PRESENCE OF *SALMONELLA*, *STAPHYLOCOCCUS AUREUS* AND *ESCHERICHIA COLI* SPECIES IN READY TO EAT FOODS SOLD IN OMDURMAN CITY, KHARTOUM STATE

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Short running title: BACTERIAL CONTAMINATION OF READY-TO-EAT FOODS FOR SALE IN MARKETS

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Abstract. As living conditions have changed and women are working longer hours, food consumption has changed as well. Ready-to-eat foods are now enjoyed outside the home in a range of locations, such as cafeterias, restaurants, and kiosks, depending on the consumer's financial capacity. Determining the prevalence of microbiological contamination in various types of ready-to-eat food in various Khartoum State establishments that supply such food was the aim of this study. As part of a cross-sectional study, 310 samples of ready-to-eat food were chosen at random from three distinct types of establishments: cafeterias, restaurants, and kiosks. The samples were analyzed between June 2019 and May 2020. These samplings included a variety of foods, including red meat, white meat, processed meat, lamb offal, falafel, bread, pastries, sweets, juices, kisra, pies, green salad, mayonnaise, fried potatoes, fried eggs, ice cream, rice, madida, and appetizers. The data showed that the kiosks had the highest incidence of bacterial infections, at 53.8%, and that 30.7% of the samples tested positive. and the lowest proportion of contamination (16.9%) was found in restaurants. Additionally, the results showed that *Salmonella* bacteria were found in 42% of all positive samples, followed closely by *Staphylococcus aureus* (41%), *and E. coli* (16.8%). This could be brought on by unkempt store environments and poor personal hygiene. Therefore, we suggest providing health awareness materials to clients and suppliers, maintaining proper cleanliness, and having the health office monitor the situation.

Keywords: contamination, foods, microbiological, markets, Omdurman

INTRODUCTION

The number of meals prepared outside the home has increased due to the increasing number of people spending time outside the home and the entry of women into the workforce. This has led to an increase in commercial food services in various locations, which in turn has increased attention to the hygiene of these foods (Saleh *et al* 2024). As a result, convenience foods have replaced home-cooked meals, which are usually complete, professionally prepared meals. As a result, more new food products are available on the market, designed using innovative technologies (Cui *et al*, 2024). Consuming tainted food might result in bacterial illnesses. In the intestines, the bacteria keep growing, resulting in an infection that makes you sick. Salmonella, E. Coli, Staphylococcus aureus, and other bacteria are examples. A major public health concern in both industrialized and developing nations, foodborne infections cover a broad spectrum of ailments (Ebrahimi et al, 2024). Many developing nations also struggle to enforce food safety laws and regulation and occasionally they lack efficient methods for tracking and identifying foodborne illnesses (Unnevehr and Laurian, 2022). In addition to providing the body with nutrients, food also harbors numerous bacteria that can lead to illnesses and food poisoning. Typically, contamination of food occurs through soil, water, sewage, and air, or during raw material harvesting, storage, transportation, handling, and processing (Silaen and Srinatalia, 2024). One of the four main causes of diarrheal disease is salmonella. With a reported incidence rate of 20 cases per 100,000 people, it is currently the second most dangerous disease in the European Union after campylobacter, causing food poisoning. Furthermore, many foodborne salmonellosis outbreaks (72.4%) are caused by Salmonella enterica (Unnevehr and Laurian, 2022). According to reports from the Food and Agriculture Organization and the World Health Organization, about one-

