

Meat and Chicken Retailers in Oman Pose a Considerable Threat to Public Health

Asil Al-Kiyumi

Sultan Qaboos University

Omaima Al-Shaqsi

Sultan Qaboos University

Arwa Al-Farsi

Sultan Qaboos University

Alghalyia Al-Toobi

Sultan Qaboos University

Kaadhia Al-Kharousi

Sultan Qaboos University

Abeer Al-Hamrashdi

Sultan Qaboos University

Afrah Al-Subhi

Muhammad Hussain

Sultan Qaboos University

Elshafie I. Elshafie

Sultan Qaboos University

Khalid Al-Habsi

khalidrr@sq.edu.om

Sultan Qaboos University

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Abstract

This study investigated bacterial contamination (*Salmonella* and *Campylobacter*) in meat and chicken from 20 retailers in the Muscat and Barka regions, collecting 100 samples from cutting boards, machines, knives, carcasses, and workers' hands. Molecular techniques, particularly PCR assays, confirmed the presence of *Salmonella enterica* and *Campylobacter coli*.

Results showed *Salmonella* contamination in 46% of samples (CI = 36–56) and *Campylobacter* in 25% (CI = 17–34), with both pathogens found in 13% of samples. Meat retailers contributed 22% of *Salmonella* isolates, while 24% came from chicken. For *Campylobacter*, 15 positive samples came from red meat and 10 from chicken. Notably, *Salmonella* was primarily found on workers' hands (23.9% of positive samples), and *Campylobacter* mainly in carcasses (32% of positives). All 20 retailers tested positive for *Salmonella*, and 50% of both meat and chicken retailers were positive for *Campylobacter*.

Serotyping revealed four *Salmonella enterica* serotypes: Typhimurium (50%), Weltevreden (28.6%), Enteritidis (14.3%), and Hadar (7.1%). Typhimurium and Weltevreden were found in meat retailers, while all four serotypes were present in chicken retailers, indicating greater diversity in poultry products.

Background

Public health organizations in developed nations have increasingly grappled with a wide range of food safety challenges in recent decades [1]. This growing array of challenges largely stems from emerging foodborne pathogens and evolving disease patterns that pose significant threats to public health [2]. Many foodborne diseases cause serious health complications that can linger long after the initial infection, reducing quality of life and placing heavy burdens on healthcare systems, particularly in the Middle East [3].

Meat produced from livestock and poultry is a foundational element in the diets of many populations, offering essential nutrients such as high-quality protein, iron, and a variety of vitamins. However, the entire supply chain—from production and processing to consumption—significantly heightens the risk of contamination with infectious agents [4]. Pathogens commonly associated with meat products, such as *Salmonella*, *Campylobacter*, *E. coli*, and *Listeria monocytogenes*, pose serious health risks that can cause severe illness [5]. For instance, in Oman, meat consumption patterns have been evolving, with impressive annual average intakes of 23.3 kg for poultry and 19.4 kg for red meat in 2022 [6].

Foodborne illnesses can manifest in many ways, ranging from mild symptoms such as gastrointestinal discomfort characterized by nausea, vomiting, and abdominal cramps to more severe conditions that include bloody diarrhea, dehydration, and, in extreme cases, organ failure (Symptoms of food poisoning, n.d.). These illnesses not only compromise individual well-being but also impose a staggering financial burden on healthcare systems through hospitalization and treatment costs [7].

Inadequate temperature control during storage and improper handling of meat products are prevalent factors that significantly contribute to high levels of contamination [8]. For example, failing to ensure proper refrigeration during transportation and storage can create an environment in which pathogenic bacteria multiply rapidly, dramatically increasing the risk of foodborne illness.

Moreover, distributing meat products involves several critical stages, including processing, packaging, transportation, and retail display. Each phase presents unique opportunities for contamination and can adversely affect not only safety but also the meat's sensory qualities—such as taste, texture, and overall freshness. Consequently, effective monitoring and stringent regulatory measures throughout these processes are essential to minimize risks and ensure that meat products reach consumers safely. Upholding rigorous food safety practices at every point in the production chain is imperative to safeguard public health and enhance the overall quality of food products. Unfortunately, the actual hygienic conditions in meat and chicken retail outlets in Oman remain largely unexamined.

