**Assessment of Microbiological Food Safety Knowledge among Broiler Chicken Farmers and Contamination of Campylobacter spp. and Salmonella spp. in Broiler Meat from Dodoma City, Tanzania**

**Original Research Article**

**ABSTRACT**

**Background:** Foodborne pathogen contamination in broiler chicken meat can occur at various points along the value chain, including production at the farm level. Farmers’ knowledge plays a vital role in maintaining microbiological food safety. *Campylobacter* and *Salmonella* are among the leading pathogenic bacteria associated with raw or undercooked chicken meat.

**Aim:** To assess microbiological food safety knowledge among broiler chicken farmers and contamination of Campylobacter spp. and Salmonella spp. in broiler meat from Dodoma City, Tanzania.

**Methods:** A cross-sectional study was conducted using a structured questionnaire to interview eighty-seven (n = 87) broiler chicken farmers. Additionally, a total of forty-five (n = 45) raw broiler chicken meat samples were randomly collected from various purposively selected production farms and analysed using microbiological standard methods (ISO 10272-1:2017 & ISO 6579-1:2017) for the detection of *Campylobacter* spp. and *Salmonella* spp.

**Results:** In this study, 62.07% of respondents demonstrated good microbiological food safety knowledge (95% confidence interval (CI): 48.06 - 69.18), 35.63% demonstrated moderate knowledge (95% CI: 28.62 - 49.54), while 2.3% demonstrated poor knowledge (95% CI: 0.91 - 5.51). Among all socio-demographic factors, only education level showed a significant association with farmers’ microbiological food safety knowledge (X2 = 6.25, p ˂ 0.05). Furthermore, Campylobacter spp. were detected in all (100%) of the analysed samples, with contamination levels exceeding the commonly recommended limit of 3 log CFU/g. The average *Campylobacter* spp. contamination was 5.30±0.23 log CFU/g. *Salmonella* spp. were detected in only two analysed samples, indicating a very low prevalence (4.44%). Moreover, all Salmonella-positive samples exceeded acceptable limits under the zero-tolerance policies of many food safety standards.

**Conclusion:** This study generally revealed that farmers had good basic microbiological food safety knowledge; however, most of them lacked understanding of specific foodborne pathogens. Moreover, there was a high prevalence and contamination by *Campylobacter* spp. and a low prevalence of *Salmonella* spp. in the analysed samples. This suggests a heightened risk of campylobacteriosis outbreaks compared to salmonellosis from consuming undercooked broiler chicken meat. The results call for the need for targeted training and education programs which should be implemented to enhance farmers' microbiological food safety knowledge, alongside with strengthened knowledge on the importance of improving biosecurity and hygiene practices in reducing the risk of pathogen contamination in broiler meat in production farms.

**Keywords:** Microbiological Food Safety;*Campylobacter*; *Salmonella*; Broiler.

**1.0 INTRODUCTION**

Chicken meat is a rich source of animal protein, and its consumption is increasing in many parts of the world. However, in the absence of best practices during rearing, slaughtering, handling, and cooking, chicken meat can be a potential source for transmission of pathogenic bacteria, leading to foodborne illness (Habib *et al*., 2022; Gemeda *et al*., 2024). As is the case in many regions of the world, broiler chicken is the primary commercialised chicken variety in urban areas of Tanzania. This preference is likely due to their short production cycle, soft and tender meat, low fat content, economic benefits, and a shift in dietary preferences from red to white meat (Gonovi *et al*., 2021; Ovai *et al*., 2022).

The World Health Organisation (WHO) reported that almost 1 in 10 people in the world fall ill after consuming contaminated food, and 420,000 people die every year (WHO, 2022). *Campylobacter* and *Salmonella* are two of the most common foodborne pathogens isolated from chicken products, and they are among the leading bacteria in causing foodborne zoonotic diseases in the world (Carron *et al*., 2018; Borges *et al*., 2019; Habib *et al*., 2022). Theyare considered as primary causes of human campylobacteriosis and salmonellosis, respectively (Munuo *et al*., 2022; Sahin *et al*., 2024). Campylobacteriosis and Salmonellosis are often associated with common symptoms like fever, bloody diarrhoea, abdominal cramps, nausea, vomiting, and may result in hospitalisation (WHO, 2018; WHO, 2020; Thames *et al*., 2022). Apart from causing public health problems, *Campylobacter* and *Salmonella* can cause financial losses in the poultry industry by increasing mortality rates, reducing growth performance, product recalls, and trade restrictions (Munuo *et al*., 2022; Kostoglou *et al*., 2023).

The habitats of *Campylobacter* and *Salmonella* in chicken are the gut flora and are mostly transferred to the carcass upon slaughtering and during further handling processes (Lopes *et al*., 2021; Habib *et al.*, 2022). Thus, the recently observed emergence of intensive broiler production systems in urban areas without practising best practices may increase the risks of foodborne diseases (Sindiyo *et al*., 2018). Different standards have been set to regulate different food contaminants, including pathogenic bacteria. In raw poultry, many microbiological food safety standards require zero tolerance for *Salmonella* spp. and the value not exceeding 1,000 CFU/g (3 log CFU/g) for *Campylobacter* spp. (Nastasijevic *et al*., 2020; Obe, 2020).