third of people in affluent nations may contract foodborne illnesses annually; in developing nations, this number is higher because of inadequate early warning systems (Raffo *et al*, 2021). Food plays a major role in human health and is deemed safe and healthy when it is free of health risks that could result in foodborne illness and its negative effects on both health and the economy (Straif et al, 2023). Food is considered spoiled when bacteria or other harmful germs enter the food, making it unfit for consumption ((Rawat and Seema,2015) . When bacteria or other dangerous microbes infiltrate food, it is referred to as biological contamination. Depending on the food type, some foods are more vulnerable than others, and it is one of the most prevalent forms of food poisoning, food spoilage, and foodborne illnesses (Jeff *et al*, 2023). When microorganisms come into touch with soil, water, equipment, people, animals, or insects, they can contaminate foods or surrounding surfaces. The most frequent microbial vectors for food are still contaminated hands and unclean surfaces (Dhaliwal et al, 2025). The severity of a salmonella infection depends on the strain causing the infection and the host's immune status. Groups most at risk from salmonella include children under five, the elderly, and those with weakened immune systems (Bjelland et al, 2020). *Salmonellosis* is characterized by gastroenteritis, headache, fever, and muscle discomfort, along with nausea, vomiting, cramping in the abdomen, and bloody diarrhea. Dehydration can occasionally result from fluid loss, particularly in the most susceptible populations (Zizza et al, 2024). In healthy humans and animals, E. coli usually lives in the intestines. The most frequent sources of E. coli contamination include raw or undercooked meat, ground beef, raw milk, and tainted fresh produce. Consequently, handling raw meat improperly and with poor hygiene, such as letting it come into contact with other foods or surfaces, can increase the risk (Cui et al, 2024). Many E. coli strains are either benign or only produce mild

diarrhea. However, some strains, including E. coli O157:H7, can result in vomiting, bloody diarrhea, and severe intestinal cramps (Basavaraju and Gunashree, 2022). Toxins produced by Staphylococcus can result in staphylococcal food poisoning. This frequently happens because of cross-contamination between raw and cooked meals or inadequate personal hygiene. At room temperature, these bacteria are most prevalent in food and create intestinal toxins that cause illness and stay on the food until it is cooked (Jimoh et al, 2022). In addition to their environmental health responsibilities in their assigned regions, public health professionals and their assistants oversee food inspection in the Republic of Sudan through the Federal Ministry of Health's Environmental Health and Food Control Department's Food Control Division. Food must be inspected at every stage of production by public health professionals and employees of other licensed establishments (Bell and Heather, 1999, Leprêtre et al, 2017).

Given that Sudan is regarded as one of the under developing countries , the proliferation of selling food that does not adhere to standards which may cause some issues with contamination on foods. Determining the amount of bacterial contamination in various food service establishments regarding Salmonella, Staphylococcus aureus, and Escherichia coli as examples of coliform bacteria was, thus, the objective of this investigation. to assist health policymakers in enacting stringent intervention measures to safeguard consumers

MATERIALS AND METHODS

Study design and setting

Khartoum is the capital of Sudan and includes three cities located in the heart of Sudan at the confluence of the White and Blue Niles. The state lies between longitudes 31.5 and 34 degrees east, and latitudes 15 and 16 degrees north. It is

bordered by River Nile State to the northeast, Northern State to the northwest, Kassala, Gedaref, Gezira, and White Nile states to the east and southeast, and North Kordofan State to the west. It is home to approximately 8 million people, representing nearly a quarter of Sudan's population (Sammani et al, 2019). There is a difference between the three types of market places targeted for research, such as health obligations, buildings, and other things that contribute to the health of foods (Leung et al, 2021).

Sample collection and analysis

Three categories of establishments, restaurants, cafeterias and kiosks – serving ready-to-eat foods in Khartoum State were selected; These establishments differ in their design and method of providing food services. The samples were collected and analyzed between June 2019 and May 2020. Each meal type was given a specific number between 1 to 20 along with the sort of site from where the samples were taken, and the samples were then put in sterile containers. After that, they were gathered in sterile containers made specifically for this kind of sample and brought to the lab in less than an hour. The first stage in the analytical process was to dilute food samples by mixing one gram with ten milliliters of sterile distilled water. After that, 4.5 ml of MacConkey broth was added to a 0.5 ml aliquot, and the mixture was cultured for 4–5 hours. The developing germs were then cultivated on electrolyte-deficient cysteine-lactose agar after being detected as turbidity in the broth, then incubated for 24 hours at 37°C. Using the Gram stain, motility test, oxidase test, and culturing characteristics on dehydro-electrolyte cysteine lactose agar, such as opaque yellow colonies of Staphylococcus aureus and yellow colonies of lactose-fermenting Escherichia coli (Harrigan and Wilkie1998) .

