RUHUNA JOURNAL OF SCIENCE
Vol 16 (1): 1-15, June 2025
eISSN: 2536-8400
http://doi.org/10.4038/rjs.v16i1.152

Faculty of Science
University of Ruhuna

Evaluation of chemical and microbiological quality of selected retail meats in Jaffna, Sri Lanka for health safety assessment

G. Rajkumar, S.C.S. Sabaragamuwa and A.C. Thavaranjit

Department of Botany, Faculty of Science, University of Jaffna, Jaffna, Sri Lanka

*Correspondence: gowrir@univ.jfn.ac.lk, ORCID: https://orcid.org/0000-0002-0783-6738

Received: 9th July 2024; Accepted: 4th June 2025; Published: 15th May 2026

Abstract Meat is an important source of high-quality protein, supplying all essential amino acids required for human nutrition. This study evaluated the physico-chemical characteristics and microbiological quality of fresh retail meat chicken, beef, and mutton to assess their safety for human consumption. A total of fifteen samples (n = 5 per meat type) were collected from retail outlets in Jaffna town, Sri Lanka, to generate baseline data relevant to public health monitoring and meat safety improvement. Physico-chemical analysis revealed variations among meat types. Chicken showed the highest pH (6.74 ± 0.12), while beef exhibited the lowest (5.87 ± 0.02). Moisture content ranged from 70.03 ± 1.51% in beef to 73.52 ± 1.22% in chicken. Mutton had the highest ash content (3.03 ± 0.10%), whereas beef recorded the highest fat (3.53 ± 0.12%) and protein content (23.16 ± 0.58%). Carbohydrate content was lowest in mutton (0.55 ± 0.05%). Water activity values ranged from 0.714 to 0.740, and beef showed the highest caloric value (578 ± 2 kcal/100 g). Microbiological analysis indicated considerable microbial loads across samples. Mesophilic counts were highest in chicken (7.39 log CFU/g). Psychrophilic bacteria were absent in chicken but detected in beef and mutton. Total and fecal coliform counts were highest in chicken and mutton, respectively. Mutton exhibited the highest Enterobacter counts, while *E. coli* levels were highest in chicken. *Staphylococcus aureus* was most prevalent in beef. *Salmonella* spp. and *Shigella* spp. were not detected in any sample. Overall, the findings emphasize the need for continuous monitoring and improved hygienic practices in retail meat handling to ensure consumer safety and protect public health.

Keywords: Chicken, beef, hygiene, microbiological parameters, mutton, safety monitoring

1 Introduction

Meat is a nutrient-rich food that provides energy and essential nutrients, including proteins as well as micronutrients such as iron, zinc, and vitamin B12, which are vital for human growth, development, and health (Klurfeld 2018). While some studies have linked high meat consumption to increased risks of cardiovascular disease, cancer, and metabolic disorders (Leonard *et al*. 2007).

Global meat consumption has risen sharply over the past century due to modern slaughtering and processing technologies, which have improved hygiene,

commercialization, and year-round availability (Alahakoon *et al*. 2016, González *et al*. 2020). Poultry, in particular, has become a dominant protein source worldwide because of its rapid growth, efficient feed conversion, short fattening period, high reproductive capacity, and relatively low cost (Kralik *et al*. 2018). In Sri Lanka, the poultry industry has transitioned from small-scale backyard systems to a highly commercialized sector over the past three decades, supported by advancements in breeding, feed formulation, hatchery management, disease control, and processing (Prabakaran 2003, Department of Census and Statistics 2014).

Meat quality, defined by physicochemical (e.g., pH, water-holding capacity), sensory (e.g., tenderness, juiciness), and nutritional attributes, is a key determinant of consumer preference and product value. Among these, pH plays a central role, as higher pH improves water-holding capacity, tenderness, and shelf life, whereas lower pH can negatively affect these qualities (Mir *et al*. 2017, Warner 2023).

Most foodborne bacteria are unable to grow at water activity (a_t) levels below approximately 0.90, although the exact threshold depends on the specific bacterial species and the prevailing temperature conditions. Water activity (a_t) is a critical factor affecting meat quality and shelf life (Fontana 2001). Most foodborne bacteria require a water activity above 0.90 to grow under typical storage conditions, and foods with higher water content are more susceptible to microbial proliferation, which can reduce shelf life (Ahmad *et al*. 2018). In meat, fat plays a key role in determining juiciness, flavor, and texture, and also provides essential fatty acids that humans cannot synthesize (Kralik *et al*. 2026). Together, water content and fat not only influence the sensory properties of meat but also affect its microbial stability and overall quality, underscoring their importance in meat processing and storage.

Meat is a high-quality protein source with high biological value, providing essential amino acids for human nutrition (Bhandare *et al*. 2007). However, its nutrient-rich composition, particularly high protein and water content, makes it highly susceptible to microbial contamination and spoilage. Contaminated raw meat is a major source of foodborne diseases, emphasizing the need for proper handling, storage, and processing to ensure safety.