Moreover, the microbiological quality and safety of broiler chicken meat depend primarily on the on-farm biosecurity practices, slaughtering process, sanitation during processing and handling, and the maintenance of an adequate cold chain throughout the entire value chain (Hertanto *et al*., 2018). Chicken farmers are among the stakeholders in the chicken value chain who are highly responsible for the microbiological quality and safety of chicken meat (Aslam *et al.*, 2020; Ngantu *et al*., 2025). The prevention of broiler chicken meat from pathogen contamination needs good knowledge, practices, and a positive attitude of handlers (Ahmed et al., 2021; Siddiky et al., 2022; Abdul-Rahiman *et al*., 2023). Literature confirms that, in most cases, farmers' good knowledge is positively associated with good practices and positive attitudes (Boakye *et al*., 2023).

Some studies assessing microbiological food safety knowledge and contamination of *Campylobacter* and *Salmonella* in chicken or chicken products have been done in Tanzania. For instance, the study conducted in the Morogoro region found a good microbiological food safety knowledge score for restaurant food service workers (66.97%) (Soingei *et al*., 2024). The study in Zanzibar found that many street food vendors (˃ 90%) had good microbiological food safety knowledge (Hassan & Fweja, 2020). Another study conducted in Mbeya region among meat retailers found that the overall average awareness score on foodborne illnesses and hygiene was 65% (Mbonabucha & Fweja, 2019). Regarding *Campylobacter* spp. and *Salmonella* spp. contamination, the study conducted in rural central Tanzania by Rukambile et al. (2021) found low prevalence of *Campylobacter (*7.2%) *and Salmonella (*11.1%) in indigenous chickens. Another study in North Tanzania by Sindiyo et al. (2018) found a 50% prevalence of *Campylobacter* and a 15% prevalence of *Salmonella* in chicken cloacal shedding.

Despite the findings from the aforementioned studies, there is a paucity of studies focusing on assessing microbiological food safety knowledge among broiler chicken farmers. Additionally, limited studies have been conducted to determine *Campylobacter* spp.and *Salmonella* spp. contamination in broiler chicken meat from production farms in Dodoma City Council—a rapidly growing urban area and the political capital of Tanzania. This lack of data can present a challenge for designing effective food safety interventions.

Therefore, this study aimed to fill this gap by assessing the microbiological food safety knowledge among broiler chicken farmers in Dodoma City Council and determining the contamination of *Campylobacter* and *Salmonella* spp. in raw broiler chicken meat collected from production farms. The information provided by this study will help to understand the current status of microbiological food safety knowledge among broiler chicken farmers and contamination of broiler chicken meat with *Campylobacter* spp. and *Salmonella* spp. This understanding is crucial in designing interventions to improve broiler chicken meat safety, which could have crucial public health benefits.

**2.0 MATERIALS AND METHODS**

**2.1 Description of the study area**

This study was conducted in the Dodoma City Council, which is part of the Dodoma region, found in central Tanzania. The region is located south of the equator between latitudes 6° 57' and 3° 82'. Longitudinally, the region is situated between 36° 26' and 35° 26' east of Greenwich (URT, 2024). According to the human population census of 2022, the region has a population of 3,085,625 people, of whom 765,179 live in the city council (NBS, 2022). The region is mostly semi-arid due to low and erratic rainfall, with total rainfall ranging from 500mm to 800mm per annum, with high geographical, seasonal, and annual variation (URT, 2024). In Tanzania, Dodoma is one of the regions with a high number of chickens, both indigenous and exotic breeds (Mramba, 2023).

**2.2 Study design**

The cross-sectional study design was employed in this study to assess the microbiological food safety knowledge among broiler chicken farmers in Dodoma City Council from January 2025 to April 2025. Also, raw chicken samples were purposively collected and transported to the food science Laboratory of Sokoine University of Agriculture (SUA) to determine contamination of *Campylobacter* and *Salmonella* spp.

**2.3 Sampling methods and data collection**

**2.3.1 Farmers’ survey**

Three wards of the Dodoma city council, namely Mnadani, Dodoma Makulu, and Nzuguni, were randomly selected for this study. Then, a snowball sampling was used to identify broiler chicken farmers. Snowball sampling is a non-probability sampling technique where existing participants help to identify the next participants for a study. It's particularly useful for researching hard-to-reach populations or when a clear sampling frame is unavailable (Shamsudin *et al.,* 2024). During our study, there was no database showing the exact number of broiler chicken farmers at the national level or even at the ward executive offices (Msoffe *et al*., 2018). Fortunately, the government extension officers assisted in identifying some farmers, who then helped the process of identifying and reaching the rest of the respondents based on the availability and convenience. It is important to note that snowball sampling may introduce selection bias, as participants are often drawn from similar networks, which limits the diversity and representativeness of the sample. This reduces the generalizability of findings to the broader population (Abubakar *et al*., 2024).

The total number of identified and individually interviewed farmers was 87, of whom 29 were from Mnadani ward, 33 from Dodoma Makulu ward, and 25 from Nzuguni ward. Data were collected through face-to-face interviews using a structured questionnaire with closed and open-ended questions coded in KoboToolbox. Information was collected on socio-demographic characteristics, knowledge of foodborne illnesses and specific foodborne pathogens, the role of cleaning and disinfection in reducing food contamination, the importance of cold storage, and the possibility of finding foodborne pathogenic bacteria in live chickens, among other topics. Questions were adopted from Habib *et al*. (2020), Azanaw *et al*. (2022), Kimindu *et al*. (2024), and Nortey *et al*. (2024) with some modifications. Verbal consent was sought from all study participants after explaining the study objectives, procedures, and the confidentiality of the data.

The questionnaire was pre-tested with 6 broiler chicken farmers in a nearby ward (Miyuji), which was not included in the study, to assess clarity, relevance, and flow. Necessary modifications were made to enhance proper contents, wording and sequencing before the final data collection (Mongi *et al*., 2022). During the interview, the questions were being translated from English to Swahili (the national language) by the interviewer to enhance respondent comprehension, although this might have affected data quality due to potential misinterpretation or loss of clear meaning to the interviewee in some items (Schembri & Jahić, 2022).

