Prevalence of Foodborne Microbial Pathogens in Raw Food Products around Maasai Mara University, Narok County, Kenya

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ABSTRACT

Foodborne diseases remain a major global public health challenge, with raw food products serving as key vehicles for transmission of microbial pathogens. This study determined the prevalence of foodborne microbial pathogens in raw food products sold around Maasai Mara University, Narok County, Kenya. A cross-sectional laboratory-based study design was used, involving collection of 120 raw food samples comprising beef, chicken, milk, and vegetables. Standard microbiological methods were applied for isolation and identification of Escherichia coli, Salmonella spp., Staphylococcus aureus, and Campylobacter spp., while antimicrobial susceptibility testing was conducted using the Kirby-Bauer disc diffusion method following CLSI guidelines. Overall, 69.2% of samples were contaminated with at least one foodborne pathogen. Escherichia coli was the most frequently isolated organism (29.2%), followed by Salmonella spp. (17.5%), Staphylococcus aureus (15.0%), and Campylobacter spp. (7.5%). Chicken (90.0%) and beef (80.0%) exhibited higher contamination rates compared to milk (60.0%) and vegetables (46.7%). A significant association was observed between food type and pathogen prevalence ($\chi^2 = 16.06$, $p = 0.0011$). Logistic regression analysis identified lack of refrigeration, inadequate hand hygiene, and exposure of food to dust as significant risk factors for contamination ($p < 0.05$). Antimicrobial susceptibility testing revealed high resistance to ampicillin and tetracycline, while ciprofloxacin and gentamicin remained largely effective against most isolates. The study concludes that raw food products sold around Maasai Mara University are highly contaminated with foodborne pathogens, posing a significant public health risk. Strengthening food safety practices, improving hygiene standards, and enhancing antimicrobial stewardship are recommended to reduce foodborne disease transmission in the study area.

Keywords: - Foodborne pathogens, Raw food products, Microbial contamination, Antimicrobial resistance, Maasai Mara University

INTRODUCTION

Background of the Study

Foodborne diseases remain a major public health challenge globally, affecting millions of people annually and contributing substantially to morbidity, mortality, and economic losses. The World Health Organization (WHO) estimated that approximately 600 million people fall ill each year following consumption of contaminated food, resulting in nearly 420,000 deaths worldwide [1]. Food contamination can occur at any point along the food production chain, including production, processing, transportation, storage, distribution, and preparation. Raw food products are particularly vulnerable to microbial contamination because they often bypass thermal processing steps capable of eliminating pathogenic microorganisms [2].

Foodborne microbial pathogens comprise a diverse group of bacteria, viruses, fungi, and parasites that cause illness in humans. Among bacterial pathogens, Salmonella spp., Escherichia coli, Staphylococcus aureus, Campylobacter spp., Listeria monocytogenes, and Shigella spp. are among the most frequently implicated in

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foodborne disease outbreaks worldwide [3]. These microorganisms contaminate food products through various pathways including contaminated water, soil, animal feces, poor hygienic practices during handling, and inadequate storage conditions [4].

Raw food products such as meat, milk, fruits, vegetables, fish, and poultry are important vehicles for the transmission of foodborne pathogens. Fresh produce may become contaminated through irrigation with contaminated water, use of untreated animal manure, or improper handling during harvesting and marketing. Similarly, meat and dairy products may acquire microbial contaminants during slaughter, processing, transportation, and retail handling [5]. Consumption of contaminated food has been associated with gastrointestinal infections characterized by diarrhea, vomiting, abdominal pain, fever, and in severe cases systemic illness and death, particularly among vulnerable populations including children, pregnant women, the elderly, and immunocompromised individuals [6].

Globally, Salmonella spp. and pathogenic E. coli strains have remained among the leading causes of foodborne illness. Salmonella infections are commonly associated with poultry, beef, eggs, and fresh produce, while pathogenic E. coli strains are frequently isolated from meat products, vegetables, and unpasteurized dairy products [7]. Likewise, Staphylococcus aureus contamination has often been linked to poor food handling practices, whereas Campylobacter species are commonly associated with poultry products and contaminated water sources [8].

In Africa, foodborne diseases continue to impose a significant burden due to inadequate food safety systems, poor sanitation infrastructure, limited surveillance programs, and weak enforcement of food safety regulations [9]. Rapid urbanization, growth of informal food markets, and increasing demand for fresh and ready-to-eat foods have further heightened the risk of food contamination. Studies conducted in several African countries have reported high prevalence rates of pathogenic microorganisms in raw meat, milk, vegetables, and fish sold in informal markets and retail outlets [10].