In a concerning incident in Oman, a significant outbreak of food poisoning linked to local restaurants resulted in 101 confirmed cases associated with *Salmonella* Weltevreden [9]. Poultry is also a common reservoir of various foodborne pathogens that can cause illnesses ranging from mild to severe [10]. Recent reports indicate a concerning 28.6% prevalence of *Campylobacter* in chicken carcasses sold in retail markets in the neighbouring United Arab Emirates [11], underscoring the potential risks of poultry consumption.

To address growing concerns about food contamination, this study will thoroughly investigate the conditions of retail meat and chicken at the butcher level in Oman's Seeb and Barka areas. The primary focus will be on recovering pathogens, such as *Salmonella* and *Campylobacter*, using microbiological and molecular methods. Moreover, the study aims to identify potential sources of contamination and establish comprehensive guidelines to enhance municipal food safety standards and personal hygiene practices, thereby improving public health outcomes.

Methods

Sample collection

Meat and chicken retailers were randomly selected in the Seeb and Barka areas, which are known for their prominence in selling and distributing meat and chicken products for personal use, as well as serving small and medium-sized hypermarkets. The study included ten meat retailers and ten chicken retailers. Samples were collected from five distinct sites at each retailer, comprising carcasses, knives, workers' hands, cutting boards, and electric cutting machines. We swabbed these sites using sterile cotton-tipped swabs (2×3 cm) with a shaft. We immediately transported swabs to the laboratory in an iced container for subsequent enrichment.

The Animal Ethics Committee at Sultan Qaboos University approved the sample collection methods (approval number RC/URG/AGR/A&V/24/112). Before initiating the sampling process, informed consent was meticulously obtained from all 20 retailers participating in the study. This consent ensured that each retailer was fully aware of the objectives, procedures, and potential implications of the sampling, thereby affirming their voluntary participation in the research. All methods adhered to the relevant guidelines and regulations established by the local municipalities in Seeb and Barka and the Animal Ethics Committee of Sultan Qaboos University.

Bacterial isolation and identification

The process for isolating *Salmonella* and *Campylobacter* was meticulously detailed in Garcia [12], providing a comprehensive guide that captures the intricacies of the procedure. All swabs were aseptically transferred to 25 mL of 0.1% Buffered Peptone Water (BPW), mixed, allowed to settle, and incubated for 18 h at 37°C. CHROMagar™ *Campylobacter* (Trafalgar Scientific Ltd, UK) was used to culture a loopful of each enrichment broth for *Campylobacter*. However, for *Salmonella* isolation, a loopful of each BPW enrichment broth was inoculated into 7 ml Rappaport–Vassiliadis (RV) broth, mixed, allowed to settle and incubated for 24 h at 42°C before it was inoculated onto Xylose Lysine Deoxycholate (XLD) (Oxoid CM0469, Basingstoke, England) agar. Each *Campylobacter* and *Salmonella* culture was incubated at 37°C for 24 hrs. We identified typical *Campylobacter* and *Salmonella* colonies by colony morphology (e.g., black and red colonies on XLD and CHROMagar, respectively). From each plate, we harvested 10–25 colonies, deposited them in Brain Heart Infusion (BHI) broth containing glycerol (20% v/v), and stored them frozen at – 80°C until further use for molecular and serotyping protocols.

Molecular characterization

Genomic DNA was extracted from a single sterile loopful from the Brain Heart Infusion (BHI) broth, which was added to a sterile vial containing 100 µL of Dnazol reagent (Invitrogen Life Technologies, UK), vortexed, incubated at 65°C for 5 min, following the manufacturer's recommendations and stored at – 20°C until use. The concentration and quality of DNA were estimated using a NanoDrop spectrophotometer 2000 (Thermo Scientific, USA) at a wavelength absorbance of 260/280nm.

