Microbial Contamination of Food stuffs industries in Khartoum State, 2020.

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ABSTRACT

Background: Foodborne diseases contribute significantly to the global burden of illness. The World Health Organization (WHO) estimates that approximately 600 million people worldwide become ill after consuming contaminated food each year, resulting in around 420,000 deaths.

Methods: A cross-sectional descriptive study was conducted among 54 food factories distributed across six localities in Khartoum State. A sample for microbial analysis was taken to representative the food industries localities of Khartoum State where one sample from each locality was taken. For the food samples, 25 g were blended with 225 ml saline peptone water (0.1% peptone and 0.9% NaCl) and decimal dilutions were prepared (Messer *et al*., 1992).Aerobic plate counts (APC) was carried out according to Stevenson and Segner (1992). Thermotolerant coliforms was investigated by the most probable number (MPN) technique using three tubes according to Hitchins, Hartman, and Todd (1992). Tubes showing gas production in EC broth were streaked on eosin metylene blue (EMB) agar to investigate the presence of Escherichia coli.Colonies appearing bluish with greenish metallic sheen on EMB plates, characteristic of E. coli, were confirmed by biochemical tests of IMViC. Staphylococci TNase-coagulase positives were investigated according to Lancette and Tatini (1992) on Baird Parker agar supplemented with tellurite and egg yolk emulsion. TNase testing were performed using DNase agar supplemented with agar, trisHCl, o-toluidine blue and calcium chloride (Be Santana, et al, 2009).

Data were analyzed using descriptive statistics and presented as frequencies, percentages, means, and standard errors.

Results: The food stuff industries in Khartoum State showed that the microbiological examination of 134 samples revealed bacterial contamination in approximately 47.0% of samples. The predominant isolates were *Escherichia coli*, followed by *Staphylococcus* spp., while *Salmonella* spp. was detected less frequently.

Conclusion: Microbial contamination in food factories is largely linked to inadequate hygiene and sanitation practices rather than isolated contamination events. The results are consistent with

previous studies conducted in Sudan and other developing countries, confirming that *E. coli* and *Staphylococcus* spp. continue to be the most common indicators of poor food handling and processing conditions.

Keywords: *Microbial contamination, food stuffs, Khartoum State, 2020.*

INTRODUCTION: Microbiological contamination of food refers to the presence of harmful microorganisms such as bacteria, viruses, parasites, molds, and yeasts in food products. These microorganisms can enter food at any stage of the food chain, including production, processing, transportation, storage, preparation, and serving. Contaminated food can cause foodborne diseases, resulting in significant public health, social, and economic consequences worldwide (WHO, 2024). Microbial contamination remains one of the leading causes of foodborne illnesses globally. According to the World Health Organization, an estimated 600 million people suffer from foodborne diseases annually, leading to approximately 420,000 deaths worldwide (WHO, 2024). Food contamination is particularly challenging in developing countries where inadequate sanitation, poor hygiene practices, and limited food safety infrastructure contribute to increased risks. Bacteria are among the most common causes of foodborne illnesses. Pathogenic bacteria can contaminate food through contaminated water, soil, equipment, food handlers, or raw materials. Common foodborne bacterial pathogens include Salmonellosis-causing *Salmonella spp.*, *Escherichia coli* O157:H7, *Listeria monocytogenes*, *Campylobacter jejuni*, and *Staphylococcus aureus* (Jay et al., 2020).

Studies show high prevalence rates in poultry chains, raw red meat, and street-vended foods. For instance, testing of raw meat across Khartoum localities revealed an E. coli incidence rate of **36%** (Khalid *et al*., 2024). Commonly isolated from poultry, raw eggs, and unpasteurized milk. It remains a major source of localized typhoid and non-typhoidal salmonellosis outbreaks (Sulieman, 2025). Frequently linked to inadequate personal hygiene among food handlers. In a study conducted in Omdurman, *S. aureus* was isolated from the nasal passages and hands of a significant percentage of food handlers, directly contributing to toxin-mediated food poisoning via ready-to-eat meals (Sulieman, 2025). *Bacillus cereus*, *Campylobacter jejuni*, and *Clostridium perfringens* are also frequently isolated from street foods, meat products, and improperly stored bulk grains (Sulieman, 2025). The present study aimed to determine the microbial contamination of food stuff industries in Khartoum State.