The primary sources of microbial contamination in meat include the animal's hide and feces. Additional external sources arise during handling and distribution, such as the floor and air of retail outlets, the slaughterhouse environment, and the vehicles used to transport meat from slaughterhouses to markets (Sofos *et al*. 1999). Globally, the leading foodborne pathogens associated with meat are *Campylobacter*, *Staphylococcus aureus*, *Escherichia coli*, *Salmonella*, and *Enterococci*, which are responsible for millions of infections and fatalities each year (Bintsis *et al*. 2017).

The aim of this study was to assess the safety and quality of retails fresh meat sold in Jaffna, Sri Lanka. Specifically, the objectives were to evaluate the physicochemical properties (pH, moisture, ash, fat, protein, carbohydrate content, water activity, and total caloric content) and microbiological quality (aerobic plate count, total coliforms, *Enterobacter*, *Escherichia coli*, *Staphylococcus aureus*, *Salmonella* spp., and *Shigella* spp.) of fresh chicken, mutton, and beef samples collected from retail outlets. The study

seeks to provide baseline data that can inform meat safety monitoring and public health strategies in the local context.

2 Material and Methods

2.1 Sample collection

Fresh chicken, beef, and mutton samples (n = 15; five per meat type) were collected from retail outlets in the main market of Jaffna using a random sampling strategy to represent typical retail-level meat quality. Only skeletal muscle portions, chicken breast, beef muscle, and mutton muscle were selected. Sampling was conducted once per week over four weeks during morning hours.

Approximately 250 g of each sample was aseptically excised, placed in sterile containers, and transported to the laboratory in insulated ice boxes at 4 ± 1 °C. Samples were processed within 30–60 minutes and stored at 4 °C until analysis. Strict aseptic precautions were followed, including the use of sterile gloves, disinfected instruments, and sealed containers to prevent cross-contamination.

2.2 Estimation of physicochemical parameters

Total caloric content

Total caloric content was carried out using Bomb calorimeter. Approximately 1 g of homogenized sample was combusted in a crucible, with water temperature recorded before and after combustion to calculate energy content (kcal/g). Triplicate measurements were performed.

Water activity

Water activity (a_v) of the meat samples was measured using a calibrated water activity meter. All measurements were performed at controlled room temperature, and the water activity values were expressed as dimensionless a_v units.

pH

The pH value of each sample was measured by a calibrated portable pH meter (model pH 25, Crison instruments). The constant pH reading for each sample was recorded, and three replicates were taken for each sample

Moisture content

Moisture content was determined by drying 5 g of homogenized samples in pre-weighed crucibles at 105°C for 24 hours (AOAC Method 925.10), until constant weight was achieved. Crucibles were cooled in a desiccator, weighed, and moisture calculated. All measurements were performed in triplicate.

Ash content

Ash content was determined by incinerating 5 g of dried, homogenized samples in a muffle furnace at 550°C ±25°C until ash was obtained under the operating conditions in the international standard (AOAC Method 923.03). The ash was cooled in a desiccator and reweighed. Three replicates were done for each sample. The above procedure was repeated for other samples too.

Ash content % was calculated as follows:

ash% = [mass of ash / weight of original sample] *100%

Fat content

Fat content was determined using Soxhlet extraction (AOAC Method 996.06). Homogenized samples (3 g) were extracted with petroleum ether for 6 hours, dried, and weighed.

Three replicates were done for one sample.

Fat content = [Initial weight- Final weight/ Initial weight] *100%

Protein content

Protein content was determined using the Kjeldahl method (AOAC Method 984.13, A-D). Protein % was calculated by converting nitrogen percentage to protein, all nitrogen in meat was assumed to be presented as protein.

Carbohydrate content

The total percentage of carbohydrate content in the meat sample was determined by the difference method (Rajkumar *et al*. 2014)

Estimation of microbiological quality of meat samples

To evaluate microbial safety in retail meat, total and fecal coliforms were enumerated. Diluents were prepared by dissolving 0.1 g bacteriological peptone in 90 mL sterile water.

Sample preparation

The muscle tissue of fresh meat was aseptically cut and 25g was weighed by using an electronic balance. Then, it was grounded well by using the mortar and pestle. Then the ground sample was transferred into 225 mL of sterile water. After that, it was mixed well and allowed to settle. The prepared sample was serially diluted up to 10^{-6} by using the sterilized diluents.

Aerobic plate count

Plate count agar (PCA) medium was prepared and it was sterilized by an autoclave. Sterile medium was poured into sterile petri dishes under aseptic conditions and allowed to set. Aliquots of 0.1 mL from each serially diluted sample were aseptically transferred to the center of separate PCA plates using sterile pipettes. The samples were

then aseptically spread evenly over the surface of the medium using a sterile glass spreader. Triplicate plates were prepared for each dilution to ensure statistical reliability. Plates were incubated at 37°C for 24 hours (mesophiles) or 10°C for 7 days (psychrophiles) in a controlled-humidity incubator. After the incubation period, plates were observed for the development of colonies and the result was expressed in the form of log CFU/g of sample.