Salmonella colonies typically appear colourless and transparent, often with a black centre in (SS -Salmonella-Shigella) agar (Salih *et al* ,2025) .

RESULTS

This study shows the results obtained from the analysis of foods collected from cafeterias, restaurants, and kiosks in the city of Omdurman, Khartoum State, to examine the bacterial presence. The number of samples collected reached 310 samples of different types, as shown in Table 1. This study also shows that the highest presence of bacteria was 53.8% of the total samples collected from kiosks, and the lowest was in the samples collected from restaurants (16.9%) (Table 2). Table 3 shows the bacterial presence and its types in the samples collected from cafeterias, where the most isolated bacteria was *Salmonella* spp, which was 14 samples out of a total of 102, followed by Oreos, then Escherichia coli. The results also show that the highest presence of bacteria in the samples that were taken from the kiosks was the *Staphylococcus aureus* bacteria, which was present in 17 samples out of a total of 78 samples (Table 4). *Staphylococcus aureus* and *Salmonella* spp bacteria were found in equal proportions in the samples collected from the restaurant, with 10 samples each (Table 5). The analysis of the food samples also shows that the total number of positive samples containing *Salmonella* was 40 samples from a group of 95 positive samples, the majority of which were from the samples collected from the kiosks (16 samples) (Table 6). Table 7 also shows the number of 16 *Escherichia coli* isolate samples out of all the positive, and 9 of them were found in the samples taken from the kiosks. The number of positive samples for Staphylococcus *aureus* bacteria, which was 39 samples, the majority of which were found in samples taken from kiosks (17 samples) (Table 8). This result shows the variation in the presence of different types and numbers of bacteria, as the

highest percentage of positive samples was from appetizers, at 66% of the total samples from which they were taken, then lamb entrails, 60%, followed by cassava, 57%, followed by salads, 43%, then processed meat, 36%, then red meat, 23%.

DISCUSSION

There are many diseases that can be spread through food, and the results of this study, which included 310 samples of foods commonly used in Sudan from different market locations in the city of Omdurman, The results showed a high level of bacterial contamination in 95 samples out of 310 or 30.7%. The highest rate of bacterial isolation was from kiosk locations, at 53.8%, which is like one of the other studies in which the isolation rate was 89% because of not tracking health obligations (El Tayeb et al, 2020) and comparable to another study carried out in Nigeria, which found that the food sold in unhygienic locations, such as kiosks, were the most infected with *E. coli* (Fang et al, 2002). All bacteria isolated from food samples in this study cause foodborne diseases, where the highest percentage of presence was for Salmonella bacteria, 13%, *then Staphylococcus aureus,* 12.6%, then Escherichia coli, 5.2%. This study indicates insufficient cooking, improper food handling, processing errors, or secondary contamination, especially the presence of *E. coli*, which often indicates poor personal hygiene. As indicated by other studies conducted for the same objectives (Umoh et al, 1999). Additionally, this study revealed that 10% of the germs recovered were from red meat and 15% were from processed meats. which is comparable to another study that examined comparable food samples like liver, beef, and kofta. which revealed that the percentage of isolated bacteria varied from 16.7% to 33.3% (Sylvia et al, 2015). The high percentage of bacteria isolated in this study is very similar to the results of another study that found coliform bacteria in 53% of all food samples which were

