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Health and Microbiological Assessment of Contamination in Traditionally Slaughtered Domestic Chicken Meat in The Markets of N'Djamena

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Abstract: The aim of this study was to conduct a health and microbiological assessment of contamination in traditionally slaughtered local chicken meat sold in the markets of N'Djamena, with a view to determining the level of bacterial contamination and identifying the most significant pathogenic bacteria associated with traditionally slaughtered local chicken meat, thereby contributing to the assessment of the associated health risks to consumers. The study involved collecting 208 samples of locally sourced, traditionally slaughtered chicken meat from four local markets in the city of N'Djamena and subjecting them to microbiological testing using appropriate culture media and biochemical tests to isolate and identify the contaminating bacteria. The results showed variation in the total bacterial load between the markets; the total number of bacterial colonies growing on Plate Count Agar (PCA) was approximately 1,125,394,600 CFU/g, whilst the average total bacterial count across the four markets was 4,328,800 CFU/g. The highest average bacterial count was recorded at Safil Market at 5.77×10^6 CFU/g, followed by Dambi Market at 5.76×10^6 CFU/g, then AlAfia Market at 5.29×10^6 CFU/g, whilst Al-Kabeer Market recorded the lowest value at 4.81×10^6 CFU/g, The results also revealed varying levels of microbial contamination in samples of locally sourced, traditionally slaughtered chicken meat, with the isolation of a number of bacteria of public health significance, including Salmonella Typhi, Escherichia coli O157 and Staphylococcus spp, in addition to other opportunistic and environmental bacterial species. In the four markets of N'Djamena, the prevalence of these isolates was as follows:

Staphylococcus spp. (80%), Shigella spp. (48%), Escherichia coli (24%), Salmonella spp. (20%), Proteus mirabilis (19%), Enterobacter spp. (18%), Citrobacter freundii (16%), Escherichia coli O157 (10%) Klebsiella pneumoniae (7%), Salmonella Typhi (7%)

Contamination levels varied between markets, which may be linked to differences in the personal hygiene of workers, the cleanliness of equipment and surfaces, the quality of the water used, and the method of slaughter and processing, These findings suggest that traditional slaughter and improper handling may be significant factors in increasing the likelihood of bacterial contamination and the transmission of foodborne diseases. The study concluded that meat from traditionally slaughtered free-range chickens in the markets of N'Djamena may constitute a potential source of health risks where good hygiene practices are not adhered to. The study recommended strengthening health inspections of slaughter and sales premises, improving hygiene and disinfection standards, providing safe drinking water, and providing ongoing training for workers on hygienic slaughter and handling methods, alongside conducting regular microbiological tests on chicken meat to reduce the risk of foodborne diseases and protect consumer health.

Keyword: chicken meat, traditional slaughter, microbial contamination, pathogenic bacteria, food safety, Angina.

INTRODUCTION

Food safety is a top priority for humanity due to its close link to health, economic development and social stability (Ahamat, 2019). According to global estimates, the number of poultry far exceeds the human population, with approximately three birds for every person (Faour and Bashi, 2023). Poultry meat is one of the world's most important sources of animal protein, owing to its high nutritional value, ease of production and cost-effectiveness compared with other protein sources. It also represents a key component of food security in many developing countries, including the Republic of Chad, where a large proportion of the population relies on backyard chickens as their main source of animal protein (FAO, 2024). Chicken meat is the most widely consumed source of animal protein in the world due to its low production costs—and consequently low price—and low fat content; high nutritional value, ease of preparation, and cultural and religious acceptability compared to red meat. However, chicken meat has a high moisture content and a high pH level, which causes it to spoil and lose its freshness rapidly (Said et al., 2025). The Food and Agriculture Organisation (FAO) emphasises that poultry meat contributes significantly to improving food