Enumeration of total Coliforms and fecal coliform bacteria

Endo Agar (EA) medium was prepared and it was sterilized by an autoclave. Sterile medium was poured into sterile petri dishes under aseptic conditions and allowed to set. Aliquots (0.1 mL) of serially diluted samples were transferred to the center of Endo Agar (EA) plates using sterile pipettes. Then samples were spread uniformly over the surface of the medium by using a sterile glass spreader. Triplicates were also prepared. This procedure was repeated for 2 times. Then these plates were incubated at 37°C for 24 - 48 hours for the total coliform count (Nashath *et al.* 2022)

The above procedure was repeated and the plates were incubated at 44.5°C for 24-48 hours for counting fecal coliforms. After the incubation period, plates were examined for colonies exhibiting red or pink coloration, which indicated the presence of total and fecal coliforms. Results were expressed as log CFU/g of sample.

Enumeration of *E. coli* and *Enterobacter*

Eosin Methylene Blue agar (EMB) medium was prepared and it was sterilized by an autoclave. Sterile medium was poured into sterile petri dishes under aseptic conditions and allowed to set.

0.1 mL from the serially diluted samples were transferred on the center of the EMB agar plates separately with the help of sterile pipettes. Then samples were spread uniformly over the surface of the medium by using a sterile glass spreader. Triplicates were also prepared. This procedure was repeated for 2 times. Then these plates were incubated at 37°C for 24 - 48 hours for the enumeration of *E. coli* and *Enterobacter*. After incubation, *E. coli* colonies appeared as tiny, black shiny or green with metallic sheen. *Enterobacter* colonies appeared as large, pink color with brown center and mucoid in nature. The result was expressed in log CFU/g of sample.

Enumeration of *Staphylococcus aureus*

Mannitol Salt Agar (MSA) medium was prepared and it was sterilized by an autoclave. Sterile medium was poured into sterile petri dishes under aseptic conditions and allowed to set.

An aliquot of 0.1 mL from each serially diluted sample was aseptically transferred onto the center of Mannitol Salt Agar (MSA) plates using sterile pipettes. Then samples were spread uniformly over the surface of the medium by using a sterile glass spreader. Triplicates were also prepared. This procedure was repeated for 2 times. Then these plates were incubated at 37°C for 24 - 48 hours. After incubation, yellow color colonies or pale-yellow colonies with yellow coloration of the surrounded medium indicated

the presence of *Staphylococcus aureus*. The result was expressed in terms of log CFU/g.

Enumeration of *Salmonella* sp. and *shigella* sp.

Salmonella Shigella Agar (SS) medium was prepared and it was sterilized by an autoclave. Sterile medium was poured into sterile petri dishes under aseptic conditions and allowed to set.

From the serially diluted samples 0.1 mL were transferred on the center of the SS plates separately with the help of sterile pipettes. Then samples were spread uniformly over the surface of the medium by using a sterile glass spreader. Triplicates were also prepared. This procedure was repeated for 2 times. Then these plates were incubated at 37°C for 24 - 48 hours. After incubation, colorless colonies with black centers indicated the presence of *Salmonella* species whereas *Shigella* species appeared as colorless colonies without black centers. The result was expressed in terms of log CFU/g.

Statistical Analysis

Statistical analyses were performed using one-way Analysis of Variance (ANOVA) with Minitab software (version 17). All measurements were conducted in triplicate, and results are presented as mean ± standard deviation.

3 Results and Discussion

3.1 Physicochemical analysis of selected fresh meat types available in Jaffna

Physicochemical parameters of fresh chicken, beef, and mutton samples from Jaffna retail outlets were analyzed to assess meat quality (Table 1).

Table 1: Physicochemical characteristics of fresh chicken, beef, and mutton samples from Jaffna retail outlets (n=5 per meet type).

Physicochemical Parameter	Chicken	Beef	Mutton
pH	6.74 ± 0.12^{a}	5.87 ± 0.02^{c}	6.00 ± 0.08^{b}
Moisture content (%)	73.52 ± 1.22^{a}	70.03 ± 1.51^{c}	71.90 ± 0.72^{b}
Ash content (%)	2.88 ± 0.61^{ab}	2.16 ± 0.61^{b}	3.03 ± 0.10^{a}
Fat content (%)	3.38 ± 0.03^{a}	3.47 ± 0.08^{a}	3.53 ± 0.12^{a}
Protein content (%)	19.11 ± 0.74^{c}	23.16 ± 0.58^{a}	20.99 ± 0.47^{b}
Carbohydrate content (%)	1.11 ± 0.05^{b}	1.19 ± 0.06^{a}	0.55 ± 0.05^{c}
Water activity (a_v)	0.74 ± 0.02^{a}	0.72 ± 0.02^{b}	0.71 ± 0.02^{b}
Total caloric content (kcal/100 g)	497.15	578.13	514.82

pH

Meat pH is a key determinant of freshness, flavor, and overall quality. It influences palatability, microbial growth, and water-holding capacity, alongside factors such as salt content and temperature (Koutsoumanis *et al*. 2006). Therefore, pH measurement is an important indicator of meat quality, affecting color and texture (Hadero *et al*. 2021).