identified in red and white meat, and 9.2% of the samples contained Escherichia coli bacteria (Ahmed et al, 2021). According to this finding, lamb intestines contained the highest percentage of Escherichia bacteria (31.3%). Given that this kind of meat requires careful preparation, this could be the result of unhealthy handling or poor cooking. The findings also revealed a significant number of bacteria isolated on salads (43.9%), which is comparable to another study where 50–66.7% of positive samples came from restaurant salads (Kaneko et al, 1991). Based on these results, we conclude that the most contaminated meat products are those made from sheep entrails, and the presence of Staphylococcus aureus found in prepared foods often indicates contamination after cooking, as it can thrive at room temperature (Olaimat et al, 2021) as they contained a variety of bacteria, the presence of which varied according to the food ingredients. We conclude that the presence of bacteria varies depending on the type of food and the places where it is sold, as uncooked meals, including green salads, red and processed meat, contain the highest percentage of coliforms. We also occlude that inappropriate buildings that can expose food sales sites to contaminants such as the highest percentage of bacterial isolation in the samples taken from kiosks. The lowest presence of bacteria was in restaurants whose premises adhered to food safety regulations. Therefore, to help stop the spread of microbes, it is recommended to commit to conducting more research to determine the source and routes of transmission of microbes to ready-to-eat foods and to enhance the microbiological safety of ready-to-eat foods through the strict use of preventive measures and the establishment of mandatory standards. Therefore, we recommend strict application of preventive measures and implementation of mandatory standards by health officials to improve Microbiological safety of ready-to-eat foods.

Table 1

Numbers of samples collected from each Sites

Types of food	Kiosk	Cafeteria	Restaurants	Total
Red meat	14	11	18	43
White meat	3	5	8	16
Processed meats	2	14	14	30
Lamb entrails	7	0	3	10
Agashi	5	2	4	11
Falafel	3	10	8	21
Bread	2	6	4	12
Sweets	1	5	8	14
Juices	0	9	7	16
Kesra	15	2	4	21
Porridge	3	3	5	11
Pies	0	5	5	10
Green salad	4	5	5	14
Mayonnaise	0	6	6	12
Chips	1	6	6	13
Fried egg	2	3	1	6
Ice cream	0	5	7	12
Rice	3	0	9	12
Madida	8	2	4	14
Appetizers	5	3	4	12
Total	78	102	130	310

Table 2

Distribution of the percentage of bacteria isolated from foods according to sampling sites in the three types of sales outlets in Khartoum city

Ready-to-eat sales sites	Total number of food samples	Frequencies positive *Salmonella* spp, *n* (%)	Frequencies positive *Escherichia coli* *n* (%)	Frequencies positive *Staphylococcus aureus* *n* (%)	Total of positives samples at all sites *n* (%)
Kiosk	78	16 (20.5)	9 (11.5)	17 (21.8)	42 (53.84)
Cafeteria	102	14 (13.7)	5 (4.9)	12 (11.8)	31 (30.39)
Restaurant	130	10 (8.5)	2 (1.5)	10 (7.7)	22 (16.92)
Total	310	40 (12.9)	16 (5.2)	39 (12.6)	95 (30.7)

Table 3

No	Types of food	Cafeteria total of samples	*Staphylococcus* positive samples	*Escherichia Coli Species* positive samples	*Salmonella,spp* positive samples	Overall frequency of positive sample *N(%)*
1.	Red meat	11	1	0	0	1(.98)
2.	White meat	5	1	0	0	1(.98)
3.	processed meats	14	2	1	1	4(3.9)
4.	Lamb entrails	0	0	0	0	0(0.00)
5.	Agashi	2	1	0	0	1(.98)
6.	Falafel	10	1	1	1	3(2.94)
7.	bread	6	0	0	1	1(.98)
8.	sweets	5	1	0	0	1(.98)
9.	juices	9	1	0	1	2(1.96)
10	kisra	2	0	0	1	1(.98)
11	porridge	3	0	0	1	1(.98)
12	pies	5	1	0	1	2(1.96)
13	green salad,	5	1	0	1	2(1.96)
14	mayonnaise	6	1	1	1	3(2.94)
15	chips	6	1	1	1	3(1.94)
16	Fried egg	3	1	0	0	1(.98)
17	Ice Creem	5	0	0	1	1(.98)
18	Rice	0	0	0	0	0(0.00)
19	madida	2	0	0	0	0(0.00)
20	Appetizers	3	1	1	1	3(2.94)
Total		102	14	5	12	31 (30)