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security and nutrition; however, its microbiological safety represents an ongoing challenge that requires the implementation of effective control measures throughout the food chain. In the city of N'Djamena, traditionally slaughtered free-range chicken is one of the most widely traded animal products in local markets, where consumers favour it for its freshness and affordability. However, traditional slaughter, plucking, processing, transport and display for sale often take place in environments that lack hygiene standards and good hygiene practices, thereby increasing the likelihood of microbial contaminants being transferred to the meat and affecting its quality and safety (WHO, 2023). Microbial contamination of chicken meat is one of the leading causes of foodborne illness, as numerous pathogenic bacteria such as Salmonella spp., Campylobacter spp., Escherichia coli and Staphylococcus aureus can be transmitted to humans through the consumption of contaminated meat or as a result of poor handling and preparation. The World Health Organisation notes that foodborne diseases comprise more than 200 illnesses caused by bacteria, viruses, parasites and chemical contaminants, and that poultry meat is one of the most significant food vectors associated with the transmission of bacterial pathogens to humans (WHO, 2025). Furthermore, there is significant consumption of poultry meat and products in both developing and developed countries (Faour and Bashi, 2023) Microbial contamination of poultry meat in retail outlets is a better indicator of public health risks than microbial contamination in slaughterhouses, as the first point of contact between the consumer and poultry meat sold in retail outlets occurs within these outlets; Consequently, poultry meat sold in retail outlets may act as a direct source of consumer exposure to foodborne pathogens; furthermore, adequate hygiene facilities and sufficient refrigeration may lead to an actual reduction in the level of isolatable bacteria in chicken meat products (Jimenez et al., 2002)

Reports from the Joint World Health Organisation–Food and Agriculture Organisation (JEMRA) meeting indicate that controlling contamination of chicken meat cannot be achieved through a single measure alone, but rather requires the implementation of an integrated series of interventions, starting from the farm, through slaughter, processing, transport and storage, right up to the point of sale to the consumer, in order to limit the spread of Salmonella and other foodborne pathogens (WHO & FAO, 2023). , one of the health issues attracting increasing global attention is the prevalence of antibiotic-resistant bacteria in food products of animal origin, resulting from the irrational use of antibiotics in animal production. This phenomenon poses a threat to public health, as resistant strains or resistance genes may be transmitted to humans via the food chain, leading to a reduction in the effectiveness of antibiotics used in treatment and making it more difficult to control bacterial infections (FAO, 2024; WHO, 2024). Despite the economic and health importance of backyard poultry in the city of N'Djamena, studies on the health and microbiological assessment of traditionally slaughtered chicken meat remain limited, and there is insufficient data on the level of bacterial contamination, the prevalence of pathogenic bacteria, or their patterns of antibiotic resistance. Consequently, conducting a scientific study to assess the microbiological status of traditionally slaughtered chicken meat in the city of N'Djamena is an important step towards providing scientific data that can be utilised in the development of health surveillance programmes and the improvement of slaughter and handling practices, thereby contributing to the protection of consumer health and the reduction of foodborne diseases.

Specific objectives

- To isolate and identify common pathogenic bacteria using conventional microbiological methods.
- To determine the prevalence of microbial contamination in traditionally slaughtered domestic chicken meat in the markets of N'Djamena
- To provide scientific recommendations that contribute to improving slaughter, handling and health control practices, and to reducing foodborne diseases in traditionally slaughtered chicken meat

MATERIALS AND METHODS

Equipment, Study Area, N'Djamena:

N'Djamena is the largest urban centre in Chad and is situated at an altitude of 294 metres above sea level at the intersection of 12° 8' north latitude and 15° 2' east longitude, on the eastern bank of the Chari River where it meets the Logone River (Saleh, 2012) N'Djamena is distinguished by its strategically important geographical location at the second Chari River delta, where the city lies at the junction of internal overland routes and is also considered the central gateway to the trans-African highway: Port Sudan – El Obeid – El Geneina – Adrei – Abeche – Mangou – N'Djamena – Midgori – Harcourt/Lagos, as well as the route: N'Djamena – Marwa – Garoua – Douala. In this way, it serves as a link between the east and west of the continent on the one hand, whilst on the other hand it has benefited from its location on the transcontinental route in the modern era, which is one of its most distinctive features, as N'Djamena has become a key hub for one of the continent's most vital overland routes. Furthermore, N'Djamena lies at the confluence of waterways, where the Chari River, flowing from Central Africa, meets the Logone River, flowing from Cameroon; via the waterway leading to Lake Chad, connections can be made to both Niger and Nigeria. N'Djamena's location is of great importance to the Chadian state, as its border location adjacent to Cameroon—from which it is separated only by the waters of the Chari River—has been a contributing factor to the flourishing of economic, social and urban development. As for its geographical

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position, which places it at the westernmost point of Chad, whilst other centres in the country are concentrated in the centre, east, south and north, this has not diminished the city's importance but rather reinforced it; it is considered a major commercial hub in the modern era for the State of Chad (Saleh, 2014).

Figure (1) shows the city of N'Djamena

Study Design

A cross-sectional, descriptive, analytical, laboratory-based study

Study population and sample size

The study population consisted of all domestically reared chickens slaughtered using traditional methods in the markets of N'Djamena during the study period. Samples were selected from a number of markets and areas representative of the study population, in accordance with the approved sampling plan for bacterial isolation and laboratory diagnosis.