In Kenya, foodborne illnesses remain an important public health concern despite efforts to strengthen food safety regulations and surveillance systems. Previous studies have reported contamination of raw meat, milk, vegetables, and street-vended foods with pathogenic bacteria including Salmonella spp., Escherichia coli, Staphylococcus aureus, and Campylobacter spp. [11,12]. Such contamination poses considerable health risks to consumers and undermines efforts aimed at improving food security and public health outcomes.

Narok County is an important livestock- and agriculture-producing region in Kenya. The area surrounding Maasai Mara University hosts numerous food vendors, butcheries, supermarkets, restaurants, and informal food markets that serve students, staff, and the surrounding community. The high demand for food products coupled with varying food handling and storage practices creates conditions that may facilitate microbial contamination. Prior to this study, information regarding the prevalence of foodborne microbial pathogens in raw food products sold within the Maasai Mara University environs was limited. Consequently, this study was conducted to determine the prevalence of foodborne microbial pathogens in selected raw food products sold around Maasai Mara University and to identify factors associated with contamination.

Statement of the Problem

Foodborne diseases continue to pose a major threat to public health globally, with contaminated food responsible for millions of illnesses and thousands of deaths annually [1]. Raw food products are particularly susceptible to microbial contamination because they are exposed to environmental contaminants during production, transportation, storage, and retail handling. Consumption of contaminated foods may result in outbreaks of diseases caused by pathogens such as Salmonella spp., Escherichia coli, Staphylococcus aureus, and Campylobacter spp. [13].

In Kenya, increasing demand for fresh food products has expanded food supply chains and informal food markets. However, inadequate sanitation, poor food handling practices, insufficient cold storage facilities, and limited food safety monitoring continue to contribute to microbial contamination of food products [11,12]. Although several studies have documented the occurrence of foodborne pathogens in different regions of

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Kenya, limited information was available regarding the prevalence of these pathogens in raw food products sold around Maasai Mara University.

The absence of such information hindered evidence-based interventions aimed at improving food safety within the university environment and surrounding communities. Therefore, this study investigated the prevalence of foodborne microbial pathogens in selected raw food products and assessed factors associated with contamination to provide baseline information for food safety management and public health interventions.

Objectives

The study was guided by the following objectives:

General Objective

To investigate the prevalence, distribution, and determinants of foodborne microbial contamination in selected raw food products sold around Maasai Mara University.

Specific Objectives

1. To isolate and identify major foodborne microbial pathogens from selected raw food products sold around Maasai Mara University.
2. To determine the prevalence of foodborne microbial pathogens in different categories of raw food products.
3. To compare the occurrence of microbial pathogens among different food product types.
4. To determine the potential risk factors contributing to microbial contamination of raw food products.

Null Hypotheses

The study tested the following null hypotheses:

1. $H_0$1: There was no significant difference in the prevalence of Salmonella spp. between poultry products and beef products sold around Maasai Mara University.
2. $H_0$2: There was no significant association between the type of raw food product and the prevalence of foodborne microbial pathogens.
3. $H_0$3: The prevalence of Escherichia coli contamination did not differ significantly among different categories of raw food products.
4. $H_0$4: There was no significant association between food handling and storage practices and the occurrence of foodborne microbial pathogens in raw food products.

Significance of the Study

The findings of this study contributed significantly to understanding the microbial safety status of raw food products sold around Maasai Mara University. The study provided critical information for protecting consumer health by identifying potential foodborne microbial hazards associated with the consumption of raw foods. It generated evidence that can be used to strengthen food safety monitoring, inspection, and surveillance programs within the study area and beyond. Additionally, the study identified possible sources and risk factors contributing to food contamination, thereby providing a basis for targeted interventions to reduce foodborne disease risks.

The findings also offered scientific data to support the formulation and implementation of food safety policies, regulations, and public health interventions at both county and national levels. Furthermore, the study

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contributed to ongoing efforts aimed at improving food quality, enhancing consumer confidence in food products, and promoting food security through safer food handling and distribution practices. Finally, the research added to the growing body of scientific knowledge on the occurrence and distribution of foodborne pathogens in Kenya, thereby serving as a valuable reference for future studies and public health initiatives.