Table 4

Occurrence of bacteria isolated from food samples from sold at kiosk

Types of food	Total number of samples	*Salmonella,spp* positive samples	*Escherichia Coli Species* positive samples	*Staphylococcus* positive samples	Overall frequency of positive sample *n* (%)
Red meat	14	3	2	4	9 (11.53)
White meat	3	1	0	0	1 (1.29)
Processed meats	2	1	0	0	1 (1.29)
Lamb entrails	7	1	4	0	5 (6.41)
Agashi	5	1	1	1	3 (3.85)
Falafel	3	2	0	0	2 (2.56)
Bread	2	0	0	1	1 (1.29)
Sweets	1	1	0	0	1 (1.29)
Juices	0	0	0	0	0 (0.00)
Kesra	15	1	1	5	7 (8.97.)
Porridge	3	1	1	1	3 (3.85)
Pies	0	0	0	0	0 (0.00)
Green sala,	4	1	0	1	2 (2.56)
Mayonnaise	0	0	0	0	0 (0.00)
Chips	1	0	0	0	0 (0.00)
Fried egg	2	1	0	0	1 (1.29)
Ice cream	0	0	0	0	0 (0.00)
Rice	3	0	0	1	1 (1.29)
Madida	8	1	0	2	3 (3.85)
Appetizers	5	1	0	1	2 (2.56)
Total	78	16	9	17	42 (53.85)

Table 5
Occurrence of bacteria isolated from food samples sold at the restaurants

Types of food	Total number of samples	*Salmonellas spp* positive samples	*Escherichia Coli* positive samples	*Staphylococcus* positive samples	Overall frequency of positive sample *n* (%)
Red meat	18	0	0	0	0 (0.00)
White meat	8	0	0	0	0 (0.00)
Processed meats	14	3	0	3	6 (4.61)
Lamb entrails	3	0	1	0	1 (.76)
Agashi	4	0	0	0	0 (0.00)
Falafel	8	0	0	0	0 (0.00)
Bread	4	1	0	1	2 (1.53)
Sweets	8	0	0	0	0 (0.00)
Juices	7	0	0	0	0 (0.00)
Kesra	4	2	0	2	4 (3.08)
Porridge	5	0	0	0	0 (0.00)
Pies	5	0	0	0	0 (0.00)
Green sala,	5	1	0	1	2 (1 53)
Mayonnaise	6	0	0	0	0 (0.00)
Chips	6	0	0	0	0 (0.00)
Fried egg	1	0	0	0	0 (0.00)
Ice cream	7	0	0	0	0 (0.00)
Rice	9	2	0	2	4 (3.08)
Madida	4	0	0	0	0 (0.00)
Appetizers	4	1	1	1	3 (2.30)
Total	130	10	2	10	22 (16.92)

Table 6
Salmonella spp positive samples in each food type (N = 40)

Salmonella spp	Sampling sites			Frequency of *Salmonella* spp *n* (%)
	Kiosk	Cafeteria	Restaurant	
Red meat	3	1	0	4 (10.00)
White meat	1	1	0	2 (5.00)
Processed meats	1	2	3	6 (15.00)
Lamb entrails	1	0	0	1 (2.50)
Agashi	1	1	0	2 (5.00)
Falafel	2	1	0	3 (7.50)
Bread	0	0	1	1 (2.50.)
Sweets	1	1	0	2 (5.00)
Juices	0	1	0	1 (2.50)
Kisra	1	0	2	3 (7.50)
Porridge	1	0	0	1 (2.50)
Pies	0	1	0	1 (.50)
Green salad	1	1	1	3 (7.50)
Mayonnaise	0	1	0	1 (2.50)
Chips	0	1	0	1 (2.50)
Fried egg	1	1	0	2 (5.00)
Ice cream	0	0	0	0 (0.00)
Rice	0	0	2	2 (5.00)
Madida	1	0	0	1 (2.50)
Appetizers	1	1	1	3 (7.50)
Total	16	14	10	40 (100)