METHODS:

Study design: The study was a quantitative analytical descriptive cross-sectional study.

Study area and setting: The study area was Khartoum state is one of the 25 states of Sudan. It has an area of 2,122 km^2 and an estimated population of 5.3 million. Khartoum, is located at 15.5881 [latitude in decimal degrees], 32.5342 [longitude in decimal degrees] at an average elevation/altitude of 378 meters and the study setting was Khartoum food stuff factories.

Study Population

The population of the study were food stuffs industries in Khartoum State.

Inclusion criteria:

Food stuffs industries in Khartoum State.

Exclusion criteria:

- Closed food stuffs industries during the period of data collection.
- Industries not work in food manufacturing.

Sample size and sample technique:

The total food stuffs industries in Khartoum State (N=331).

The sample size was calculated according using the finite population sample size formula (Cochran with finite population correction) (1997);

$$\mathbf{n=N\ Z^2\ *\ Pq/\ e^2\ (N-1)\ /\ pq\ +Z^2\ Pq}$$

Whereas;

n=The required sample size

N= number of population =331

Z^2= normal distribution (1.96)

P=Probability = 1

Q=1-p=1.0-0.5=0.5

e2=10%

n==**74.5**

3

Thus, approximately 75 factories would be required with a 10% margin of error.

The data was collected from 54 food industries to financial problem related to the researcher which resulting from increased cost of laboratory for analyzing food sampling in addition to cost of the analyzer.

A total of **54 food processing factories** were included in the study. Although statistical formulas may suggest a larger sample, the final sample size was determined based on the accessibility of operational factories during the study period, available resources, security conditions, and the feasibility of conducting detailed Good Manufacturing Practices (GMP) assessments together with microbiological sampling. The selected factories represented approximately **16.3%** of the total registered food processing factories (54 out of 331), providing adequate representation of the major food industry sectors operating in Khartoum State.

Sample technique:

A multistage sampling technique was used.

- Stage 1: A list of the 331 registered food processing factories in Khartoum State was obtained from the relevant regulatory authority.
- Stage 2: The factories were stratified according to the type of food industry (for example, dairy, beverages, bakery, edible oils, meat processing, confectionery, bottled water, and other food manufacturing sectors).
- Stage 3: The number of factories selected from each stratum was determined using proportionate allocation based on the size of each sector.
- Stage 4: Within each stratum, factories were selected using simple random sampling until the required sample of 54 factories was obtained.

This approach ensured that the sample included factories from the major food processing sectors and improved the representativeness of the study findings.

Table 1: Sample size calculation according to proportion of each population in each locality

Locality	No. of factories	% from total	Sample size for each locality (% from total* Sample size)
Khartoum	44	13.3	7
Jabal awlia	72	21.8	12
Omdurman	56	16.9	9
Ombada	0	0.0	0
Karari	56	16.9	9
Bahri	101	30.5	16
Sharig Elneel	2	0.6	1
State	**331**	**100.0**	**54**

A total of **134 food samples** were collected from **54 food factories** in Khartoum State. Since each factory produced more than one food product or production batch, multiple samples were collected from individual factories. The number of samples obtained from each factory depended on the variety of food products manufactured and their availability at the time of data collection. All samples were collected using standard aseptic sampling procedures and transported to the laboratory for microbiological analysis.

Methods of data collection:

Microbial analysis:

Microbial standards to measure the presence of staphylococci TNase-coagulase positives and thermotolerant coliform/Escherichia coli in foods which are ready to eat will be used. International standard plate counts were used on utensils (Solberg *et al*., 1990). A sample for microbial analysis was taken to representative the food industries localities of Khartoum State where one sample from each locality was taken. For the food samples, 25 g were blended with 225 ml saline peptone water (0.1% peptone and 0.9% NaCl) and decimal dilutions were prepared (Messer *et al*., 1992).Aerobic plate counts (APC) was carried out according to Stevenson and Segner (1992). Thermotolerant coliforms was investigated by the most probable number (MPN) technique using three tubes according to Hitchins, Hartman, and Todd (1992). Tubes showing

gas production in EC broth were streaked on eosin metylene blue (EMB) agar to investigate the presence of Escherichia coli.

