demographic characteristics, coupled with extensive training and experience, contribute.

CONCLUSION

This study offers insights into the effects of handling, transportation, and storage on the microbiological and chemical quality of frozen lamb. Significant differences were observed in microbiological counts, particularly TVC, and chemical parameters such as pH, fat content, TVBN levels, and colour stability. Shorter transportation times were more favorable for maintaining microbial quality, with no detection of *E. coli* or *Salmonella* at any stage. The increase in TVC during storage highlights the need for stringent monitoring. Chemical analyses showed variations in pH, fat content, and TVBN levels, emphasizing the importance of optimal storage conditions. The colour stability suggests maintained visual quality, but careful storage is essential. The survey results reflected high food safety knowledge and compliance among catering staff, demonstrating effective training programs. Regular temperature checks, proper storage, and safe thawing methods were widely recognized and implemented.

In conclusion, while current practices are effective in maintaining certain quality parameters, improvements in transportation and long-term storage are needed. Further research on optimizing protocols and continuous staff training is recommended to ensure high food safety and quality standards. Exploring sensory attributes and consumer acceptance of frozen lamb can further validate these practices and enhance market opportunities.

CONFLICT OF INTREST

Author declares no conflict of interests.

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