Calculation of the total number of laboratory samples

The total number of laboratory samples was determined based on the study design by calculating the number of sampling units (chickens) and multiplying this by the number of samples taken from each chicken, in accordance with the general principles of sample design in epidemiological and veterinary studies (Cochran, 1977; Thrusfield, 2018).

The study covered four areas in each city, with 13 chickens selected from each area, bringing the total number of chickens in each city to 52 (4 × 13 = 52). Four samples were collected from each hen (meat, liver, gizzard and intestinal contents), bringing the total number of laboratory samples per city to 208 (52 × 4 = 208).

Sample collection

A total of 208 samples were collected from locally reared chickens slaughtered using traditional methods from various areas of the city of N'Djamena.

The method for collecting samples to detect the presence of pathogenic bacteria in locally sourced, traditionally slaughtered chickens can be summarised as follows:

- The samples were taken using the same tools as those used by the vendor
- The samples were placed in pre-sterilised sample collection bags fitted with a seal and labelled with an identification tag bearing the sample number, name, and date and place of collection; these bags were then transported under refrigerated conditions to the laboratory
- Prior to analysis, the bags were left at room temperature (25 °C)
- The tests were carried out on the samples within 24 hours

Inoculation of samples

Samples taken from internal organs, including meat, liver, caecum and intestinal contents, were immediately inoculated into culture media specifically designed for the growth of the bacteria under study. Isolates were cultured to selectively grow Salmonella on one of the following media:Bismuth Sulphite Agar or Xylose Lysine Deoxycholate Agar. The media used for the growth of E. coli are: Eosin-Methylene Blue and MacConkey Agar

Methods for isolating bacteria belonging to the Entero bacteriaceae family

First: The isolation and identification of bacteria belonging to the Enterobacteriaceae family were

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carried out according to (Ranjan, 2007) and (Morello et al., 2006):

1. 25 g of chicken meat was added to 225 ml of physiological saline (comprising 8 g of sodium chloride and 1 g of peptone, made up to 1000 ml with distilled water and mixed thoroughly), thereby obtaining the first dilution; the procedure was carried out in a sterile environment
2. One millilitre of the first dilution was then pipetted and added to a tube containing 9 ml of physiological dilution solution to obtain the second dilution. The process was repeated to achieve the required dilution
3. Under sterile conditions, transfer 1 ml of the required dilution to a sterile Petri dish; use two replicates for each dilution.

Sterile MacConkey agar was added to the dishes. The solution was then mixed with the agar by swirling the dish in a circular motion, first clockwise and then anti-clockwise, and the dishes were left to set. The plates were then incubated upside down in an incubator at 37 °C and 44.5 °C for 48 hours, with two replicates at each temperature.

The pink-coloured, growing colonies on MacConkey Agar at both incubation temperatures were considered typical colonies. They were transferred to methylene blue eosin (EMB) medium by streaking under sterile conditions, and the plates were incubated upside down at 37 °C for 24 hours.

A series of microbiological tests were carried out on the growing isolates, such as Gram staining and microscopic examination, in addition to a further set of microbiological tests:

A. Total Aerobic Plate Count (APC) The total aerobic plate count was carried out to estimate the total microbial load in samples of conventionally slaughtered chicken meat; Plate Count Agar (PCA) was used for this purpose. After performing serial decimal dilutions of the sample, the appropriate dilutions were inoculated onto the culture medium, and the plates were then incubated at the temperature and for the duration specified in the protocol used. After the incubation period had elapsed, plates containing an adequate and countable number of colonies were selected, and the total number of aerobic microorganisms was calculated; the results were expressed in colony-forming units per gram (CFU/g) or (CFU/mL) for chicken meat samples. The microbial count was calculated based on the dilution factor and the volume of inoculum used, taking into account the selection of appropriate plates for counting in accordance with approved standards. Reference (2013, 15) 1:2013-4833 ISO

B. Total coliform count and detection of Escherichia coli

4- Total Coliform Count and Escherichia coli Detection

A total coliform count and detection of Escherichia coli were carried out on samples of conventionally slaughtered chicken to assess the level of microbial contamination and hygiene indicators. Violet Red Bile Agar (VRBA) was used for the detection and enumeration of coliforms, whilst TBX Agar (Tryptone Bile Xglucuronide Agar) can be used for the selective detection of Escherichia coli, in accordance with the purpose of the test and the approved standard method.