**2.3.2 Chicken meat sample collection**

A total of 45 broiler chickens (15 from each ward, at least two chickens per farm) were randomly selected from the production farms after purposive identification of the farms. Purposive sampling is a non-probability sampling technique in which units are selected because they have characteristics that are needed to suit a particular purpose (Nyimbili & Nyimbili, 2024). Broiler chicken farms included in this study were purposively selected based on having chicken readiness for market, specifically those at typical marketing age and about to be sold by farmers to intermediaries or market vendors (Nonga *et al*., 2013; Bokhtiar *et al*., 2023).

The sample size was determined based on the need to ensure representation across different farms and locations while considering practical constraints such as laboratory capacity, financial resources, and limited time. Importantly, the selection was further influenced by the challenge of accessing broiler chickens at marketing age, as not all farmers had ready-to-sell chickens within the short sampling period.

Farmers were informed in advance about obtaining their consent before going for sample collection. Collected broiler chickens were being slaughtered at their respective collection farms, and 150 g of the breast of each carcass was cut and separately packaged in polyethylene bags, labelled accordingly, and then immediately stored in a cooler ice box with ice packs before being transported to the food science laboratory of Sokoine University of Agriculture. In the laboratory, samples were stored at -20°C until analysis (Ulomi *et al*., 2022; Gomez *et al*., 2024).

**2.3.3 Analysis of *Campylobacter* spp.**

The analysis was done according to International Organisation for Standardisation (ISO), (2017a) and Kagambèga *et al*. (2018). During the analysis, 25 g of each raw chicken breast meat was aseptically transferred into separate sterile stomacher bags containing 225 ml of Bolton broth (Oxoid, UK). The samples (in duplicate) were separately homogenised and incubated at 42 °C for 48 hours under microaerophilic conditions to allow selective enrichment of *Campylobacter* spp. Following incubation, a loopful of the enriched broth was streaked onto Modified Charcoal Cefoperazone Deoxycholate Agar plates (mCCDA; Oxoid, UK), which were then incubated at 42 °C for 48 hours under microaerophilic conditions. Suspected *Campylobacter* colonies were identified based on typical colony morphology and appearance. Typical *Campylobacte*r colonies are distinguished by their small, grey point shape in mCCDA (Awada *et al*., 2023). The number of *Campylobacter* spp*.* colonies in petri dishes were counted with the help of a digital colony counter to calculate colony-forming units per gram (CFU/g), which was then transformed into log CFU/g. The catalase biochemical test was performed for confirmation.

**2.3.4 Analysis of *Salmonella* spp.**

The analysis was conducted according to the International Organisation for Standardisation (ISO) (2017b) and Kagambèga *et al*. (2018). During the analysis, 25 g of each raw chicken breast samples (in duplicate) was transferred into a separate sterile stomacher bag containing 225 ml of buffered peptone water (BPW; Techno Pharmchem, India). Bags were vigorously massaged and shaken for 2 minutes at room temperature. Rinse solutions were transferred to glass bottles and incubated at 37°C for 24 hours. After incubation, a 1 ml aliquot was transferred to 10 ml of selective enrichment media, namely Rappaport-Vassiliadis Broth (RV: Oxoid, Basingstoke, UK) and incubated for 24 hours at 42°C. A loopful (10 μl) was then plated on xylose-lysine-deoxycholate (XLD) agar (Techno Pharmchem, India) and incubated at 37°C for 24 hours. XLD agar plates with colonies exhibiting typical *Salmonella* morphology were counted and recorded. On XLD agar, *Salmonella* colonies typically appear red with a black centre.

**2.4 Data analysis**

The data were analysed using Statistical Package for the Social Sciences (SPSS) version 27 and Microsoft Excel 2019. Descriptive statistics, namely means, standard deviations, frequency, percentages and 95% confidence interval (CI), were computed. The Pearson Chi-squared test (χ²) was conducted to identify the association between the socio-demographic characteristics and microbiological food safety knowledge. One-way ANOVA was used to compare the means of *Campylobacter* spp*.* in samples from different wards. The value of *p* < 0.05 was considered statistically significant. During analysis of survey (knowledge assessing) data, correct responses were assigned the number 1, while incorrect and don’t know responses were assigned the number 0. The total number of knowledge assessing statements was 15; hence, the total correct scores ranged from 0-15. The participant with average correct score statements greater than or equal to 70% (11/15) were considered having good knowledge, 40-69% (6/15-10/15) were considered having moderate knowledge and correct score below 40% (6/15) were regarded as poor knowledge (Tegegne *et al*., 2017; Habib *et al*., 2020).

**3.0 RESULTS**

**3.1 Socio-demographic characteristics**

The results of the socio-demographic characteristics of interviewed broiler chicken farmers are shown in Table 1 and Figure 1.A total of 87 respondents were interviewed individually. Most (67.82%) of them were females (95% CI: 57.80 - 77.80). The dominant age group was 31 - 44 years, representing 62.1% of respondents (95% CI: 51.7–72.5) and nearly half (50.57%) had a primary education level (95% CI: 39.86 - 61.29). Additionally, over half (56.32%) of the respondents had broiler chicken rearing experience of 5 years and above (95% CI: 45.69­­ - 66.95), with most (33.33%) having a flock size ranging from 401- 600 (95% CI: 22.17- 42.20).