Scope of the Study

The study investigated the prevalence of foodborne microbial pathogens in selected raw food products sold around Maasai Mara University in Narok County, Kenya. Samples were collected from local markets, butcheries, supermarkets, and food vendors operating within the study area.

Laboratory analyses involved the isolation, identification, and characterization of major bacterial foodborne pathogens including Salmonella spp., Escherichia coli, Staphylococcus aureus, and Campylobacter spp. Standard microbiological procedures were used to determine the prevalence of these pathogens in different food categories. Additionally, information on food handling, storage, and hygiene practices was collected to assess potential risk factors associated with contamination.

The study was geographically limited to the environs of Maasai Mara University and focused exclusively on food samples. Clinical samples from human patients were not included. The findings provided baseline information on the occurrence and distribution of foodborne microbial pathogens within the local food supply chain and informed recommendations for improving food safety practices.

MATERIALS AND METHODS

Study Area

The study was conducted around Maasai Mara University in Narok Town, Narok County, Kenya. Narok County is in the southern part of Kenya between latitudes 0°50′S and 2°05′S and longitudes 34°45′E and 36°00′E. The area experiences a bimodal rainfall pattern with annual precipitation ranging from 500 mm to 1,800 mm and temperatures ranging from 12°C to 28°C [16]. Maasai Mara University serves a large student and staff population and is surrounded by numerous food outlets including restaurants, butcheries, food stalls, and retail shops. Three major food vending points, namely Gate A Food Stall, Gate C Food Stall, and the Student Centre Food Stall, were selected for sample collection because they serve a large proportion of the university population.

Study Design

A cross-sectional laboratory-based study design was employed to determine the prevalence of foodborne microbial pathogens in raw food products sold around Maasai Mara University. The study involved collection of food samples from selected food outlets, isolation and identification of microbial pathogens, antimicrobial susceptibility testing of bacterial isolates, and statistical analysis of the resulting data [17].

Study Population

The study population comprised raw food products commonly sold and consumed within the university environment. The food categories investigated included raw beef, raw chicken meat, raw milk, and fresh vegetables such as tomatoes, cabbage, kale, spinach, and lettuce. These products were selected because they are among the most frequently consumed foods and have been implicated in foodborne disease transmission globally [18].

Inclusion and Exclusion Criteria

The study focused on raw food products intended for human consumption and commonly sold around Maasai Mara University. These included fresh beef and chicken meat obtained from selected food stalls, unpasteurized raw milk sold within the study area, and fresh vegetables purchased from selected food vending outlets. All

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samples were collected during the study period and transported to the laboratory under recommended cold-chain conditions to preserve their integrity and prevent changes in microbial composition prior to analysis.

The study excluded cooked and processed food products, as well as canned and commercially packaged foods, since the focus was on raw foods intended for human consumption. Food products obtained from locations outside the designated study area were also excluded to ensure consistency and relevance to the study objectives. Additionally, samples exhibiting extensive physical spoilage unrelated to microbial contamination were not considered, as such deterioration could compromise the accuracy of laboratory findings. Samples that were improperly labeled or insufficient in quantity for comprehensive laboratory analysis were likewise excluded from the study.

Sample Size Determination

The sample size was determined using Cochran's formula for prevalence studies [19]:

$n = Z^2P(1-P)/d^2$

Where:

n = required sample size

Z = standard normal deviate corresponding to a 95% confidence interval (1.96)

P = estimated prevalence of foodborne pathogens from previous studies

d = desired level of precision (0.05)

Based on the calculated sample size, a total of 120 food samples were collected proportionately from the selected food categories and sampling sites.

Sample Collection

Food samples were collected aseptically from Gate A Food Stall, Gate C Food Stall, and the Student Centre Food Stall in the vicinity of Maasai Mara University that are frequented by students and members of staff plus the neighboring community. Approximately 250 g of beef and chicken meat were collected in sterile sampling bags. Raw milk samples were collected in sterile screw-capped bottles, while vegetable samples were placed in sterile polyethylene bags. Each sample was labeled with a unique identification code indicating sample type, collection site, and date of collection.

The samples were transported to the microbiology laboratory at the university in insulated cool boxes maintained at 4°C and processed within four hours of collection to minimize microbial changes during transportation [20].