Serial decimal dilutions were prepared from samples of conventionally slaughtered chicken meat; appropriate dilutions were then inoculated onto the specified culture media, and the plates were incubated under the approved incubation conditions for each method. After the incubation period, the plates were examined and colonies with characteristic features were counted; the results were then expressed in colony-forming units per millilitre (CFU/mL) for the chicken samples. The counting and detection procedure was based on the standard method ISO 21528-2:2017 for the detection and enumeration of intestinal coliforms, bearing in mind that ISO 21528-2 relates specifically to enumeration by plate culture, whilst the appropriate ISO standard for the detection of E. coli should be selected according to the method and medium used. Coliform bacteria, and in particular E. coli, are important indicators for assessing the quality and safety of chicken meat; high levels may indicate potential faecal contamination or inadequate hygiene practices during slaughter, washing or handling (ISO 2017)

Identification of Bacterial Isolates

The bacterial isolates obtained from the samples under study were subjected to a series of laboratory tests to identify and characterise them. These included macroscopic examination of the colonies, microscopic examination of bacterial cells, and biochemical tests, based on established diagnostic criteria and standard bacteriological references (Al-Jamali, 2017)

Macroscopic examination of colonies (Colony Morphology)

The bacterial isolates were initially identified based on the morphological characteristics of the colonies growing on various culture media, in accordance with the diagnostic criteria set out in recognised bacteriological references, including (Holt et al., 1994)

The morphological examination involved the assessment of a number of characteristics, including colony shape, size, colour, margins, height, consistency, surface texture and degree of transparency, as well as the nature of their growth on the culture medium. The growth behaviour of the isolates on Blood Agar and MacConkey Agar was also recorded, noting the ability of some isolates on to

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cause haemolysis on blood agar, and recording the pattern of haemolysis where present.

5- Microscopic Examination

Microscopic examination of bacterial isolates was carried out to determine the shape of the bacterial cells, the Gram stain result, and the arrangement of the cells. This was done after preparing a smear from a single bacterial colony on a clean glass slide, fixing it, and performing a Gram stain in accordance with standard procedure.

The slides were examined microscopically using a light microscope to distinguish between Gram-positive and Gramnegative bacteria, as well as to identify cell shapes, such as cocci and bacilli, and the arrangement of the cells, whether in pairs, chains, clusters or singly.

The results of the Gram stain and the microscopic characteristics of the isolates were interpreted on the basis of standard bacteriological references (Holt et al., 1994).

Detection of Salmonella spp

Salmonella spp. were detected in the samples studied in accordance with the standard methodology set out in ISO 65791:2017, through a series of laboratory steps comprising recovery and pre-enrichment, followed by selective enrichment, then isolation and confirmatory diagnosis.

Recovery and pre-enrichment:

Pre-enrichment was carried out on Salmonella spp. cells present in the samples, with the aim of recovering bacterial cells that may have been stressed or damaged as a result of collection, transport and storage conditions, and preparing them for growth in subsequent stages of the test.

Selective enrichment:

The selective enrichment stage was carried out to promote the growth of Salmonella spp. and limit the growth of competing microorganisms present in the sample, thereby increasing the likelihood of detecting the target bacteria.

Isolation on selective and differential media:

Following the selective enrichment stage, isolation was carried out on selective and differential culture media suitable for the detection of Salmonella spp., the most important of which is Xylose Lysine Deoxycholate Agar (XLD), with the option of using Hektoen Enteric Agar (HE) as an additional medium for the isolation and differentiation of suspected colonies.

Screening and confirmation:

The growing colonies were examined for morphological characteristics, and colonies suspected of belonging to Salmonella spp were selected for the necessary biochemical tests for confirmation. Identification may be supplemented using serological tests or molecular techniques, depending on the study objectives and the laboratory's capabilities.

To ensure the accuracy, reliability and reproducibility of results, quality control and quality assurance procedures have been implemented at all stages of laboratory work, from sample receipt and preparation, through isolation, diagnosis and microbial enumeration, to the recording and analysis of results, in accordance with the general requirements for microbiological testing set out in ISO 7218:2024 (ISO, 2024).

Culture media:

Standardised, approved culture media were used, whether readyto-use or in the form of dehydrated powder, ensuring their suitability, the integrity of their packaging and their storage conditions, and preparing them in accordance with the manufacturers' instructions and approved standard requirements (ISO, 2024).

Calibration of laboratory equipment:

Incubators, thermometers and other equipment used in the analyses were calibrated and monitored periodically, with the accuracy of temperatures and operating conditions verified, in accordance with the requirements of Good Laboratory Practice for microbiological testing (ISO, 2024).