Salmonella samples that were positive by XLD culture were re-screened by one-step PCR of the invasion gene using the *invA* forward primer: 5'–TTGTTACGGCTATTTTGACCA–3' and *invA* reverse primer: 5'–CTGACTGCTACCTTGCTGATG–3' as previously described by Swamy et al. [13], producing a product of ~ 521 bp.

Similarly, *Campylobacter* samples that were positive by CHROMagar culture were re-screened by one-step PCR of the hippuricase gene (*hipO*) (344 bp amplicon) to detect jejuni species, using the primers *hipO*-F 5'–GACTTCGTGCAGATATGGATGCTT–3' and *hipO*-R 5'– GCTATAACTATCCGAAGAAGCCATCA–3' and PCR conditions described by Persson and Olsen [14].

Furthermore, all culture-positive *Campylobacter* samples were re-screened for *C. coli* by using the *Ceu* gene of the lipoprotein component of the enterochelin gene (*COL-1*) (894 bp amplicon) 5'–ATG AAA AAA TAT TTA GTT TTT GCA–3' and *COL-2* 5'– ATT TTA TTA TTT GTA GCA GCG–3' and PCR conditions described by Gonzalez et al. [15]. At each PCR run, positive (*Salmonella enterica*, *Campylobacter jejuni* and *Campylobacter Coli*) and negative (no DNA) controls were used. Table 1 lists the target genes, PCR primers, and conditions used for each protocol.

Table 1

Primers set and PCR conditions used to characterize *Salmonella* enterica spp. and *Campylobacter*.

Target pathogen/gene/ Primer	Nucleotide sequence (5'–3')	PCR	Annealing Temperature °C	Amplicon length (bp)	Reference
Salmonella enterica invasion gene					
invA-F	TTGTTACGGCTATTTTGACCA	One- step	42	521	Swamy et al. (1996)
invA-R	CTGACTGCTACCTTGCTGATG				
Campylobacter jejuni hippuricase gene					
HipO-F	GACTTCGTGCAGATATGGATGCTT	One- step	50	344	Persson and Olsen, (2005).
HipO-R	GCTATAACTATCCGAAGAAGCCATCA				
Campylobacter Coli lipoprotein component of enterochelin gene					
COL1	ATG AAA AAA TAT TTA GTT TTT GCA	One- step	52	894	Gonzalez et al. (1997)
COL2	ATT TTA TTA TTT GTA GCA GCG				

[Insert Table 1]

Salmonella serotyping

PCR *Salmonella*-positive isolates from meat and chicken sources were subcultured onto xylose lysine tergitol 4 (XLT-4; Oxoid, Hampshire, England) and incubated aerobically at 37°C for 18–24 h. Serotyping was performed by slide agglutination with monovalent and polyvalent antisera (Microgen, UK), according to the Kauffmann-White-Le Minor Scheme [16].

Statistical analysis

Point prevalence for pathogen genera (*Salmonella* or *Campylobacter*) was determined as the proportion of meat/chicken retailers positive for the pathogen by PCR. We calculated 95% confidence intervals for prevalence using Jeffrey's interval method [17].

Results

PCR of *Salmonella* and *Campylobacter*

Salmonella enterica and *Campylobacter* spp. positive cultures were further characterised by *invA*, *hipO*, and *Ceu* genes, producing 521 bp, 344 bp, and 894 bp amplicons, respectively (Table 1). However, the *hipO* gene did not amplify in *Campylobacter*, indicating that *C. jejuni* was absent from the isolates.

Molecular prevalence of *Salmonella* and *Campylobacter* in meat and chicken retailers