**Table 1: Socio-demographic characteristics of interviewed broiler chicken farmers**

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Category** | **Frequency, n (%)** | **95% CI** |
| Sex | Male | 28 (32.18) | 22.00-42.00 |
| Female | 59 (67.82) | 57.80-77.80 |
| Age group (years) | 18-30 | 8 (9.20) | 3.00-15.3) |
| 31-44 | 54 (62.10) | 51.67-72.47 |
| 45-59 | 23 (26.44) | 16.98-35.89 |
| ≥60 | 2 (2.30) | 0.90-5.51 |
| Farming experience (years) | ˂5 | 38 (43.68) | 33.05-54.31 |
| ≥5 | 49 (56.32) | 45.69-66.95 |
| Flock size | 100-200 | 6 (6.90) | 2.22-13.88 |
| 201-400 | 27 (31.03) | 21.12-40.95 |
| 401-600 | 29 (33.33) | 22.17-42.20 |
| 601-800 | 13 (14.94) | 7.30-22.58 |
| 801-1000 | 7 (8.05) | 2.22-13.88 |
| ˃1000 | 5 (7.75) | 0.76-10.74 |

**Figure 1: Education level of respondents**

**3.2 Farmers’ microbiological food safety knowledge**

This study assessed farmers’ microbiological food safety knowledge by using fifteen statements (S = 15). Regarding the overall microbiological food safety knowledge, 62.07% of respondents demonstrated good knowledge (95% CI: 48.06 - 69.18), 35.63% demonstrated moderate knowledge (95% CI: 28.62 - 49.54), while 2.3% demonstrated poor knowledge (95% CI: 0.91 - 5.51) (Figure 2). Notably, all respondents (100%) were aware that contaminated food is the source of foodborne illness. The majority didn't know about the specific micro-organisms causing foodborne illness, as only 4.60% and 12.64% demonstrated understanding of *Campylobacter* and *Salmonella* foodborne pathogens, respectively.

Notably, all of the respondents (100%) demonstrated good knowledge about the role of contaminated water in spreading foodborne pathogens. Additionally, many respondents (64.37%) demonstrated poor knowledge of the possibility of a healthy person to bear pathogenic microbes while demonstrating good knowledge (88.50%) on refrigeration or freezing storage as the recommended techniques to reduce or prevent the contamination and spoilage of raw chicken meat (Table 2).

**Figure 2: Farmers' overall microbiological food safety knowledge**

|  |  |  |  |
| --- | --- | --- | --- |
| **The Statement (S = 15)** | **Response (n = 87)** | | |
| *Correct (Yes) (%)* | *Incorrect (No) (%)* | *Don’t know (%)* |
| *Contaminated food is the source of foodborne illness.* | 100.00 | 0.00 | 0.00 |
| *Raw or undercooked chicken meat is the source of foodborne illness.* | 96.55 | 0.00 | 3.45 |
| *Pathogenic bacteria can naturally be present in a live chicken.* | 60.92 | 3.45 | 35.63 |
| *Campylobacter is one of the foodborne pathogens.* | 4.60 | 10.34 | 85.06 |
| *Salmonella is one of the foodborne pathogens.* | 12.64 | 8.05 | 79.31 |
| *Inappropriate evisceration can increase the chance of bacterial contamination in raw chicken meat.* | 66.67 | 3.45 | 29.88 |
| *Humans can transmit pathogens to chicken meat when handling or slaughtering.* | 78.16 | 3.45 | 18.39 |
| *Contaminated water can spread foodborne pathogens.* | 100.00 | 0.00 | 0.00 |
| *Contaminated feed can be a source of bacteria in live chickens.* | 79.31 | 1.15 | 19.54 |
| *Pathogenic microbes can be present on the skin, nose, and mouth of healthy chicken meat/ food handlers.* | 35.63 | 16.09 | 48.28 |
| *Flies or pests can contaminate chicken meat during slaughter.* | 100.00 | 0.00 | 0.00 |
| *Practicing good personal hygiene reduces the risk of food contamination.* | 95.40 | 0.00 | 4.60 |
| *Cleaning and disinfecting the working environment prevents food contamination.* | 96.55 | 0.00 | 3.45 |
| *Refrigeration or freezing storage is recommended to reduce or prevent the contamination and spoilage of raw chicken meat.* | 88.50 | 6.90 | 4.60 |
| *Regular cleaning of the chicken house reduces the chance of bacterial contamination in live chickens.* | 57.47 | 4.60 | 37.93 |
| **Average response estimates** | **71.49** | **3.83** | **24.68** |

**Table 2: Response of farmer’s on microbiological food safety knowledge statements**

**3.3 Association of farmers’ microbiological food safety knowledge with socio-demographic characteristics**

In this study, among all socio-demographic characteristics, only education level was significantly associated with farmers' microbiological food safety knowledge (X2=6.25, p ˂ 0.05). For other demographic factors, the chi-squared test (X2) and significance value (*p*) were 3.27 and 0.20, 5.70 and 0.46, 0.04 and 0.98, and 9.23 and 0.51 for sex, age, farming experience, and flock size, respectively (Table 3).