Documentation and laboratory records:

All procedures and results were recorded in approved laboratory records, including the sample number, the date of receipt and testing, the type of culture medium used, incubation conditions, test results, and any observations or deviations that occurred during the analysis, thereby ensuring the traceability and verifiability of the results (ISO, 2024)

The coefficient of variation and repeatability were calculated using the following equations:

Coefficient of variation (%) = (number of positive samples ÷ total number of samples tested) × 100

$100 \times Y = x/n$

where: ; number of positive samples (x): the number of samples in which the pathogen was detected

Total number of samples (n): the total number of samples tested Frequency

Frequency = the number of times the trait appears or the number of positive samples

Culture media used in the bacteriological study

A range of culture media was used to isolate, culture and identify bacteria, in addition to the use of Mueller-Henton medium to carry out antibiotic susceptibility testing. The culture media were prepared in accordance with the manufacturers' instructions, as follows:

A. Nutrient Agar

Nutrient Agar was prepared by weighing out 28 g of the medium powder and dissolving it in 1,000 ml of distilled water, then mixing thoroughly using a magnetic stirrer and a hotplate until the medium was completely dissolved. The medium was then placed in an autoclave and sterilised at 121°C for 15 minutes. Once sterilisation was complete, the medium was cooled to a temperature of 45–50°C, then poured into sterile Petri dishes under sterile conditions and left to solidify before being used for bacterial culture.

b. Blood Agar

Blood agar was prepared by weighing 40 g of the base medium powder and dissolving it in 1,000 ml of distilled water, then mixing thoroughly using a magnetic stirrer and a water bath until completely dissolved. The medium was sterilised in a steam autoclave at 121°C for 15 minutes. The medium was then cooled in a water bath to a temperature of approximately 50–56°C, after which sterilised blood was added in the specified proportion in accordance with the manufacturer's instructions, and gently mixed to ensure uniform distribution. The medium was then poured into sterile Petri dishes under sterile conditions and left to solidify.

C. MacConkey Agar

MacConkey Agar was prepared by weighing 49.53 g of the agar powder and dissolving it in 1000 ml of distilled water, then mixing thoroughly using a magnetic stirrer and a heater until completely dissolved. The medium was then sterilised in a steam autoclave at 121°C for 15 minutes. After sterilisation, the medium was cooled to approximately 50°C, then poured into sterile Petri dishes under sterile conditions and left to set before being used for bacterial isolation.

Biochemical Tests

A series of biochemical tests were carried out on bacterial isolates grown on culture media, with the aim of determining their biochemical characteristics and assisting in their diagnosis and identification. These tests were carried out on the isolates after an appropriate incubation period, based on the macroscopic and microscopic characteristics of the isolates, in accordance with standard methods set out in recognised bacteriological references, including (Cowan and Steel, 2004).

Several biochemical tests were carried out to identify the bacterial genera, namely: indole, Fox-Proskauer, catalase, citrate, oxidase, methyl red and urease.

The interpretation of the results was based on the change in the colour of the medium resulting from a change in pH; a change in colour from red to yellow indicates the fermentation of sugars, whilst gas production can be observed through the appearance of cracks, bubbles or a rise in the level of the medium within the tube. Blackening of the medium, on the other hand, indicates the production of hydrogen sulphide (H_2S). The results were interpreted in accordance with the manufacturer's instructions for the medium. Research materials

Results 1- Table 1 shows the total for the four markets in N'Djamena

No.	Bacteria	Frequency / Positive Isolates	Dembi Market	The Grand Market	Sanfel Market	Al-Afia Market	Prevalence (%)	Total samples
1	*Salmonella Typhi*	15	5	1	2	7	7.21	
2	*Klebsiella pneumoniae*	15	6	2	2	5	7.21	
3	*Escherichia coli* O157	21	5	7	0	9	10.10	
4	*Citrobacter freundii*	35	4	10	12	9	16.83	
5	*Enterobacter* spp.	38	11	6	11	10	18.27	
6	*Proteus mirabilis*	40	12	11	0	17	19.23	
7	*Salmonella* spp.	42	10	15	4	13	20.19	
8	*Escherichia coli*	50	4	11	17	18	24.04	
9	*Shigella* spp.	100	48	17	29	6	48.08	
10	*Staphylococcus* spp.	167	49	33	49	36	80.29	
Total	**Total**	**523**	**154**	**113**	**126**	**130**	—	208

Discussion Total Plaits Count

The results obtained from the present study showed that the total number of bacterial colonies growing on the Plaits Count medium was (1,125,394,600) CFU/g, of which ($^{10^6}\times$ 5.29) colonies were from the Wellness

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Market, (10^6× 5.77) for the Safil Market, ($^{10^6}$× 4.81) for the Grand Market, and ($^{10^6}$× 5.76) for the Dambi Market

The overall average for these bacteria across the four markets was (4,328,800).