Colonies appearing bluish with greenish metallic sheen on EMB plates, characteristic of E. coli, were confirmed by biochemical tests of IMViC. Staphylococci TNase-coagulase positives were investigated according to Santana, et al., (2009) on Baird Parker agar supplemented with tellurite and egg yolk emulsion. TNase testing were performed using DNase agar supplemented with agar, trisHCl, o-toluidine blue and calcium chloride (Santana et al., 2009).

Data analysis:

Data was analyzed using SPSS version 20.0. Descriptive statistics such as frequency, percentage were used. Inferential statistic was used where appropriate. P-value considered significant at less than 0.05 levels.

Ethical considerations:

The study approval was taken from the University Research Committee. The owners of the food stuffs industries were informed about the process of the research, the research problem, the purpose and the objectives of the study and the benefits. Verbal consent was obtained from all industries owners to allow them to take part in the study voluntarily.

RESULTS:

Based on the uploaded laboratory data, the identified bacterial isolates were mainly ***Escherichia coli*** **(E)**, ***Staphylococcus spp.*** **(Staph)**, and ***Salmonella spp.*** **(S)**, while many samples showed **no growth (Nil)**. A total of **134 samples** were examined across six batches. Bacterial growth was detected in approximately **63 samples (47.0%)**, while the remaining samples showed no growth. The predominant isolates were **Escherichia coli**, followed by **Staphylococcus spp.**, whereas **Salmonella spp.** were detected less frequently. The findings indicate that fecal contamination represented by *E. coli* was the major microbiological concern in the analyzed samples, table 1.

Table 2 summarizes the bacterial isolates identified from the factory samples collected in Khartoum State. A total of **63 bacterial isolates** were recovered. **Escherichia coli** was the most frequently isolated organism, accounting for **32 isolates (50.8%)**. This was followed by **Staphylococcus spp.**, with **24 isolates (38.1%)**. **Salmonella spp.** was the least common isolate, representing **7 isolates (11.1%)**. Overall, the findings indicate that *Escherichia coli* was the

predominant bacterial contaminant in the factory samples, followed by *Staphylococcus* species, while *Salmonella* species were detected less frequently.

The table 3 compares food safety and hygiene standards between **positive** and **negative** groups. Statistical significance was determined using the p-value (Sig.), with **p < 0.05** considered significant. Regarding personal hygiene, there was a statistically significant difference between the two groups (**p = 0.036**). The negative group had a slightly higher mean score (12.4 ± 1.6) than the positive group (12.0 ± 1.8), suggesting better personal hygiene practices among the negative group. For food preparations, a statistically significant difference was observed (**p = 0.005**). Although the mean scores appear similar (9.7), the statistical test indicates a meaningful difference between the groups. In terms of refrigerators and freezers, no significant difference was found between groups (p = 0.693). Refrigeration and freezer practices were comparable. In respect to food storage, no significant difference was detected (**p = 0.247**). Food storage practices were similar in both groups. However, in terms of utensils and equipment no statistically significant difference was observed (**p = 0.250**), indicating comparable standards regarding utensils and equipment. For dash washing, no significant difference was found (**p = 0.438**). Dishwashing practices did not differ substantially between groups. In addition, for garbage storage and pest control, no significant difference was observed (**p = 0.534**), suggesting similar waste management and pest control measures. For food hygiene inspection the groups showed nearly identical scores, with no significant difference (**p = 0.918**).

Regarding good manufacturing practice (GMP), no significant difference was found (**p = 0.581**), indicating similar compliance with GMP requirements. For facility and equipment, no statistically significant difference was observed (**p = 0.611**). Facility and equipment conditions were comparable between groups. Regarding personnel, no significant difference was detected (**p = 0.933**), suggesting similar personnel-related practices and standards.

The analysis indicates that most food safety and hygiene domains did **not differ significantly** between the positive and negative groups. Significant differences were identified only in **Personal Hygiene (p = 0.036)** and **Food Preparations (p = 0.005)**. These findings suggest that personal hygiene practices and food preparation procedures may be important factors associated with the observed positive and negative outcomes. However, all other assessed domains

including storage, refrigeration, equipment, sanitation, pest control, facility conditions, and personnel practices showed no statistically significant differences between the groups.