**Table 3: Association of farmers’ microbiological food safety knowledge with socio-demographic characteristics**

|  |  |  |
| --- | --- | --- |
| **Variable** | **X2** | ***p*-value** |
| Sex | 3.27 | 0.20 |
| Age group (years) | 5.70 | 0.46 |
| Education level | 6.25 | 0.04\* |
| Farming experience (years) | 0.04 | 0.98 |
| Flock size | 9.23 | 0.51 |

*X2 = Pearson Chi square test.,**\* Significant association (p ˂ 0.05)*

**3.4 Prevalence and levels of Campylobacter spp. contamination**

The results showed that all of the analysed samples (100%) contained *Campylobacter* spp. All tested samples had contamination levels exceeding the commonly recommended limit of 3 log CFU/g. The overall mean of the contamination level was 5.30±0.23 logCFU/g.The highest mean contamination level was observed in samples from Nzuguni (5.39±0.37 logCFU/g), followed by Mnadani (5.27±0.22 logCFU/g ) and lastly by Dodoma Makulu (5.26±0.27 logCFU/g). Moreover, there was no significant difference in the level of *Campylobacter* spp. contamination among the samples from three wards (p˃0.05) (Table 4).

**Table 4: Prevalence and mean contamination level of Campylobacter spp. in the analysed samples**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Ward** | **No. of tested samples** | **No. (%) of positive samples** | **No. (%) of positive samples exceeding 3 log CFU** | **Mean ±SD (logCFU/g)** |
| Mnadani | 15 | 15(100) | 15(100) | 5.27±0.22a |
| Dodoma Makulu | 15 | 15(100) | 15(100) | 5.26±0.27a |
| Nzuguni | 15 | 15(100) | 15(100) | 5.39±0.37a |
| **Total** | **45** | **45(100)** | **15(100)** | **5.30±0.23** |

***a*** *Values within the same column with the same superscript letters are not significantly different from each other at P ≤ 0.05*

**3.5 Prevalence of *Salmonella* spp.**

The results indicate that, of the samples analysed, only 2 were positive for *Salmonella* spp. Indicating a very low prevalence (4.44%). Moreover, of all the three wards, all samples from Nzuguni ward did not have *Salmonella* spp., while the rest two wards each recorded 1( 6.67%) of their samples testing positive for *Salmonella* spp. Moreover, all Salmonella-positive samples exceeded acceptable limits under the zero-tolerance policies of many food safety standards. The results are shown in Table 5.

**Table 5: Prevalence of *Salmonella* spp. in the analysed samples**

|  |  |  |  |
| --- | --- | --- | --- |
| **Ward** | **No. of tested samples** | **No. (%) of positive samples** | **No. (%) of positive samples exceeding acceptable limit** |
| Nzuguni | 15 | 0(0) | 0(0) |
| Mnadani | 15 | 1(6.67) | 1(6.67) |
| Dodoma Makulu | 15 | 1(6.67) | 1(6.67) |
| **Total** | **45** | **2(4.44)** | **2(4.44)** |

**4.0 DISCUSSION**

**4.1Farmers’ microbiological food safety knowledge**

Good food safety knowledge among handlers is very key to the overall safety and quality of the broiler meat delivered to consumers (Al Banna *et al*., 2021). In this study, farmers generally demonstrated good knowledge regarding microbiological food safety, with 62.07% showing good knowledge. In addition, the average correct scores for knowledge assessing statements were 71.49%. Similar findings were reported by a study conducted in Ghana, which found good knowledge of food hygiene and safety among fruit and vegetable vendors (Boakye *et al*.,2023). On the other hand, findings disagree with those of Bahir *et al.* (2022), who found poor food safety knowledge with a mean correct score of 39% among meat carcass handlers in Morocco.

Furthermore, nearly all respondents provided the correct scores, demonstrating their good knowledge about the role of flies, pests, contaminated water, and raw or undercooked chicken meat in the spread of foodborne pathogens. The findings agree with those of Osaili *et al*. (2022), who reported that 87.7 % of respondents in Dubai were aware of the role of contaminated food in spreading foodborne illness. It is important to note that flies and pests can carry pathogens on their bodies and transmit them to food, contaminate food with their droppings, urine, and other bodily substances (Hassan *et al.,* 2021). When used in chicken processing, contaminated water can introduce pathogens into the chicken meat (Uzoho, 2025). Raw chicken meat is a common source of pathogens like *Salmonella* and *Campylobacter*, which can cause illness if not properly cooked (Thames & Theradiyil, 2020). Good knowledge of those facts among farmers or any other food handlers can influence best practices, thus reducing the risk of chicken meat contamination upon slaughtering or further handling (Sterniša *et al*., 2018; Al Banna *et al*., 2021).

Regarding the role of personal hygiene and cleaning, nearly all farmers scored correctly about the role of good personal hygiene, and cleaning and disinfection of the working environment in reducing the risk of food contamination. This was similar to the findings of Azanaw *et al*. (2022), who found that 91.4% of the food vendors knew the importance of good personal hygiene in reducing the risk of food contamination in Ethiopia. Similarly, the study conducted in Kenya, most workers (98.7%) knew that cleaning equipment and surfaces after slaughter operations is vital in reducing cross-contamination. There is evidence that poor personal and environmental hygiene are the major risk factors for food contamination leading to food poisoning (Kamboj *et al*., 2020; Azanaw *et al*., 2022). The knowledge of personal and environmental cleaning, disinfection, and hygiene is very important to reduce the risk of cross-contamination and prevent the spread of foodborne pathogens (Osaili *et al*., 2022).

Moreover, the majority of farmers (88.5%) understood the importance of cold storage, as many of them understood the importance of freezing and refrigeration in preventing or reducing the rate of microbial spoilage or contamination of chicken meat. The same findings were recorded by Assefa *et al*. (2023) in Burkina Faso. It is well known that chicken meat stored at inappropriate temperatures for long durations can result in contamination with pathogenic bacteria (Osaili *et al*., 2022). Hence, good farmers' knowledge of these facts can influence their practice of cold chain storage.