Table 7
Escherichia Coli positive samples in each food types (N = 16)

Type of food	Sampling sites			Frequency of *Escherichia Coli* *n* (%)
	Kiosk	Cafeteria	Restaurant	
Red meat	2	0	0	2 (12.50)
White meat	0	0	0	0 (0.00)
Processed meats	0	1	0	1 (6.25)
Lamb entrails	4	0	1	5 (31.50)
Agashi	1	0	0	1 (6.25)
Falafel	0	1	0	1 (6.25)
Bread	0	0	0	0 (0.00)
Sweets	0	0	0	0 (0.00)
Juices	0	0	0	0 (0.00)
Kisra	1	0	0	1 (6.25)
Porridge	1	0	0	1 (6.25)
Pies	0	0	0	0 (0.00)
Green salad	0	0	0	0 (0.00)
Mayonnaise	0	1	0	1 (6.25)
Chips	0	1	0	1 (6.25)
Fried egg	0	0	0	0 (0.00)
Ice cream	0	0	0	0 (0.00)
Rice	0	0	0	0 (0.00)
Madida	0	0	0	0 (0.00)
Appetizers	0	1	1	2 (12.50)
Total	9	5	2	16 (100)

Table 8
Staphylococcus aureus positive samples in each food type (N = 39)

Type of food	Sampling sites			Frequency of Staphylococcus aureus *n* (%)
	Kiosk	Cafeteria	Restaurant	
Red meat	4	0	0	4 (10.25)
White meat	0	0	0	0 (0.00)
Processed meats	0	1	3	4 (10.25)
Lamb entrails	0	0	0	0 (0.00)
Agashi	1	0	0	1 (2.56)
Falafel	0	1	0	1 (2.56)
Bread	1	1	1	3 (7.69)
Sweets	0	0	0	0 (0.00)
Juices	0	1	0	1 (2.26)
Kisra	5	1	2	8 (20.51)
Porridge	1	1	0	2 (5.12)
Pies	0	1	0	1 (2.26)
Green salad	1	1	1	3 (7.69)
Mayonnaise	0	1	0	1 (2.26)
Chips	0	1	0	1 (2.26)
Fried egg	0	0	0	0 (0.00)
Ice cream	0	1	0	1 (2.26)
Rice	1	0	2	3 (7.69)
Madida	2	0	0	2 (5.12)
Appetizers	1	1	1	3 (7.69)
Total	17	12	10	39 (100)

Table 9
The percentage of positive samples out of the total samples for each type of food

Type of foods	Total number of samples	Positive isolated out of the total, *sample item n* (%)
Red meat	43	10(23.26)
White meat	16	2(12.50.)
Processed meats	30	11(36.67)
Lamb entrails	10	6(60.00)
Agashi	11	4(36.36)
Falafel	21	5(23.80)
Bread	12	4(33.33)
Sweets	14	2(14.29)
Juices	16	2(12.50)
Kesra	21	12(57.14)
Porridge	11	4(36.36)
Pies	10	2(20.00)
Green salad	14	6(42.86)
Mayonnaise	12	3(25.00)
Chips	13	3(23.77)
Fried egg	6	2(33.33)
Ice cream	12	1(8.33)
Rice	12	5(41.67)
Madida	14	3(21.43)
Appetizers	12	8(66.67)
Total	310	95(30.65)

ACKNOWLEDGEMENTS

We extend our sincere thanks to everyone who helped us in this study, especially those working in various food selling sites

CONFLICTS OF INTEREST DISCLOSURE

The authors declared no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

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