Table 1. food samples taken from the selected factories investigation in Khartoum State

Batch	No. of Samples	Positive Samples	%
Batch 1	24	10	41.7
Batch 2	12	7	58.3
Batch 3	22	9	40.9
Batch 4	29	16	55.2
Batch 5	26	10	38.5
Batch 6	21	11	52.4
Total	134	63	47.0

Table 2. Summary isolates of bacteria in factories samples in Khartoum State

Organism	No. positive	%
Escherichia coli	32	50.8
Staphylococcus spp.	24	38.1
Salmonella spp.	7	11.1
Total	63	100.0

Table 3. Association between positivity status and food standard in factories samples in Khartoum State

Food standard	Result						Sig.
	Positive		Negative		Total		
	Mean	SD	Mean	SD	Mean	SD	
Personal hygiene	12.0	1.8	12.4	1.6	12.2	1.7	**.036***
Food preparations	9.7	1.6	9.7	1.5	9.7	1.6	**.005***
Refrigerators and freezer	8.3	1.9	8.5	1.6	8.4	1.8	**.693**
Food storage and storage	7.2	1.7	7.8	1.7	7.5	1.7	**.247**
Utensils and equipment	10.4	2.4	9.6	2.9	9.9	2.7	**.250**
Dishwashing	6.0	2.0	5.6	1.7	5.8	1.8	**.438**
Garbage storage and pest control	3.9	1.5	4.2	1.9	4.0	1.7	**.534**
Food Hygiene Inspection	10.1	2.4	10.1	2.3	10.1	2.3	**.918**
Good manufacture practice	2.2	.6	2.3	.6	2.3	.6	**.581**
Facility and equipment	54.1	6.9	53.1	6.4	53.6	6.7	**.611**
Personnel	21.4	4.3	21.3	4.2	21.3	4.2	**.933**

DISCUSSION:

The study showed that the predominance of food bacteria was Escherichia coli and Staphylococcus spp. and lower frequency of Salmonella spp among positive samples in food factories. The predominance of *E. coli* suggests possible fecal contamination resulting from inadequate personal hygiene, contaminated water, or poor sanitation during food processing. Likewise, the presence of *Staphylococcus spp.* is commonly associated with contamination from food handlers, as these bacteria are naturally found on the skin, hands, and in the nasal passages. Their detection indicates deficiencies in hand hygiene, the use of protective clothing, and

adherence to good manufacturing practices. The relatively low frequency of *Salmonella spp.* may reflect the effectiveness of certain control measures, such as routine cleaning and disinfection, proper cooking temperatures, and monitoring of raw materials. However, even low levels of *Salmonella* contamination remain a significant public health concern because the organism can cause severe foodborne illness. Therefore, continuous microbiological surveillance and strict implementation of food safety management systems are essential to prevent contamination and ensure the production of safe food. These findings are consistent with previous studies conducted in Sudan and other developing countries, where *E. coli* and *Staphylococcus spp.* have been reported as the most common bacterial contaminants in food processing environments, whereas *Salmonella spp.* is generally detected less frequently. Similar observations have been reported in Ethiopia, Kenya, and Saudi Arabia, highlighting that inadequate personal hygiene, cross-contamination, and poor sanitation remain major contributors to bacterial contamination in food industries (Alemayehu *et al*., 2023; Alqurashi *et al*., 2022; World Health Organization, 2022). Strengthening hygiene training, enforcing Good Manufacturing Practices (GMP), and implementing Hazard Analysis and Critical Control Point (HACCP) systems are critical strategies for reducing microbial contamination and improving food safety.

CONCLUSION: These findings demonstrate that microbial contamination in food factories is largely linked to inadequate hygiene and sanitation practices rather than isolated contamination events. The results are consistent with previous studies conducted in Sudan and other developing countries, confirming that *E. coli* and *Staphylococcus* spp. continue to be the most common indicators of poor food handling and processing conditions. Strengthening food safety through regular microbiological monitoring, continuous training of food handlers, strict enforcement of Good Manufacturing Practices (GMP), and effective implementation of Hazard Analysis and Critical Control Point (HACCP) systems is essential to minimize contamination risks, protect consumer health, and improve the quality and safety of food products.

DECLARATION OF COMPETING INTEREST:

The authors declared that there is no conflict of interest.

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