As shown in Table 1, chicken exhibited the highest mean pH (6.74 ± 0.12), greater than beef (5.87 ± 0.02) and mutton (6.00 ± 0.08). pH is a result of postmortem metabolic changes that persist during the storage period, and it is dependent on the quantity of glycogen breakdown to lactic acid during anaerobic glycolysis (Hadero *et al*. 2021). Elevated pH in chicken samples may indicate ante-mortem stress, which depletes glycogen reserves and limits postmortem lactic acid production.

Such stress could be physical in nature (e.g., temperature extremes, noise, confinement, crowding) or psychological (e.g., social group disruption, novel environments, noxious odors) (Cappellozza *et al*. 2021). These pH values align with literature reports for beef (6.36–7.01; Hadero *et al*. 2021) and ruminant meats (5.5–6.0; Sristi *et al*. 2025), confirming typical postmortem acidification in non-stressed animals.

Moisture content

Moisture is regarded as one of the key physicochemical characteristics of meat considering that it is fundamental to meat's palatability. Fresh meat typically contains 70–75% moisture, varying by species and cut (Ahmad *et al*, 2018). It affects the weight, density and viscosity of meat and it allow microorganisms to grow. As shown in Table 1, chicken exhibited the highest mean moisture content (73.52 ± 1.22% w/w), followed by mutton (71.90 ± 0.72%) and beef (70.03 ± 1.51%).

Ash content

Ash content represents the inorganic mineral residue in meat after combustion of organic matter and is typically expressed as a percentage, reflecting total mineral concentration. In this study, mean ash content was highest in mutton (3.03 ± 0.10% w/w) and lowest in beef (2.16 ± 0.61% w/w). These values are consistent with published data, where poultry ash typically ranges from 1.67–3.13% (Ahmed *et al*. 2018), beef from 1.5–2.9% and mutton from 2.8–3.4% (Ahmed *et al*. 2021), confirming the reliability of the present findings.

Fat content

Fat, a key macronutrient alongside protein and carbohydrates, comprises triglycerides and contributes to meat’s energy content, sensory attributes. Variously sized fatty tissues (fat cells packed with lipids) can be found in meat. In meat, fat serves as an energy source, padding for the skin and around organs, particularly the heart and kidney, and insulation against temperature loss.

Fat constitutes of an animal's carcass, with variability depending on species, diet, and anatomical location (Schumacher *et al*. 2020). External body fat, which is higher in unsaturated fatty acids, is generally softer than internal fat surrounding the organs. The skin is the primary source of fat in meat. Fat content also significantly influences meat quality attributes such as flavor, juiciness, and texture (Dransfield 2008). In the present study, fat content ranged from 3.38 ± 0.03% in chicken, 3.47 ± 0.08% in beef, and 3.53 ± 0.12% in mutton, with the highest values observed in mutton and the lowest in chicken.

Protein Content

Meat is a protein-rich food with high biological value, providing essential amino acids critical for human nutrition. Proteins are complex nitrogenous substances that exist naturally and have a very high molecular weight. They contain nitrogen, carbon, hydrogen, and oxygen. As shown in Table 1, protein content ranged from 19.11 ± 0.74 in chicken and 23.16 ± 0.58, 20.99 ± 0.47 in beef, and mutton respectively. The elevated protein content of beef enhances its nutritional value by providing essential amino acids, such as leucine and lysine, which are critical for muscle repair and growth (Valenzuela *et al*. 2019, Church *et al*. 2020, Wolfe, 2024).

Carbohydrate content

Carbohydrates in meat are very low because most glycogen is metabolized after slaughter; skeletal muscle typically contains about 0.5–1.5% total carbohydrates (mostly glycogen) on a wet weight basis, and liver can contain somewhat higher levels, although muscle meat contributes minimally to overall carbohydrate nutrition. As shown in Table 1, mean carbohydrate content was highest in beef (1.19 ± 0.06% w/w), followed by chicken (1.11 ± 0.05%) and mutton (0.55 ± 0.03%). These values are consistent with previous reports indicating that carbohydrate content in meat is generally low, typically ranging from 0.5 to 1.5% (wet weight), primarily due to residual glycogen in muscle tissues (Lawrie & Ledward, 2006; FAO, 2011). Similar carbohydrate levels in beef and poultry muscle have been reported by Aberle *et al*. (2012), while lower values in mutton are attributed to species-specific differences in muscle glycogen storage and post-mortem metabolism.

Water activity

Water is an essential component of all foods and strongly influences their quality and shelf life. Based on moisture content, foods can be classified into perishable products (moisture >70%) and less perishable items (Ahmad *et al*. 2018). Water activity, defined as the ratio of a food's vapor pressure to that of pure water, directly affects microbial growth and thereby governs the shelf life of meat and other perishable products.

Spoilage and increases the concentration of solutes. However, different food varieties with the same water content have significantly different shelf life and spoilage characteristics. As shown in Table 1, mean water activity was 0.74 ± 0.02 (chicken), 0.72 ± 0.02 (beef), and 0.71 ± 0.02 (mutton).

Total caloric content

Total caloric content is the measurement of energy released from macronutrients. In meat, total caloric content is in the form of fats and proteins. In this study the total caloric content 497.15 in chicken, 578.13 (kcal/100 g) in beef and 514.82 (kcal/100 g) in mutton.