Despite having overall good microbiological food safety knowledge, the majority demonstrated limited knowledge concerning specific food pathogens such as *Campylobacter* and *Salmonella,* with the possibility of finding them in the skin, nose, and mouth of healthy meat/ food handlers. The findings were in line with those of Osaili *et al*. (2022), who reported that only a few respondents in Dubai demonstrated good knowledge of specific food pathogens, namely *Staphylococcus aureus* (7.9%), *Botulinum* (10.3%), *Salmonella* (51.6%), and *Campylobacter* (4.0%). Additionally, the study in Ethiopia found low knowledge regarding *Salmonella* pathogens among poultry farmers (Kabeta *et al*., 2024). Farmers’ unsatisfactory knowledge of foodborne pathogens and the risk of skin, nose, and mouth of healthy food handlers on pathogen transmission may trigger the spread and contamination of foodborne pathogens (Siddiky *et al*., 2022).

The findings suggest that farmers had basic microbiological food safety knowledge but lacked in-depth understanding and training. This highlights the need for targeted educational initiatives focusing on food pathogens to enhance understanding of their zoonotic potential, modes of transmission, and prevention. Such measures will not only reduce human health risks posed by foodborne pathogens but also improve poultry health systems (Kabeta *et al*., 2024).

**4.2 Association of farmers’ microbiological food safety knowledge with socio-demographic characteristics**

Among all socio-demographic factors, only the level of education was found to be the most significant factor associated with farmers' food safety knowledge. Farmers who had attained tertiary education were more likely to demonstrate good knowledge compared to those with only primary education. Similar findings were reported in Ghana by Nortey *et al*. (2024), who found that education level was a main factor which influenced knowledge and concluded that food vendors who had attained tertiary education were 63% less likely to have low knowledge of food safety as compared to vendors with a low education level. Another study in Egypt by Aquino *et al*. (2021) reported that education was a strong predictor of good food safety knowledge among food handlers.

The positive association between knowledge and education level can be attributed to the fact that a higher education level increases the chance of individuals getting better information regarding food safety through formal training, extension services, or media. Also, more educated individuals are likely to read texts on food safety from leaflets, posters, books, etc., which may improve their knowledge of food safety (Nortey *et al*., 2024). In addition, through education and professional training, individuals are exposed to food safety issues such as importance of good biosecurity, personal hygiene, cleaning, use of safe water in processing, separation of raw and cooked foods as well as identifying the pathways through which they can contaminate meat during the handling process (Al Banna *et al*., 2021). Thus, farmers’ education and training on microbiological food safety issues are important for the production of less or free contaminated chicken meat.

**4.3Prevalence and contamination of *Campylobacter* spp*.***

*Campylobacter* is considered among the leading bacteria in causing bacterial gastroenteritis worldwide (Awada *et al*., 2023). This study revealed a very high prevalence of *Campylobacter* spp. (100%) in raw broiler chicken meat from production farms in the study area. The findings were comparable to the high prevalence of *Campylobacter* (85.2%) reported by Popa *et al*. (2022) in the caeca of broiler chickens in Romania. Other similar results were reported by Kostoglou *et al*. (2023), who found 90% prevalence in raw chicken meat in Greece, and Sahin *et al*. (2024), who recorded 93% prevalence in broiler chicken farms in the United States of America (USA).

The results suggest that broiler chickens in the study area are likely colonised with *Campylobacter* spp. during production at the farm level, probably due to contaminated chicken drinking water, poor biosecurity practices (Awada *et al*., 2023) and contaminated feed (Mramba, 2023). Additionally, the high prevalence of *Campylobacter* spp.could also be due to reasons such as chickens being the hosts and hence serving as reservoirs for *Campylobacter* (Castro *et al*., 2023). The normal body temperature of live chickens (42 0C) corresponds to the optimum temperature for the growth of *Campylobacter* and thus chickens act as a natural habitat (Guyard-Nicodème *et al*., 2023). *Campylobacters* mostly colonise and proliferate in the chicken gastrointestinal tract without any clinical symptoms (Kostoglou *et al*., 2023).

Furthermore, high *Campylobacter* spp. prevalence could indicate their resistance to the veterinary antimicrobials used. For example study by Castro *et al*. (2023) in Paraguay found 85% *Campylobacter* resistance to ciprofloxacin, Popa *et al*. (2022) in Romania recorded 79.2% and 49.5% *Campylobacter* resistance to ciprofloxacin and tetracycline, respectively. All those factors can contribute to the high prevalence and facilitate *Campylobacter* transmission to humans, thus increasing the chance of foodborne illness and consequently harming public health.

On the other hand, the prevalence of *Campylobacter* spp. in this study was higher than those reported by Kagambèga *et al*. (2018), who found 50% prevalence of *Campylobacter* spp. in chicken carcasses sold in Burkinafaso, Jahromi et al. (2021), who reported 54.8% prevalence in poultry carcasses in Iran, and Castro *et al*. (2023, who found 63.6% prevalence in chicken cloaca swabs in Paraguay.

The difference in prevalence could be mainly due to the differences in season in which the study was conducted, geographical location of farms, sample types, bacterial enumeration techniques, sample preparation, sampling methods, farm management practices and ages of the investigated chickens (Popa *et al*., 2022; Castro *et al*., 2023; Guyard-Nicodème *et al*., 2023). Seasonal variation can affect Campylobacter prevalence in broiler chickens, as warmer and more humid seasons create favourable conditions for bacterial survival and spread within the farm environment. The geographical location of farms can influence Campylobacter prevalence due to variations in climate, farm density, sanitation infrastructure, and local biosecurity practices (Andritsos *et al*., 2023; Urdaneta *et al*., 2023). The ages of the investigated chickens can influence Campylobacter prevalence, as the likelihood of colonisation increases with age due to longer exposure to contaminated environments (Babacan *et al*., 2020; Lynch *et al*., 2022).