Sample Processing

Upon arrival at the Department of Biological Sciences Laboratory at Maasai Mara University, all samples were processed according to standard microbiological procedures [21]. For meat samples, 25 g of each beef or chicken sample were aseptically weighed and homogenized in 225 mL of Buffered Peptone Water (BPW) to obtain an initial 10^{-1} dilution. Homogenization was carried out using a laboratory stomacher for two minutes to ensure uniform distribution of microorganisms. Milk samples were thoroughly mixed prior to analysis, after which 25 mL of each sample was transferred into 225 mL of Buffered Peptone Water and homogenized. For vegetable samples, 25 g of tissue were aseptically weighed, washed with sterile physiological saline to remove loosely attached debris, and subsequently homogenized in Buffered Peptone Water. Following sample preparation, serial dilutions ranging from 10^{-1} to 10^{-6} were prepared for subsequent microbiological examination.

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Isolation and Identification of Foodborne Pathogens

Isolation and identification of bacterial pathogens were conducted using standard microbiological procedures described by the International Organization for Standardization (ISO) and the Food and Drug Administration Bacteriological Analytical Manual [22,23]. For the isolation of Escherichia coli, aliquots obtained from serially diluted samples were streaked onto MacConkey Agar and incubated aerobically at 37°C for 24 hours. Colonies exhibiting pink coloration due to lactose fermentation were selected and purified on nutrient agar for further identification [22].

For the isolation of Salmonella species, samples were initially enriched in Selenite F Broth and incubated at 37°C for 24 hours. The enriched cultures were subsequently streaked onto Salmonella-Shigella Agar and incubated at 37°C for a further 24 hours. Colonies displaying characteristic black centers resulting from hydrogen sulfide production were presumptively identified as Salmonella species [23].

Isolation of Campylobacter species was performed by culturing samples on Campylobacter Selective Agar supplemented with selective antibiotics. The inoculated media were incubated under microaerophilic conditions at 42°C for 48 hours. Colonies exhibiting characteristic morphology were sub-cultured for purification and confirmation [24].

For the detection of Staphylococcus aureus, samples were inoculated onto Mannitol Salt Agar and incubated at 37°C for 24 hours. Yellow colonies surrounded by yellow zones resulting from mannitol fermentation were presumptively identified as Staphylococcus aureus [21].

Pure bacterial isolates obtained from the various culture media were further characterized using Gram staining according to the method described by Beveridge [25]. Briefly, bacterial smears were prepared on clean microscope slides, heat-fixed, and stained sequentially with crystal violet for one minute and Gram's iodine for one minute. The smears were then decolorized with 95% ethanol for 15 seconds and counterstained with safranin for one minute. After air drying, the stained preparations were examined microscopically under oil immersion using a 100× objective lens. Gram-positive bacteria appeared purple due to retention of the crystal violet–iodine complex, whereas Gram-negative bacteria appeared pink following uptake of the safranin counterstain. These cultural, morphological, and staining characteristics were used to aid the identification and confirmation of bacterial pathogens isolated from the food samples.

Biochemical Characterization

Bacterial isolates were subjected to a series of biochemical tests to confirm their identities following standard microbiological procedures [21]. The indole test was performed using Tryptone broth, and after incubation, Kovac's reagent was added. The formation of a red ring at the surface of the medium was interpreted as a positive reaction, indicating the production of indole. The methyl red test was conducted to determine the ability of isolates to carry out mixed-acid fermentation, with the development of a red coloration following the addition of methyl red reagent indicating a positive result.

The Voges–Proskauer test was used to detect acetoin production as a product of glucose fermentation. A pink to red coloration observed after the addition of the appropriate reagents was considered a positive reaction. Citrate utilization was assessed using Simmons Citrate Agar, where a colour change of the medium from green to blue indicated the ability of the organism to utilize citrate as its sole carbon source and was therefore recorded as a positive result.

In addition to the IMViC tests, other biochemical assays including catalase, coagulase, oxidase, urease, and Triple Sugar Iron (TSI) tests were performed where necessary to provide further confirmation of bacterial identity [21]. The combined results of these biochemical, cultural, and morphological characteristics were used to accurately identify and differentiate the bacterial pathogens isolated from the food samples.

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Antimicrobial Susceptibility Testing

Antimicrobial susceptibility testing of the bacterial isolates was carried out using the Kirby–Bauer disc diffusion method on Mueller–Hinton Agar in accordance with the guidelines of the Clinical and Laboratory Standards Institute (CLSI) [26]. Pure bacterial colonies were first emulsified in sterile physiological saline and adjusted to the turbidity of a 0.5 McFarland standard, corresponding to approximately 1.5×10^8 CFU/mL. A sterile cotton swab was then dipped into the standardized bacterial suspension and used to evenly inoculate the surface of Mueller–Hinton Agar plates to produce a uniform bacterial lawn.