3.2 Estimation of microbiological quality of selected fresh meat types

The microbiological safety and hygienic conditions were assessed by using the ICMSF- (International Commission on Microbiological Specifications for Foods) recommended sampling and enumeration methods. All samples exhibited microbial loads above baseline levels, with Aerobic Plate Count (APC) exceeding 10^5 CFU/g in most, indicating post-slaughter contamination consistent with raw meat handling. The Table 2 shows the results of microbiological analyses for the three different fresh meat samples.

Table 2: Microbiological characteristics of fresh meat samples (n=5, Mean ± SD, log CFU/g).

Organism	Chicken (log CFU/g)	Beef (log CFU/g)	Mutton (log CFU/g)
Mesophiles	7.39 ± 0.00 [a]	6.96 ± 0.00 [b]	6.74 ± 0.01 [c]
Psychrophiles	Nil	3.70 ± 0.52 [b]	4.60 ± 0.18 [a]
Total coliforms	5.52 ± 0.19 [a]	5.24 ± 0.07 [b]	5.51 ± 0.19 [a]
Fecal coliforms	5.53 ± 0.01 [a]	5.41 ± 0.04 [b]	5.54 ± 0.01 [a]
Enterobacter spp	6.28 ± 0.03 [b]	6.38 ± 0.02 [a]	6.70 ± 0.00 [c]
Escherichia coli	6.03 ± 0.12 [a]	5.07 ± 0.15 [b]	5.14 ± 0.15 [b]
Staphylococcus aureus	3.88 ± 0.25 [c]	5.16 ± 0.27 [a]	5.02 ± 0.31 [b]
*Salmonell*a sp. and *Shigella* sp.	Nil	Nil	Nil

Aerobic Plate Count

The Aerobic Plate Count (APC) is used as an indicator of bacterial populations on a sample. It is also called as aerobic colony count, or Standard plate count. It is a generic test for organisms that grow aerobically at mesophilic temperatures 25℃ to 37℃ and psychrophiles generally lower than 10℃. The results of this study showed that mesophilic counts were highest in chicken, ranging from 7.39 ± 0.00 log CFU/g, followed by beef (6.96 ± 0.00 log CFU/g) and mutton (6.74 ± 0.01 log CFU/g). Psychrophilic bacteria were absent in chicken, while the count was 3.70 ± 0.52 log CFU/g in beef and 4.60 ± 0.18 log CFU/g in mutton.

According to the Sri Lankan Food Act No. 26 (1980), the aerobic plate count (mesophilic bacteria) in fresh meat should be less than 5×10^6 CFU/g (≈ 6.70 log CFU/g). In the current study, this limit was exceeded in all meat samples, indicating high mesophilic contamination. The mesophilic counts in chicken is higher than values reported in other regional studies (Kulasooriya *et al*. 2019). Absence of psychrophilic

bacteria in chicken samples may reflect the actual storage conditions (rapid cooling and short storage period) rather than limitations of the assay (ICMSF, 2011). In contrast, mutton exhibited higher psychrophilic counts than beef, suggesting longer storage or higher susceptibility to cold-tolerant microbes.

The higher mesophilic counts in chicken could be associated with elevated moisture content and pH, as reported in previous studies where increased water activity and neutral pH support microbial proliferation (Racchi *et al*. 2015) This is consistent with our own measurements, which showed slightly higher moisture and pH values in chicken samples compared to beef and mutton (Table 1). Given that poultry dominating the Sri Lankan meat market, these elevated mesophilic loads highlight potential food safety risks, including spoilage and the presence of opportunistic pathogens. This underscores the need for improved hygiene during slaughtering, processing, transportation, and retail storage to ensure microbial safety of meat products.

Enumeration of total coliform count

Coliform bacteria are often referred to as indicator organisms for fecal contamination and potential enteric pathogens in food (Erkmen 2022). Specific types of coliform bacteria may be tested especially after a total coliform bacterium is present. These subgroups of coliform bacteria include fecal coliform and *E. coli*.

The mean value of total coliform count (TCC) of three meat samples is presented in Table 2. The mean TCC was slightly higher in chicken (5.52 ± 0.19 log CFU/g), followed by mutton (5.51 ± 0.19 log CFU/g) and beef (5.24 ± 0.07 log CFU/g).

There were no recommendations on the total coliform count in the Sri Lankan Food Act No.26 of 1980. According to ICMSF specifications for the total coliform count, none of the samples had coliform counts under $2*10^3$ CFU/g (3.30 log CFU/g), however, in this study all raw meat samples had total coliform counts much exceeded the acceptable limit (>2000 CFU/g).

In a previous research high unacceptable levels of total coliforms were reported in both chicken breast and liver (Yammine and Karam 2020). As a result, a high coliform count indicates poor sanitary quality and may be accountable for economic losses as well as the presence of enteric pathogens that pose public health risks. High TCC highlights the need for hygiene improvements in Jaffna's poultry supply.