Regarding the *Campylobacter* spp*.* contamination level, a high contamination level was observed in all samples, with an overall mean contamination of 5.30 ± 0.23 log CFU/g. International organisations like the Codex Alimentarius Commission and many regional standards don’t yet enforce a strict limit for Campylobacter, since the focus is on **reducing prevalence** through risk-based measures (Codex Alimentarius Commission, 2011). Although some regional standards, such as the European Union, recommend a limit not exceeding **1,000 CFU/g (**3 log CFU/g) (EU, 2017). Hence, based on the European Union standard, it can imply that all analysed samples (100%) contained *Campylobacter* spp. above the recommended limit.

The results differed from those of Habib *et al.* (2022), who reported that only 7% of the samples contained *Campylobacter* at contamination greater than 3 log CFU/g in the United Arab Emirates (UAE). The high *Campylobacter* spp. contamination in raw chicken meat has been linked to the increase in the risk of campylobacteriosis in humans, especially upon consumption of undercooked chicken meat (Queenan & Häsler, 2025). Campylobacteriosis can cause severe gastrointestinal symptoms such as diarrhoea, abdominal cramps, fever, and in rare cases, lead to long-term complications like Guillain-Barré syndrome (Endtz, 2020; Kannan *et al*., 2025).

To reduce the prevalence of Campylobacter contamination observed in this study, several specific interventions are recommended. Farm-level biosecurity measures such as restricting access to poultry houses, regular cleaning and disinfection of equipment, and rodent control are essential. In addition, water sources used in poultry farming and processing should be properly treated, for example by chlorination, to minimise microbial contamination (Arabi *et al.,* 2021; Naumovska *et al*., 2025).

Additionally, targeted hygiene training for farmers can improve awareness and adoption of safe handling practices. Regular microbial monitoring of farms will also help identify contamination sources early and prevent outbreaks (Nyokabi et al., 2021; Gomes *et al*., 2023). Finally, the best practices during the handling of Campylobacter-contaminated raw chicken meat are critical for reducing or preventing the chance of cross-contamination (Queenan & Häsler, 2025), and the cooking process should be able to achieve at least a 7-log reduction of *Campylobacter* (Qu *et al*., 2024).

**4.4Prevalence of *Salmonella* spp*.***

*Salmonella* is among the group of bacteria that cause enteric and systemic infection in humans and animals worldwide (Munuo *et al*., 2022). This study revealed a low prevalence of *Salmonella* spp. (4.44%) in the analysed samples. The findings were comparable to those of Moawad *et al.* (2017), who reported 8.3% *Salmonella* prevalence in chicken carcasses in Egypt, Munuo *et al*. (2022), who reported 4% *Salmonella* prevalence in broiler chicken meat in Tanzania, and Kostoglou *et al*. (2023), who reported 15% and 2.5% prevalence in raw chicken meat and salads, respectively, in Greece. The low *Salmonella* spp. prevalence could be attributed to various reasons, such as lower natural colonisation rates at the farm level and reduced cross-contamination due to controlled slaughter.

The body temperature of the live chickens (42 0C) is slightly higher than the optimum growth temperature required by *Salmonella* (37 °C), hence *Salmonella* are less adapted to the intestinal flora of chicken as opposed to *Campylobacters* (Guyard-Nicodème *et al*., 2023). Also, chicken vaccination programs against salmonellosis could help to reduce the prevalence of *Salmonella* pathogens (Chota *et al*., 2023). Another reason could be that *Salmonella* spp. might be susceptible to antimicrobials used in broiler chicken treatment (Lenchenko *et al*., 2020; Castello *et al*., 2023).

On the other hand, the prevalence of *Salmonella* spp. was lower than the 60% prevalence in chicken meat as reported by Bantawa *et al.* (2018) in Nepal. Also, the higher *Salmonella* prevalence was reported by Kagambega *et al*. (2018), who found 90% and 52.42% prevalence in chicken carcass and faeces, respectively, in Burkinafaso, and Pavelquesi *et al*. (2023) who found 46.1% in chilled chicken meat in Brazil. The difference in *Salmonella* prevalence could be mainly due to the differences in season in which the study was conducted, geographical location of farms, bacterial enumeration techniques, sampling methods, farm management practices, antimicrobial susceptibility of *Salmonella* pathogens, and ages of the investigated chickens (Popa *et al*., 2022; Castro *et al*., 2023; Guyard-Nicodème *et al*., 2023).

Regarding the comparison with the recommended *Salmonella* spp. the contamination limit was exceeded in all Salmonella-positive samples (4.44%). This is because there is **no acceptable or recommended level** of Salmonella spp. in raw chicken meat in most international and national food safety standards. According to the European Union (EU), (2011) and East African Standards (EAS), (2024), regardless of serotypes, there should be no salmonella-positive chicken samples (zero tolerance). Hence, this study indicates that only a small number of samples violated the recommended standards.

Despite the low prevalence, *Salmonella* remains a potential public food safety hazard, since even a small proportion of *Salmonella-*contaminated food can lead to an outbreak of salmonellosis due to *Salmonella*'s low infectious dose. Salmonellosis can lead to various symptoms like diarrhoea, fever, and abdominal cramps, with severe cases requiring hospitalisation or even resulting in death (Yada, 2023; O’Neill *et al*., 2024). Apart from harming human health due to contaminated chicken meat, *Salmonella* spp. infections in the live chickens can lead to economic losses due to increased mortality and morbidity, lower feed intake, reduced weight gain, and decreased productivity and growth rates (Kabeta *et al*., 2024).