This study shows that the average bacterial colony count in the present study is 4.3 × 10^6× cells/gram. The current results were higher than those of a number of previous studies but similar to others; in particular, they were higher than those reported by Melhem (2016), whose results did not exceed$^{10^3}$× 8.53 cells/gram. The high count may be attributed to a failure to follow hygiene protocols within the traditional slaughterhouse, where the person carrying out traditional slaughter or preparing for slaughter does not wear any protective equipment to prevent contamination, such as gloves, and does not carry out effective and regular cleaning of the slaughterer's tools and clothing, as reported in the study by Edris2012.. Furthermore, most of the operations carried out during traditional slaughter take place in open areas that are exposed to dust, dirt and insects.

The current study also shows that bacterial counts are high across all four markets in N'Djamena, with similar levels ($^{10^6}$× 4.8 – 10^6× 5.6 cells/gram respectively. These results are consistent with those reported by Mohamed and Abdulmohsen (2008). Based on the findings of this study, it can be said that the high rates of bacterial isolation recorded—which represent an important indicator in epidemiological studies— are indicative of the sanitary conditions under which locally produced, traditionally slaughtered chicken meat is produced, which do not comply with the health standards recommended by international health organisations . This is in addition to the poor methods used in the storage and display of these carcasses, and the impact of low hygiene standards in this sector on increased levels of contamination.

Furthermore, this study did not concur with the findings of Shaib et al. (2026), which showed that bacterial counts were significantly higher in the May Market (Market 6) at 10^5× 1.05 cells/gram, compared with the Al-Ashar Popular Market in Khartoum at 10^4× 8.51 cells/gram and the Omdurman Market at 10^4× 9.33 cells/gram respectively, which is lower than the figures in this study. This discrepancy may be due to the poor hygiene of traditional abattoirs and a lack of awareness amongst workers, as well as the use of unclean and contaminated tools, in addition to the poor hygiene of workers within these abattoirs; or it may be due to climatic differences.

This study is consistent with the findings of a study by Aning et al. (2012), which showed that the total count of aerobic bacteria exceeded the permissible limits in 78 per cent of chicken samples, with a high prevalence of E. coli

The most contaminated area was the Al-Afia Market, due to the potential for contamination arising from the tools used in slaughter, plucking, cutting and cleaning, starting from the slaughter area—which was on ground contaminated with poultry faeces— through the slaughterer's feet—which were wearing shoes—onto a table that had not been washed for some time; the chicken was then placed in hot water that had not been changed for some time; and finally onto a table that had not been washed for some time to remove the feathers. The removal of heads, feet and entrails all takes place in areas where poultry is sold and reared; this may be due to the lack of regular inspection campaigns by the Control Centre's offices.

As for the areas under study with the highest levels of contamination, these are the Sanfil Market area; this is because the areas where the chickens are slaughtered were free of poultry droppings, in addition to the relative cleanliness of the wooden table on which the feathers and internal organs are removed. The least contaminated areas under study are the Grand Market and the Dambi Market; this is because the sales areas are somewhat distant from the slaughter areas, and the chickens are slaughtered in bags to collect the blood in one place. The slaughterer does not place his foot on the slaughtered chicken, and the feathers are removed and cleaning carried out on the same table where the slaughter took place, although it is washed every 24 hours. These results also differ from those reached by Hoshayar (1978), as the bacterial counts on the surface of the chicken ranged between (10^4× 100 – 10^4× 0.05 cells/gram). They are also consistent with the findings of Hashim (2005), who observed fluctuations in bacterial counts, particularly of Staphylococcus aureus, in chicken meat sold in markets.

The study's results revealed a clear variation in the isolation rates of pathogenic bacteria across the four markets under investigation—Al-Afia Market, Sanfel Market, Al-Kabeer Market and Dambi Market—indicating differences in the level of microbial contamination between the sites where locally sourced, traditionally slaughtered chicken is slaughtered, sold and handled. This variation may be attributed to differences in hygiene standards, slaughter and processing methods, water sources used, storage temperature (as there were no refrigeration facilities in any of the four markets), meat handling practices, and differences in health awareness among workers.