Enumeration of faecal coliform

A faecal coliform test was created because total coliform counts are insufficient to distinguish between faecal and non-faecal contamination. Fecal coliforms are bacteria that digest lactose in an endoagar medium and produce gas within 48 hours at 45.5 ℃. Faecal coliforms are thought to be more closely linked to fecal contamination in warm-blooded animals than other members of the coliform family (Greenberg and Hunt 1985, Paille *et al*. 1987).

In this study, the prevalence and loads of fecal indicators, specifically fecal coliforms, were assessed to determine the microbial quality of three different meat

samples. Fecal coliforms were detected in all samples. The counts in chicken ranged from 5.53 ± 0.01 log CFU/g, in beef from 5.41 ± 0.04 log CFU/g, and in mutton from 5.54 ± 0.01 log CFU/g. Since there are no specific limits for fecal coliforms in the Sri Lankan Food Act (1980), the LIBNOR standard was used, which sets a satisfactory level at 100 CFU/g (≈ 2 log CFU/g). All samples in this study exceeded this acceptable level.

Enumeration of *Enterobacter and E. coli*

There are about 20 genera in the family Enterobacteriaceae, which include *E. coli* and the group of coliform bacteria. Members of the family are gram-negative and rod-shaped. They are facultative anaerobes that ferment sugar to produce various acids. Enterobacteriaceae are unable to form spores. Most species have flagella to move. Numerous Enterobacteriaceae are found in the intestines of humans and other animals, some occur in water or soil whereas others are parasites on animals and plants. Enterobacter counts were highest in mutton samples compared to chicken and beef. Counts in chicken ranged from 6.28 ± 0.03 log CFU/g, in beef from 6.38 ± 0.02 log CFU/g, and in mutton from 6.70 ± 0.00 log CFU/g. *E. coli* counts varied among the meat samples. In chicken, counts ranged from 6.03 ± 0.12 log CFU/g, in beef from 5.07 ± 0.15 log CFU/g, and in mutton from 5.14 ± 0.15 log CFU/g.

According to Sri Lankan Food act No.26 1980, the *E. coli* count in fresh meat should be less than $1x10^3$ CFU per gram, and according to LIBNOR standards, it was 500 CFU/g. In the current study, each and every sample exceeded those acceptable levels in the *E. coli* count. So, it revealed that the butcher shops in Jaffna town are highly contaminated with faecal coliform, *E. coli*. Fecal contaminations occurred by water and the butcher shops are mostly in open areas. This contamination occurred when handling, transportation, and storage, maybe they are contaminated with animal feces. This result showed that sufficient hygiene measures were not placed at the butcher shops in the Jaffna town area, which leads to a high level of bacterial contamination in all meat samples. Nonetheless, the presence of *E. coli* is concerning, as some strains, such as *E. coli* O157:H7, have been linked to the synthesis of Shiga toxins and have been linked to foodborne illness in people (Ncoko *et al*. 2020).

Enumeration of *Staphylococcus aureus*

Many pathogens have been responsible for food safety in recent years. *Staphylococcus aureus* is a prominent foodborne pathogen found in fresh and ready-to-eat foods that causes a variety of diseases around the world (Kadariya *et al*. 2014). It could grow at temperatures ranging from 15°C to 45°C, with NaCl concentrations as high as 15%. (Missiakas and Schneewind 2013). At room temperature, this bacterium multiplies rapidly and produces toxins that cause sickness. Naturally, *S. aureus* was found all over the world, but the most common infection source for *S. aureus* was food.

In this study, *Staphylococcus aureus* counts were lowest in chicken, ranging from 3.88 ± 0.25 log CFU/g, whereas beef samples had the highest counts ranging from 5.16 ± 0.27 log CFU/g, and from 5.02 ± 0.31 log CFU/g in mutton. According to Food Act

No. 26 (1980), Staphylococcus aureus counts should be less than 1×10^3 CFU/g (≈3 log CFU/g), and the ICMSF standard sets a limit of 5×10^2 CFU/g (≈ 2.70 log CFU/g). All three meat samples in this study exceeded these acceptable limits.

Enumeration of *Salmonella* sp. and *Shigella* sp.

Salmonella sp. and *Shigella sp.* were not detected in any of the meat samples analyzed in this study. Previous studies identified *Salmonella* as one of the most major pathogenic genera implicated in foodborne bacterial outbreaks and disorders (Kadariya *et al*. 2014). *Salmonella* infections are found all throughout the world and are a major public health issue in Turkey and many other countries (Erdem *et al*. 2005). *Salmonella* causes an estimated 1.4 million episodes of foodborne disease and more than 500 deaths in the United States each year, according to reports. *Salmonella* is a growing public health concern because it is one of the most commonly implicated pathogenic microorganisms of bacterial food poisoning, especially in poultry meat. Infection occurs when raw poultry carcasses and products are handled, as well as when undercooked poultry meat is consumed (Panisello *et al*. 2000).