Of the total 100 samples, *Salmonella* and *Campylobacter* were isolated from 46% and 25%, respectively. Using molecular tools targeting the designated genes, both pathogens were concurrently present in 13% of samples. Of the 46% *Salmonella*-positive samples, 22% were recovered from meat retailers (L1-L10), whereas the remaining 24% were from chicken retailers (L11-L20). Among the *Campylobacter*-positive samples, 15 originated from red meat, and 10 were from chicken. Swabs were recovered from five sites at each retailer (Cutting boards, Electric Cutting Machines, Knives, Meat, and Workers' Hands); most *Salmonella* were recovered from workers' hands (23.9%). However, most *Campylobacter* recovered from meat samples (32%). For *Salmonella*, the lowest positives were recovered from meat (15.2%), while the lowest *Campylobacter* positives were from knives (12%). All 20 meat and chicken retailers showed positive results for *Salmonella* (minimum 1 positive, maximum 4 positives per location). However, 5 out of 10 (50%) meat retailers and 5 out of 10 (50%) chicken retailers demonstrate positive results for *Campylobacter*. Investigation revealed that 13% of samples showed mixed infection with both *Salmonella* and *Campylobacter*. The PCR detection of *Salmonella* and *Campylobacter* in meat and chicken retailers is further indicated in Table 2.

Table 2
Campylobacter and *Salmonella* detection in meat (L1-L10) and chicken retailers (L11-L20).

Location/ Sample	Cutting boards	Electric Cutting-Machine	Knives	Carcass	Worker's Hands
Campylobacter- PCR positive isolates					
L1	☒	☒	☒	☒	
L2	☒	☒		☒	
L3	☒	☒		☒	
L4	☒	☒	☒	☒	
L9				☒	
L14		☒			
L17				☒	☒
L18				☒	☒
L19	☒		☒	☒	☒
L20					☒
Salmonella- PCR positive isolates					
L1		☒	☒		
L2	☒	☒	☒		☒
L3	☒				☒
L4	☒		☒	☒	
L5		☒	☒	☒	☒
L6	☒				
L7			☒	☒	
L8					☒
L9		☒			
L10		☒	☒		
L11					☒
L12	☒	☒	☒		☒
L13					☒
L14				☒	
L15	☒	☒		☒	☒
L16	☒	☒		☒	☒
L17		☒			

Location/ Sample	Cutting boards	Electric Cutting-Machine	Knives	Carcass	Worker's Hands
L18	☒	☒	☒		
L19	☒		☒	☒	☒
L20					☒

[Insert Table 2]

Serotypes of Salmonella isolates

Based on the surface O and H antigens, four distinct *Salmonella* serotypes (Typhimurium, Weltevreden, Enteritidis and Hadar) were identified from the serotyped PCR-positive *Salmonella* isolates. Of these, 50% (Typhimurium), 28.6% (Weltevreden, 14.3% (Enteritidis) and 7.1% (Hadar). Only Typhimurium and Weltevreden were serotyped from meat retailers, whereas the four serotypes were recovered from the chicken retailers.

DISCUSSION

We systematically collected sterile swabs from meat and chicken retailers at two locations in Oman—Seeb and Barka. Upon conducting thorough microbiological and molecular analyses, we found a notable prevalence of *Salmonella* (46%) and *Campylobacter* spp. (25%). This research primarily aimed to use advanced molecular tools to validate and confirm the presence of *Salmonella* and *Campylobacter* spp. in culture. The study focused on meat and chicken retail outlets that consumers commonly visit in Oman's two most densely populated areas.

Our exhaustive literature review revealed a substantial gap in existing research concerning microbial contamination in meat and poultry outlets across Oman. This deficiency underscores the urgent need for further studies to assess and enhance the safety and hygiene standards these establishments uphold. Considering this, we plan to gather and analyze data from neighbouring countries, particularly the United Arab Emirates. By comparing their microbial safety records and contamination levels with those found in Oman, we aim to identify meaningful parallels and insights that may illuminate the microbial landscape within Oman's meat and poultry sector. This comparative analysis is expected not only to highlight potential health risks but also to identify strategies to improve food safety practices across the region.

In our study, we found that a significant portion of the *Salmonella* spp. (46%) predominantly came from chicken retailers, with most positive samples (24%) identified from these outlets. Alarminglly, our findings showed the highest levels of *Salmonella* contamination on workers' hands, suggesting potential lapses in personal hygiene and food-handling protocols. This concern is further compounded by a recent report from Al-Habib, which found a 14.29% prevalence of *Salmonella* in chicken carcasses imported from Oman and sold by UAE retailers [18]. Together, this report and our findings underscore the critical need to reassess and update the sanitation policies governing butcher shops in Oman. Such revisions are essential to address specific issues related to cleanliness, food handling practices, and comprehensive hygiene measures, ensuring the safety and well-being of both consumers and employees.