Based on the results presented in Table 1 for all four markets
Salmonella Typhi was detected in 7 isolates (13.5 per cent) at Al-Afia Market, 2 isolates (3.8 per cent) at Sanfil Market, 1 isolate (1.9 per cent) at Al-Kabeer Market, and 5 isolates (9.6 per cent) at Dambi Market, It is clear that the highest number of isolates was found at Al-Afia Market, whilst the lowest rate was at

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AlKabeer Market. The presence of Salmonella is an important indicator of the likelihood of faecal contamination and poor hygiene practices during slaughter and handling; furthermore, its presence in samples of locally sourced, traditionally slaughtered chicken poses a potential risk to public health.

As for Klebsiella pneumoniae, five isolates (9.5 per cent) were recorded at AlAfia Market, and (2 isolates) at a rate of 3.8 per cent in Sanfil Market and the Grand Market, respectively, and (6 isolates) at a rate of 11.5 per cent in Dambi Market, indicating a gradual increase in the number of isolates, with the highest rate recorded in Dambi Market. The presence of this bacterium may be linked to contamination of the environment, water and slaughtering equipment, and it can also be transmitted from contaminated hands and surfaces to traditionally slaughtered chicken meat.

As for Escherichia coli O157, there were 9 isolates (17 per cent) at Al-Afia Market; no Escherichia coli O157 was isolated at Sanfel Market; 7 isolates (13 per cent) at Al-Kabir Market; and 5 isolates (9.6 per cent) at Dambi Market. These results indicate a clear increase in the Al-Afia Market compared with the other markets. The present study did not concur with the study by Hussein et al. (2016), conducted in Basra Governorate, Iraq, where E. coli O157 was isolated and identified in fresh and minced chicken and beef, with an isolation rate of 5 per cent of the total samples. This difference in contamination levels between the study areas is attributed to variations in hygiene standards, slaughter and processing methods, handling practices, storage conditions and display duration. The contamination rate was higher in the present study compared with that study, and this finding is of significant public health importance, as E. coli O157 is a foodborne pathogen and can be associated with severe illness, underscoring the need to improve slaughter and hygiene procedures and prevent cross-contamination.

As for Citrobacter freundii, 9 isolates (17 per cent) were recorded at Al-Afia Market, 12 isolates (23 per cent) at Sanfil Market, and 10 isolates (19 per cent) at Al-Kabeer Market, and 4 isolates (7.6 per cent) at Dambi Market. It is clear that Sanfil Market and Al-Kabeer Market recorded the highest figures, whilst Dambi Market had the lowest. The presence of these bacteria may indicate potential environmental or faecal contamination, particularly given the poor hygiene controls during the processing of locally slaughtered chicken using traditional methods, As for Enterobacter spp., the number of isolates was 10 (19 per cent) in Al-Afia Market, and 11 (21 per cent) in Sanfil Market and Dambi Market respectively, and (6 isolates) representing 11.5 per cent at the Big Market. These results show a clear difference between the markets, with higher isolation rates at Sanfil Market and Dambi Market compared to the other markets. Proteus mirabilis was recorded at (17 isolates) representing 32.7 per cent at Al-Afia Market, whilst this bacterium was not isolated from the Asanfil Market; 11 isolates (21 per cent) were recorded in the Al-Kabeer Market; and 12 isolates (23 per cent) in the Dambi Market. The highest rate was observed in the Al-Afia Market, whilst this bacterium was not detected in the Sanfil Market. The presence of Proteus is likely to be linked to contamination of meat and the surrounding environment, particularly where there is a failure to adhere to proper cleaning and disinfection of utensils and surfaces. As for Salmonella spp., 13 isolates (25 per cent) were recorded at Al-Afia Market, 4 isolates (7.7 per cent) at Sanfil Market, (11 isolates) at a rate of 21 per cent at the Grand Market, and (12 isolates) at a rate of 23 per cent at Dambi Market. It is clear that Al-Afia Market had the highest number of Salmonella isolates, due to the fact that the slaughter area is not washed, followed by Dambi Market, whilst Sanfil Market had the lowest number. The high prevalence of Salmonella in some markets indicates the need to tighten health controls on traditionally slaughtered freerange chickens during the slaughter, processing and marketing stages. Salmonella is widespread throughout the markets studied, with a prevalence of 20 per cent. This study did not concur with the findings reported by (Chea et al 2021), whose study—conducted in a province of Cambodia in South-East Asia— indicated a high prevalence of Salmonella in chicken meat sold in markets. Furthermore, reports from the US Department of Agriculture in 2003 stated that the rate of Salmonella contamination in chicken meat reached 42 per cent This discrepancy may be due to the large number of samples taken or differences in climate. As for E. coli not classified as O157, 18 isolates (34 per cent) were recorded at Al-Afia Market, 17 isolates (32 per cent) at Sanfil Market, (11 isolates) at a rate of 21 per cent in the Grand Market, and 4 (4 isolates) at a rate of 7.6 per cent in Dambi Market. A clear increase is observed in Al-Afia Market and Sanfil Market compared with the other markets, which may indicate a higher level of faecal contamination or poor hygiene practices in these markets. The results also showed that Shigella spp. were significant isolates, with 6 isolates (11.5 per cent) recorded at Al-Afia Market, 29 isolates (55.8 per cent) at Sanfil Market, and 33 isolates (32.7 per cent) at Al-Kabeer Market, and 49 isolates (92 per cent) at the Dambi Market. The highest levels were found at the Dambi and Al-Kabir Markets, whilst the lowest level was at the Al-Afia Market. The presence of Shigella in samples of traditionally slaughtered chicken is considered an important indicator of potential faecal contamination and poor hygiene conditions during food handling. As for Staphylococcus spp, (36 isolates) at a rate of 69 per cent in Al-Afia Market, (49 isolates) at a rate of 94 per cent in Sanfil Market and Al-Dambi Market respectively, and (33 isolates) at a rate of 63 per cent in Al-Kabeer Market. Overall, the results indicate that Al-Afia Market exhibits high levels of certain significant isolates, particularly Salmonella Typhi, Salmonella spp, E. coli O157 and Klebsiella