4 Conclusions

Based on the results, variations in the physicochemical and microbiological quality of chicken, beef, and mutton were observed, and microbial counts of almost all samples exceeded the acceptable limits set by international and local standards. These findings highlighted the need for routine monitoring and verification to assess the efficiency of control measures and food safety recommendations. These markets in Jaffna town are exposed directly to open environment. Contamination, likely associated with the high moisture content and pH of poultry meat, may result from unhygienic slaughtering practices and open-air retailing under the warm climatic conditions of Jaffna. Faecal coliforms were high in every sample. So, there's a high risk of presence of pathogens in these samples. *Salmonella* sp. and *Shigella* sp were absent in all meat samples. Faecal contaminations were found due to poor hygienic conditions, and possibly from water.

Acknowledgements

Authors acknowledge the critical comments from two anonymous RJS reviewers, and RJS editors.

References

Aberle ED, Forrest JC, Gerrard DE, Mills EW. 2012. *Principles of meat science* (5th ed.). Kendall Hunt Publishing.

Ahmad RS, Imran A, Hussain MB. 2018. Nutritional composition of meat. *In* Y. H. Hui (Ed.), *Meat science and nutrition* (pp. 61–77). IntechOpen. https://doi.org/10.5772/intechopen.77045

Alahakoon AU, Jo C, Jayasena DD. 2016. An overview of meat industry in Sri Lanka: A comprehensive review. *Food Science of Animal Resources* 36(2):137–144. https://doi.org/10.5851/kosfa.2016.36.2.137

AOAC, Official methods of analysis, 20th edition. Association of Analytical Chemists. Washington D.C. 2016.

Bhandare SG, Sherikar AT, Paturkar AM, Waskar VS, Zende RJ. 2007. A comparison of microbial contamination on sheep/goat carcasses in a modern Indian abattoir and traditional meat shops. *Food Control* 18(7): 854–858. https://doi.org/10.1016/j.foodcont.2006.04.012

Bintsis, T. (2017). Foodborne pathogens. *AIMS Microbiology* 3(3): 529–563. https://doi.org/10.3934/microbiol.2017.3.529

Cappellozza BI, Marques RS. 2021. Effects of pre-slaughter stress on meat characteristics and consumer experience. In Bruno I. Cappellozza & Rodrigo S. Marques (Eds.), *Meat quality*. IntechOpen. https://doi.org/10.5772/intechopen.96742

Church DD, Hirsch KR, Park S, Kim I-Y, Gwin JA, Pasiakos SM, Wolfe RR, Ferrando AA. 2020. Essential amino acids and protein synthesis: Insights into maximizing the muscle and whole-body response to feeding. *Nutrients* 12(12): 3717. https://doi.org/10.3390/nu12123717

Department of Census and Statistics . 2014. *Livestock and poultry statistics*. Ministry of Finance and Planning, Colombo, Sri Lanka.

Dransfield E. 2008. The taste of fat. *Meat Science* 80(1): 37–42.

Erdem B, Ercis S, Hasceli, G, Gur D, Aysev AD. 2005. Antimicrobial resistance of Salmonella enterica group C strains isolated from humans in Turkey, 2000–2002. *International Journal of Antimicrobial Agents* 26(1): 33–37. https://doi.org/10.1016/j.ijantimicag.2005.03.007

FAO 2011. *FAO food composition table for use in Africa*. Food and Agriculture Organization.

Fontana AJ Jr. 2001. Water activity's role in food safety and quality. Food Safety Magazine. Accessed at https://www.food-safety.com/articles/4420-water-activitye28099s-role-in-food-safety-and-quality.

Geletu US, Usmael MA, Mummed YY, Ibrahim AM. 2021. Quality of cattle meat and its compositional constituents. *Veterinary Medicine International* 2021:1–9. https://doi.org/10.1155/2021/7340495

González N, Marquès M, Nadal M, Domingo JL. 2020. Meat consumption: Which are the current global risks? A review of recent (2010–2020) evidences. *Food Research International* 137, 109341. https://doi.org/10.1016/j.foodres.2020.109341

Greenberg A E, Hunt CW. 1985. Fecal coliforms as indicators of water quality. *Journal of Water Pollution Control Federation* 57(7):715–719.

Hadero T, Nigusse G. Banerjee S. 2021. Assessment of beef meat handling, physicochemical and bacteriological properties of selected butcheries in Hawassa City, Ethiopia. *SINET: Ethiopian Journal of Science* 44(1): 62–73. https://doi.org/10.4314/sinet.v44i1.6

Erkmen O. 2022. Practice 13 – Isolation and counting of coliforms and *Escherichia coli. In:* Microbiological analysis of foods and food processing environments (pp. 105–140). Academic Press. https://doi.org/10.1016/B978-0-323-91651-6.00051-3

ICMSF 2011. Microorganisms in foods 7: Microbiological testing in food safety management. Springer.