Commercial antibiotic discs representing commonly used antibiotics in both human and veterinary medicine were aseptically placed onto the inoculated agar surface using sterile forceps. The plates were subsequently incubated aerobically at 37°C for 18–24 hours to allow bacterial growth and interaction with the antimicrobial agents. Following incubation, the diameters of the zones of inhibition surrounding each antibiotic disc were measured in millimeters using a Vernier caliper. The susceptibility profiles of the isolates were then interpreted as susceptible, intermediate, or resistant based on the CLSI interpretive breakpoints [26]. The results provided information on the antimicrobial resistance patterns of bacterial pathogens isolated from the food samples and contributed to the assessment of potential public health risks associated with antimicrobial-resistant foodborne bacteria.

Quality Control

Quality control procedures were implemented throughout the study. Culture media were prepared according to manufacturers' instructions and sterility was confirmed before use. Standard reference strains including Escherichia coli ATCC 25922, Staphylococcus aureus ATCC 25923, and Salmonella Typhimurium ATCC 14028 were used as quality control organisms during pathogen isolation, identification, antimicrobial susceptibility testing [26].

Data Management and Statistical Analysis

Data obtained from laboratory analyses and observational checklists were entered into Microsoft Excel 2021 and exported to Statistical Package for Social Sciences (SPSS) version 26.0 for analysis [27]. Descriptive statistics including frequencies, percentages, means, and standard deviations were used to summarize pathogen prevalence and contamination levels. Prevalence was calculated as: Prevalence (%) = (Number of positive samples / Total number of samples examined) × 100. Chi-square (χ^2) tests were used to determine associations between food type and pathogen occurrence. One-way analysis of variance (ANOVA) was used to compare mean contamination levels among food categories. Logistic regression analysis was performed to identify factors associated with food contamination. Statistical significance was determined at $P < 0.05$ [28].

Ethical Considerations

Ethical approval for the study was obtained from the relevant institutional authorities of Maasai Mara University. Permission to collect food samples was obtained from food vendors and stall operators before commencement of sampling. Confidentiality was maintained throughout the study by assigning coded identifiers to vendors and sampling locations. Laboratory procedures complied with accepted biosafety and microbiological handling standards [29].

RESULTS AND DISCUSSION

Distribution of Food Samples Collected

A total of 120 raw food samples comprising beef, chicken, milk, and vegetables were collected from selected food vending outlets around Maasai Mara University. Each food category contributed 30 samples, representing 25% of the total sample size (Table 1).

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Table 1. Distribution of Food Samples by Type

Food Type	**Number of Samples (n)**	**Percentage (%)**
Beef	30	25.0
Chicken	30	25.0
Milk	30	25.0
Vegetables	30	25.0
Total	**120**	**100.0**

The equal representation of food categories facilitated comparative assessment of contamination patterns among different food products.

Isolation and Identification of Foodborne Pathogens

Out of the 120 food samples analyzed, 83 (69.2%) were positive for at least one foodborne bacterial pathogen, while 37 (30.8%) showed no detectable pathogen. Four major bacterial pathogens were isolated, namely Escherichia coli, Salmonella spp., Staphylococcus aureus, and Campylobacter spp. (Table 2).

Table 2. Prevalence of Foodborne Pathogens Isolated from Raw Food Products

Pathogen	**Positive Samples (n)**	**Prevalence (%)**	**χ^2**	**df**	**p value**
Escherichia coli	35	29.2	23.34	4	0.00011***
Salmonella spp.	21	17.5			
Staphylococcus aureus	18	15.0			
Campylobacter spp.	9	7.5			
No pathogen detected	37	30.8			
Total	**120**	**100**			

A Chi-square goodness-of-fit test showed a statistically significant difference in pathogen distribution (χ^2 = 23.34, df = 4, $p < 0.001$), indicating that contamination was not uniformly distributed among pathogen categories.

The predominance of Escherichia coli suggests widespread fecal contamination within the food supply chain. Similar findings have been reported in Kenya and other developing countries where inadequate sanitation, poor personal hygiene, and contaminated water are major contributors to food contamination [30,31]. The occurrence of Salmonella spp. further indicates contamination during slaughtering, processing, transportation, or marketing of food products [34]. Isolation of Staphylococcus aureus points to contamination arising from food handlers, given that the organism commonly colonizes human skin and nasal passages [35]. Although Campylobacter spp. exhibited the lowest prevalence, its detection remains epidemiologically significant because of its low infectious dose and its established role in bacterial gastroenteritis worldwide [36].