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pneumoniae, whilst Sanfil Market shows a marked increase in E. coli, Shigella spp, Citrobacter freundii and Enterobacter spp. As for the Grand Market, it recorded the highest levels of certain bacteria, particularly Proteus mirabilis, as well as high levels of E. coli O157 and Shigella spp, whilst the Al-Dambi Market had relatively lower levels of most isolates compared with the other markets.

Consequently, the differences between markets may reflect variations in health and environmental conditions, as well as in local chicken slaughter practices and the handling of carcasses, Furthermore, the diversity of bacterial species isolated from the samples confirms that traditionally slaughtered local chicken meat sold in these markets may represent a potential source of pathogenic bacteria, particularly where appropriate storage temperatures, personal hygiene, and the cleanliness of tools and surfaces are not adhered to.

RECOMMENDATIONS

The study recommends the following

1. Separation of the slaughter and processing stages, particularly separating the evisceration process from the other stages of carcass processing, to reduce the likelihood of meat contamination by the contents of the digestive tract.
2. Improving traditional slaughter practices by carrying out slaughter in designated, hygienically prepared areas, providing surfaces and tools that are easy to clean and disinfect, and minimising the carcass's contact with contaminated surfaces.
3. The hygienic disposal of blood, feathers, offal and waste, and ensuring these are not left near slaughter or sales areas, as they may attract insects and rodents and increase the risk of contamination and the transmission of microbes
4. Train staff involved in the slaughter and processing of poultry in the principles of personal hygiene, hand washing, the proper handling of carcasses and offal, and the prevention of practices that lead to the transmission of bacterial contaminants.
5. Clean and disinfect tools and surfaces regularly, particularly knives, chopping boards and meat storage containers, using clean water that is fit for food use.
6. Ensure a continuous supply of clean water at slaughter and processing premises, and use it to wash equipment, surfaces and workers' hands.
7. Prevent the slaughter of sick poultry; ensure that birds undergo veterinary inspection before and after slaughter; and exclude carcasses unfit for human consumption.
8. Prevent cross-contamination by separating raw chicken from ready-toeat food, and avoid using the same utensils without proper cleaning and disinfection.
9. Strengthening health and veterinary controls at markets and traditional slaughter sites through regular inspection visits, and monitoring compliance with health requirements.
10. Carry out periodic microbiological tests on chicken meat to detect pathogenic bacteria, particularly Salmonella spp., Escherichia coli, Staphylococcus spp. and other foodborne pathogens of significance.
11. Establish programmes to monitor bacterial resistance to antibiotics in chicken isolates, particularly where high rates of resistance are observed, and link the results of this monitoring to policies on the prudent use of antibiotics in poultry.
12. Encourage future studies covering a wider range of markets and slaughterhouses, whilst examining factors associated with bacterial contamination and antibiotic resistance, thereby helping health authorities to develop more targeted prevention and control programmes.

Figure 1

Figure 2

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Figure 3

Figure 4

Figure 5

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