Kadariya J, Smith TC, Thapaliya, D. 2014. *Staphylococcus aureus* and staphylococcal food-borne disease: An ongoing challenge in public health. *BioMed Research International* 2014: 1–9. https://doi.org/10.1155/2014/827965

Klurfeld DM. 2018. What is the role of meat in a healthy diet? *Animal Frontiers* 8(3):5-10. https://doi.org/10.1093/af/vfy009

Koutsoumanis K, Stamatiou A, Skandamis P, Nychas GJ E. 2006. Development of a microbial model for the combined effect of temperature and pH on spoilage of ground meat, and validation of the model under dynamic temperature conditions. *Applied and Environmental Microbiology, 72*(1), 124–134. https://doi.org/10.1128/aem.72.1.124-134.2006

Kralik G, Gallo V, Svoboda J. 2018. Poultry meat quality. *Animal Husbandry and Nutrition*. https://doi.org/10.5772/intechopen.72865

Kulasooriya GDBN, Amarasiri MKUT, Abeykoon AMH, Kalupahana RS. 2019. *Salmonella*, *Campylobacter* and *Escherichia coli* in raw chicken meat, chicken products and cooked chicken in retail markets in Kandy, Sri Lanka. *Sri Lanka Veterinary Journal* 66(1):19. https://doi.org/10.4038/slvj.v66i1.33

Lawrie RA, Ledward DA. 2006. *Lawrie's meat science* (7th ed.). Woodhead Publishing.

Leonard WR, Snodgrass JJ, Robertson ML. 2007. Effects of brain evolution on human nutrition and metabolism. *Annual Review of Nutrition* 27*:* 311–327. https://doi.org/10.1146/annurev.nutr.27.061406.093659

Mir NA, Dar MA, Bhat ZF, Kumar S. 2017. Determinants of broiler chicken meat quality and factors affecting them: A review. *Journal of Food Science and Technology* 54(10): 2997–3009. https://doi.org/10.1007/s13197-017-2789-z

Missiakas DM, Schneewind O. 2013. Growth and laboratory maintenance of *Staphylococcus aureus*. *Current Protocols in Microbiology* 28(1):9C.1.1-9C.1.9 https://doi.org/10.1002/9780471729259.mc09c01s28

Ncoko P, Jaja IF, Oguttu, JW. 2020. Microbiological quality of beef, mutton, and water from different abattoirs in the Eastern Cape Province, South Africa. *Veterinary World* 13(7):1363–1371. https://doi.org/10.14202/vetworld.2020.1363-1371

Nashath NF, Thavaranjit AC, Rajkumar G, Srikaran R. 2022. Microbial and chemical quality of selected dried fish available in a retail market as an approach for assessing health safety. *Journal of Food and Agriculture* 15(1). https://doi.org/10.4038/jfa.v15i1.5259

Paille D, Hackney C, Reily L, Cole M, Kilgen M. 1987. Seasonal variation in the fecal coliform population of Louisiana oysters and its relationship to microbiological quality. *Journal of Food Protection* 50(7): 545–549. https://doi.org/10.4315/0362-028x-50.7.545

Panisello PJ, Rooney R, Quantick PC, Stanwell-Smith R. 2000. Application of foodborne disease outbreak data in the development and maintenance of HACCP systems. *International Journal of Food Microbiology* 59(3): 221–234. https://doi.org/10.1016/s0168-1605(00)00376-7

Prabakaran R. 2003. Good practices in planning and management of integrated commercial poultry production in South Asia. Food and Agriculture Organization.

Racchi I, Scaramuzza N, Hidalgo A, Berni E. 2020. Combined effect of water activity and pH on the growth of food-related ascospore-forming molds. *Annals of Microbiology* 70: 69. https://doi.org/10.1186/s13213-020-01612-6

Rajkumar G, Silva R, Weerasena J, Fernando K. 2014. Comparison of general nutritional composition of wild rice *Oryza rhizomatis* D.A. Vaughan and the commercial variety Bg352. *Tropical Plant Research* 1(2): 8–10.

Schumacher M, DelCurto-Wyffels H, Thomson J, Boles J. 2022. Fat deposition and fat effects on meat quality: A review. *Animals* 12(12):1550. https://doi.org/10.3390/ani12121550

Sofos JN. 2008. Challenges to meat safety in the 21st century. *Meat Science* 78(1–2): 3–13. https://doi.org/10.1016/j.meatsci.2007.07.027

Sristi PR, Das NR, Akhter A, Kaniya NM, Hashem MA. 2025. Relation among meat pH, color and tenderness: A review. *Meat Research* 5(3):117: 1–7.

https://doi.org/10.55002/mr.5.3.117

Valenzuela PL, Mata F, Morales JS, Castillo-García A, Lucia A. 2019. Does beef protein supplementation improve body composition and exercise performance? A systematic review and meta-analysis of randomized controlled trials. *Nutrients* 11(6): 1429. https://doi.org/10.3390/nu11061429

Warner RD. 2023. The eating quality of meat: IV-Water holding capacity and juiciness. *In*: Lawrie's Meat Science, 9th Edition, Chapter IV, 457–508. https://doi.org/10.1016/b978-0-323-85408-5.00008-x

Wolfe RR. 2024. Consideration of the role of protein quality in determining the dietary requirement for protein and amino acids. *Frontiers in Nutrition* 11:1389664. https://doi.org/10.3389/fnut.2024.1389664

Yammine J, Karam L. 2020. Microbiological quality and safety of retail chicken and beef products in Lebanon. *Journal of Food Quality and Hazards Control* 7(2): 2885. https://doi.org/10.18502/jfqhc.7.2.2885