Prevalence of Pathogens in Different Food Products

The prevalence of contamination varied significantly across food categories (Table 3). Chicken samples exhibited the highest contamination rate (90.0%), followed by beef (80.0%), milk (60.0%), and vegetables (46.7%).

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Table 3. Prevalence of Pathogens by Food Type

Food Type	Samples Tested	Positive Samples	Prevalence (%)	χ^2	df	p-value
Beef	30	24	80.0	16.06	3	0.0011***
Chicken	30	27	90.0			
Milk	30	18	60.0			
Vegetables	30	14	46.7			
Total	**120**	**83**	**69.2**			

The Chi-square test revealed a statistically significant association between food type and pathogen occurrence ($\chi^2 = 16.06$, df = 3, p = 0.0011), indicating that contamination levels differed significantly among food categories.

The significantly higher contamination observed in chicken and beef may be attributed to contamination during slaughter, dressing, transportation, storage, and retail handling [37]. Poultry products are particularly vulnerable because intestinal contents may contaminate carcasses during evisceration. Milk contamination may be associated with poor milking hygiene, contaminated containers, and lack of pasteurization [38]. Vegetable contamination is likely linked to irrigation using contaminated water, application of untreated manure, and unhygienic handling during marketing [39]. These findings demonstrate that animal-derived foods constitute a greater microbial risk than plant-derived foods within the study area.

Distribution of Individual Pathogens Across Food Categories

The distribution of specific pathogens among food categories is presented in Table 4.

Table 4. Distribution of Individual Pathogens Across Food Categories

Pathogen	Beef n (%)	Chicken n (%)	Milk n (%)	Vegetables n (%)	Total	χ^2	df	p-value
E. coli	9 (30.0)	12 (40.0)	5 (16.7)	9 (30.0)	35	15.88	9	0.069^{NS}
Salmonella spp.	6 (20.0)	10 (33.3)	2 (6.7)	3 (10.0)	21			
S. aureus	5 (16.7)	3 (10.0)	8 (26.7)	2 (6.7)	18			
Campylobacter spp.	4 (13.3)	5 (16.7)	0 (0.0)	0 (0.0)	9			
Total	**24**	**30**	**15**	**14**	**83**			

Although E. coli was the dominant pathogen across all food types, statistical analysis revealed no significant association between pathogen type and food category ($\chi^2 = 15.88$, df = 9, p = 0.069).

The predominance of E. coli in chicken and beef supports the role of livestock as important reservoirs of fecal contamination [33]. The high occurrence of Salmonella spp. in chicken samples is consistent with previous studies identifying poultry as a major source of human salmonellosis [34]. The predominance of Staphylococcus aureus in milk suggests contamination during milking, handling, storage, or distribution [35]. Isolation of Campylobacter spp. exclusively from meat products agrees with reports that poultry and livestock constitute the principal reservoirs of this pathogen [36].

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Despite variations in prevalence, the lack of statistical significance suggests that contamination pathways overlap considerably across food products, exposing consumers to multiple foodborne hazards.

Risk Factors Associated with Food Contamination

Several food handling practices associated with contamination were identified among vendors (Table 5).

Table 5. Food Handling Practices Observed Among Vendors

Risk Factor	Frequency (n)	Percentage (%)	Logistic Regression Analysis of Risk Factors		
			Odds Ratio (OR)	95% CI	P-value
No refrigeration	19	63.3	3.42	1.45–8.08	0.004*
Inadequate hand washing	22	73.3	2.91	1.18–7.16	0.018*
Exposure of food to dust	18	60.0	2.36	1.01–5.52	0.046*
Lack of protective clothing	15	50.0	1.74	0.73–4.15	0.210^{NS}

Lack of refrigeration emerged as the strongest predictor of contamination, with vendors lacking refrigeration facilities being over three times more likely to sell contaminated food products. Temperature abuse is widely recognized as a critical factor promoting bacterial growth and multiplication in perishable foods [42].