Additionally, the prevalence of *Campylobacter* spp. found in our investigation—at 25%—is consistent with a reported 28.6% prevalence of *Campylobacter* in chicken retailers in the UAE [11]. Most of the poultry consignment analyzed in the previous study was reportedly sourced from Oman, suggesting a potential link between poultry origin and this bacterium's prevalence. This connection highlights broader concerns about food safety and the need for rigorous quality control measures in the poultry production chain. This correlation underscores the need to address microbial contamination in the poultry industry and improve food safety across the region.

Conclusion

The significant rise in meat and poultry consumption in Oman has highlighted the pressing need for effective measures to combat foodborne pathogens. To address this issue, Oman must implement comprehensive control programs to reduce these harmful pathogens in butcher shops nationwide significantly.

One primary strategy is to improve hygiene practices in the meat and poultry industry. This involves not only ensuring that butchers maintain high standards of cleanliness but also providing training in proper food-handling techniques. Additionally, it is crucial to establish rigorous sanitation protocols that cover everything from equipment maintenance to the hygiene of personal protective gear.

Another vital component is developing risk-based monitoring systems to oversee the sale of meat and poultry products. This could include regular inspections and audits of butcher shops to ensure compliance with health regulations and identify potential contamination sources before they become public health issues.

Moreover, raising consumer awareness about food safety is imperative. Educating the public on how to store, handle, and cook meat and poultry properly can significantly reduce the risk of foodborne illness. This awareness campaign could involve workshops, informational brochures, and social media outreach to reach a wider audience.

By focusing on these essential measures—strengthening hygiene practices, implementing risk-based monitoring, and actively raising consumer awareness—Oman can take significant steps to reduce the risks posed by foodborne pathogens and ensure that meat and poultry products are safe and free of contamination from the butcher to the dining table.

Abbreviations

BPW Buffered Peptone Water

mL Milliliter

RV Rappaport–Vassiliadis

XLD Xylose Lysine Deoxycholate

BHI Brain Heart Infusion

DNA Deoxyribonucleic acid

Bp Base pairs

InvA Invasion protein A

HipO Hippurate hydrolase

C. coli *Campylobacter coli*

C. jejuni *Campylobacter jejuni*

Ceu *Campylobacter* enterochelin uptake

CI Confidence interval

WHO World Health Organization

Kg Kilogram

Cm Centemeter

°C Degree Celsius

v/v Volume/volume percent

μL Microliter

Declarations

Ethics approval and consent to participate

The Research Ethics Committee at Sultan Qabbos University granted approval for the use of microorganisms, specifically *Salmonella* and *Campylobacter*, under the designation RC/URG/AGR/A&V/24/112. Prior to sampling, informed consent was obtained from all 20 retailers. This experimental research adhered to all applicable institutional, national, and international guidelines and regulations.

Consent for publication

Not applicable.

Competing interest

The authors declare no conflict of interest.

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data collection, analysis, and interpretation, which are solely the authors' responsibility when writing the manuscript.

Author Contribution

AK: Sample collection (equal), laboratory analyses (equal), manuscript setup (equal) OS: Sample collection (equal), laboratory analyses (equal), manuscript setup (equal) descriptive analysis (equal) AF: Sample collection (equal), laboratory analyses (equal), manuscript setup (equal) AT: Microbiological techniques supervision (equal), review materials and methods (equal) KK: Molecular techniques supervision (equal), review materials and methods (equal) AH: Endnote referencing (equal), review materials and methods (equal) AS: Salmonella culture and serotyping (equal) EE: Data statistical analyses (equal); writing—review and editing (equal) MH: Data statistical analyses (equal); writing—review and editing (equal) KA: Resources (equal); data curation (equal); formal analysis (equal); investigation (equal); writing—original draft (equal); writing—review and editing (equal).

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Data availability

The datasets employed in this study are available from the corresponding author upon request.

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Figures



Figure 1

Swabs collected from different butcher sites.