The interventions previously discussed for controlling Campylobacter contamination such as improved farm hygiene, water treatment, and food handler training, are equally applicable for reducing Salmonella contamination, given the shared contamination pathways and risk factors (WHO, 2018; Wardhana *et al*., 2021). Addressing these common risk points can effectively mitigate the prevalence of both pathogens within broiler chicken production environment.

**5.0 CONCLUSION**

This study generally revealed that farmers had good basic microbiological food safety knowledge; however, most of them lacked understanding of specific foodborne pathogens. Moreover, the findings revealed a high prevalence and level of *Campylobacter* spp. contamination, and a low prevalence of *Salmonella* spp. in the analysed samples. This suggests a heightened risk of campylobacteriosis outbreaks compared to salmonellosis following consumption of undercooked broiler chicken meat. Additionally, the high *Campylobacter* prevalence observed in this study may reflect non-adherence to biosecurity and hygiene practices at the production farms, highlighting the need for targeted interventions.

**6.0** **RECOMMENDATIONS**

To address concerns raised by this study, there is a critical need for:-

(i) *Enhanced education and training*

The observed lack of in-depth microbiological food safety knowledge suggests the need of targeted education and training programmes which should be implemented by regulatory authorities such as the Ministry of Health, the Ministry of Livestock and Fisheries, Tanzania Bureau of Standards (TBS), Ward Executive Authorities among other stakeholders. The programmes should aim to enhance farmers' microbiological food safety knowledge, emphasizing the importance of improved biosecurity, slaughtering and hygiene practices in reducing contamination in broiler chicken meat. The education and training can be achieved through using different media like radios, televisions, online webinars, social media, printed materials, and conducting farmers’ workshops and seminars in their localities.

(ii) *Improved infrastructure and hygiene facilities*

The observed *Campylobacter* and *Salmonella* contamination suggest a need for improved infrastructure, including access to clean water, well designed chicken house, hygienic rearing and slaughtering environments, and proper waste disposal systems. This will help to reduce the risk of outbreak and colonization of *Campylobacter* and *Salmonella* in live chickens and consequently reduce the contamination upon slaughtering and further handling of chicken meat.

(iii) *Policy and regulatory enforcement*

The high *Campylobacter* contamination, which might reflect possible non-adherence to biosecurity practices, points to the weak enforcement; therefore, strengthening regulatory frameworks and routine inspections is essential to ensure compliance with food safety standards. The enforcement can be achieved by the aforementioned regulatory authorities.

(iv) *Future research*

Future research should explore food safety practices, attitudes, barriers, and facilitators among broiler chicken farmers and other stakeholders in various contexts and settings. Further investigation is needed to evaluate other food pathogens commonly associated with broiler chicken meat with a larger sample size. Additionally, future studies should consider employing probabilistic sampling techniques to enhance representativeness and reduce selection bias associated with snowball sampling, as well as incorporating molecular methods such as PCR for more accurate and specific confirmation of Campylobacter and Salmonella spp.

**7.0 LIMITATIONS OF THE STUDY**

**The absence of reliable statistics of broiler chicken farmers in the study area necessitated the use of snowball sampling for farmers’ identification, which, while effective for accessing hidden populations, may have** introduce selection bias, as participants are often drawn from similar networks, which limits the diversity and representativeness of the sample. This may reduce the generalizability of findings to the broader population. **In addition, t**he study did not assess food safety practices and attitudes, although it is known that knowledge can influence the farmers’ practices and attitudes regarding safe broiler chicken production, slaughtering, and further handling. Unfortunately, t**he high cost of laboratory analysis and limited time restricted the number of broiler chicken samples that could be analysed and limited the scope to assess only *Campylobacter* and *Salmonella*. Also,** due to the same constraints, we did not proceed with serological verification and bacterial confirmation by molecular methods like polymerase chain reaction (PCR). **Together, these limitations may affect the representativeness of the study findings at the broader population level.**

**ETHICAL CONSIDERATION**

Ethical approval with reference number SUA/ADM/R.1/8/1326 was provided by Sokoine University of Agriculture (SUA) on behalf of the Tanzania Commission for Science and Technology (COSTECH). In addition, the research permit letters were also obtained from the respective local authorities. Furthermore, verbal consent was sought from all study participants after explaining the study objectives, procedures, and the confidentiality of the data. Participants were informed of the ability to withdraw from the study at any time with no prejudice.

DATA AVAILABILITY

The data produced and examined in this study can be obtained from the corresponding author upon a reasonable request.

Competing interests

Authors have declared that no competing interests exist.

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**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Authors hereby declare that NO generative AI technologies such as Large Language Models   
(ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

list of Acronyms & Abbreviations

ANOVA – Analysis of Variance

BPW - Buffered Peptone Water

CAC - Codex Alimentarius Commission

CFU – Colony Forming Unit

CI – Confidence Interval

COSTECH - Tanzania Commission for Science and Technology

EAS – East African Standards

EU – European Union

ISO – International Organisation for Standardisation

mCCDA – Modified Charcoal Cefaperazone Agar

NBS – National Bureau of Statistics

PCR- Polymerase Chain Reaction

SD – Standard Deviation

SPSS - Statistical Package for the Social Sciences

SUA – Sokoine University of Agriculture

TBS – Tanzania Bureau of Standards

UAE – United Arab Emirates

UK – United Kingdom

URT – United Republic of Tanzania

USA – United States of America

WHO – World Health Organisation

XLD – Xylose Lysine Deoxycholate

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