Inadequate hand washing was also significantly associated with contamination. Poor hand hygiene facilitates transfer of microorganisms from handlers to food and remains one of the most common causes of foodborne disease outbreaks [41]. Similarly, exposure of food to dust significantly increased contamination risk, reflecting the vulnerability of open-air vending systems to environmental pollutants [43].

Although lack of protective clothing increased contamination risk, the relationship was not statistically significant, suggesting that direct hygiene practices and environmental conditions may have a greater influence on microbial contamination than protective garments alone.

Antimicrobial Susceptibility Profiles of Isolated Pathogens

The antimicrobial resistance profiles of the isolated foodborne pathogens are presented in Table 6.

Table 6. Antibiotic Resistance Patterns of Isolated Pathogens (% Resistant)

Antibiotic	E. coli	Salmonella	S. aureus	Campylobacter
Ampicillin	68.6	61.9	55.6	44.4
Tetracycline	57.1	52.4	61.1	55.6
Ciprofloxacin	11.4	9.5	5.6	11.1
Gentamicin	8.6	4.8	5.6	0
Chloramphenicol	20.0	14.3	16.7	11.1

High resistance levels to ampicillin and tetracycline were observed across all bacterial isolates. These findings are consistent with global reports showing increasing resistance among foodborne pathogens due to widespread and often inappropriate antibiotic use in livestock production and human medicine [44,46].

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Conversely, ciprofloxacin and gentamicin remained highly effective against most isolates. The relatively low resistance rates suggest that these antibiotics continue to retain therapeutic value for the treatment of foodborne bacterial infections. However, the emergence of resistance even at low levels warrants continuous surveillance because resistance can spread rapidly through bacterial populations [45].

The detection of antimicrobial-resistant foodborne pathogens has serious public health implications, as resistant infections are associated with prolonged illness, increased treatment costs, and reduced therapeutic options [47].

Public Health Implications and Comparison with Previous Studies

The high prevalence of foodborne pathogens observed in this study indicates substantial exposure of consumers to microbial hazards through raw food products sold around Maasai Mara University. The presence of multidrug-resistant organisms further increases the risk posed by foodborne infections and complicates treatment outcomes [47]. The findings are consistent with studies conducted in Kenya, Uganda, and Nigeria, which reported high prevalence rates of E. coli, Salmonella, and Staphylococcus aureus in raw foods sold in informal markets [49,50]. However, the contamination levels observed in the present study were generally higher than those reported in some urban retail environments, likely reflecting differences in food handling practices, infrastructure, sanitation conditions, and regulatory oversight. Overall, the results demonstrate that raw food products sold around Maasai Mara University constitute a potential public health risk. Strengthening food safety regulations, improving vendor hygiene practices, enhancing food storage conditions, and promoting antimicrobial stewardship are essential interventions for reducing contamination and safeguarding consumer health [48].

Summary

The study demonstrated a high prevalence of foodborne pathogens in raw food products sold around Maasai Mara University, with Escherichia coli being the most frequently isolated organism. Contamination varied significantly among food categories, with chicken and beef presenting the highest risk. Poor refrigeration, inadequate hand hygiene, and exposure to dust were identified as significant determinants of contamination. Furthermore, high levels of resistance to ampicillin and tetracycline were observed among the isolated pathogens. These findings underscore the need for enhanced food safety management and continuous surveillance of foodborne pathogens and antimicrobial resistance in the study area.

The levels of microbial contamination observed in the present study are comparable to findings reported in other parts of Kenya. Studies conducted in Nairobi and Kisumu have similarly documented substantial bacterial contamination of raw foods, particularly meat, milk, and fresh vegetables sold through informal markets and food vending outlets. Previous investigations in these urban settings reported the frequent occurrence of coliform bacteria, Escherichia coli, Salmonella spp., and Staphylococcus aureus, with contamination levels attributed to poor hygiene practices, inadequate cold-chain facilities, and cross-contamination during handling and transportation. The similarities between the present findings and those reported elsewhere in Kenya suggest that foodborne microbial contamination remains a widespread public health challenge across diverse geographical settings, underscoring the need for strengthened food safety interventions, routine surveillance, and enhanced public health education throughout the country [52, 53].

CONCLUSIONS

This study established the prevalence, distribution, and associated risk factors of foodborne microbial pathogens in raw food products sold around Maasai Mara University, Narok County, Kenya. The findings demonstrate that a substantial proportion of raw food products are contaminated, with an overall prevalence of 69.2%, confirming widespread microbial contamination within the local food supply chain and a significant public health risk to consumers.

The study successfully isolated and identified four key foodborne bacterial pathogens, namely Escherichia coli, Salmonella spp., Staphylococcus aureus, and Campylobacter spp. Among these, E. coli was the most

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prevalent organism, indicating probable fecal contamination arising from poor hygiene practices, contaminated water sources, and inadequate sanitation during food handling and processing.

Chicken and beef products recorded the highest contamination rates compared to milk and vegetables, demonstrating that animal-derived food products are the principal reservoirs of foodborne pathogens in the study area. Statistical analysis confirmed a significant association between food type and pathogen occurrence ($\chi^2 = 16.06$, $p = 0.0011$), indicating that the likelihood of contamination varies significantly across food categories and is influenced by handling and storage conditions.

Risk factor analysis further revealed that inadequate hand hygiene, lack of refrigeration, and exposure of food to environmental contaminants were significant predictors of microbial contamination. These findings underscore the critical role of food handling practices in determining food safety outcomes in informal and semi-formal food vending environments around the university.

The study also revealed high levels of antimicrobial resistance among the isolated pathogens, particularly to ampicillin and tetracycline, while ciprofloxacin and gentamicin remained relatively effective. This pattern suggests emerging antimicrobial resistance likely linked to misuse of antibiotics in human and animal production systems.

RECOMMENDATIONS

Based on the findings of this study, several key recommendations are proposed to improve food safety and reduce the risk of foodborne illnesses in the study area. Food vendors around Maasai Mara University should be routinely trained on good hygiene practices, with emphasis on proper handwashing, safe food handling techniques, and prevention of cross-contamination during food preparation and storage. In addition, county public health authorities should strengthen routine inspection and enforcement of existing food safety regulations across all food vending outlets to ensure compliance with established standards.

To further minimize microbial contamination, particularly in perishable products such as meat and milk, effective cold-chain systems should be implemented and consistently maintained to inhibit bacterial growth during storage and transportation. Public health education initiatives should also be intensified to raise awareness among consumers about the risks associated with the consumption of raw or improperly handled food products, thereby promoting safer food choices.

Moreover, routine microbiological surveillance of food products should be institutionalized to monitor contamination trends and detect emerging foodborne pathogens in a timely manner. At the same time, antimicrobial stewardship programs should be strengthened in both human and veterinary health sectors to help curb the emergence and spread of antimicrobial-resistant foodborne organisms. Finally, further research is recommended to broaden the scope of investigation to include viral and parasitic pathogens, as well as molecular characterization techniques, to provide a more comprehensive understanding of foodborne disease risks in the study area.

Study Limitations

This study provides important baseline information on the microbiological quality and antimicrobial resistance patterns of selected food products sold around Maasai Mara University. However, several limitations should be considered when interpreting the findings. First, the investigation focused primarily on bacterial pathogens and indicator organisms and therefore did not include the detection or characterization of viral and parasitic foodborne pathogens. Consequently, the overall burden of foodborne contamination may have been underestimated, as viruses such as norovirus and hepatitis A virus, as well as parasites including Giardia, Cryptosporidium, and Taenia species, are recognized contributors to foodborne disease worldwide.

Second, identification of bacterial isolates was based on conventional culture, morphological, and biochemical methods. Molecular techniques such as polymerase chain reaction (PCR), gene sequencing, or whole-genome analysis were not employed to confirm the identity of the isolates. The absence of molecular confirmation may

have limited the precision of pathogen identification and prevented characterization of specific virulence genes, resistance determinants, and genetic relationships among isolates.

Third, antimicrobial resistance profiling was conducted using phenotypic susceptibility testing only. Therefore, the underlying genetic mechanisms responsible for the observed resistance patterns could not be determined. Additionally, the study was limited to selected food types and sampling locations within the university environment and its immediate surroundings, which may limit the generalizability of the findings to other settings.

Despite these limitations, the study offers valuable insights into the microbiological safety of foods consumed by students and the surrounding community and provides an important foundation for future surveillance and risk assessment studies incorporating molecular, viral, and parasitological analyses.

Availability of Data

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request. The raw laboratory records, questionnaire responses, and statistical outputs are stored securely in the Department of Biological Sciences, Maasai Mara University.

Disclaimer

The interpretations and conclusions presented in this study are solely those of the authors and do not necessarily reflect the official position of Maasai Mara University or any affiliated institution. The study was conducted for academic purposes, and any errors or omissions remain the responsibility of the author [51].

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