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Microbiological Analysis of Food Products Sold on Street Stalls (MALEWA) in the City of Kisangani, DR Congo

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Abstract

The overall objective of this study was to assess the hygienic quality of food sold on the streets of Kisangani and to identify alternative solutions to combat the pathogenic bacteria contaminating these foods. Bacteriological analyses of the samples (isolation and enumeration) revealed high bacterial loads of FMAT, Enterobacteria, and Salmonella, indicating significant food contamination. Thus, the average bacterial counts ranged from 13,209.09 to 648,272.42 CFU/g for FMAT; 30 to 809.09 CFU/g for Enterobacteria; and 0 to 1,663.64 CFU/g for Salmonella. Furthermore, Staphylococci were not detected at any of the sites. High levels of FMAT, Enterobacteria, and Salmonella were observed in the municipalities of Makiso, Kisangani, and Kabondo, respectively.

Keywords: Food hygiene, Street foods, Bacteriological analysis, Kisangani, Enterobacteria, Salmonella.

INTRODUCTION

The sale of food on public streets is a common practice in developing countries such as the Democratic Republic of the Congo. However, this can pose public health risks due to poor hygiene and a lack of quality control. This study aims to assess the microbiological quality of food offered for consumption in public areas of the city of Kisangani, in order to identify potential risks to consumer health.

Microbiological contamination of food, which is particularly due to poor hygiene among food handlers, can cause foodborne illnesses, highlighting its importance both for public health and from a social perspective (Mutsch, L., 2018).

It should be noted that foodborne illnesses are a global public health problem with significant implications for health and the economy. They cause a wide variety of symptoms and even deaths; the survival of spores, germination, proliferation, and toxin production in food are responsible for these incidents (Kasereka, B., *et al.,* 2020).

The costs incurred in addressing diseases associated with food contamination are considerable; this is why regulatory measures and adequate control are necessary at every stage of food production, processing, and service to minimize the risks of contamination (Basandja, L., 2025). However, consumer education is also important, as evidenced by the increase in foodborne illnesses in developed countries where hygiene and quality control measures are implemented (Benbrahim, M., 2013).

Bacterial contamination can be transferred to food directly through simple contact or indirectly via a vector such as the hand. The hand is the part of the body most frequently used for various tasks involving handling, moving objects, and greeting others. As a result, it is highly exposed to various microorganisms and has consequently become the most likely means of transmitting these microorganisms, including Staphylococcus, Salmonella, and others.

In this regard, it must be subject to strict regulations aimed at protecting consumers. It is with this in mind that this study was conducted to assess the

hygienic quality of food sold on public streets (AVP) in the Kisangani region, which requires significant research in the field of food hygiene and public health, while also aiming to assess the microbiological quality of the food offered for consumption in these locations, in order to identify potential risks to consumer health.

MATERIALS AND METHODS

Study Setting

This study was conducted in the city of Kisangani, the capital of Tshopo Province. Kisangani, the country's third-largest city, is located in the central Congolese basin and is bordered to the north by the territory of Banalia, to the northeast by the territory of Bafwasende, to the west by the territory of Opala, to the northwest by the territory of Isangi, and to the south by the territory of Ubundu.

With an area of 1,910 km², the city of Kisangani has a population density of 229 inhabitants per km². It is located at 0°31'00'' north latitude relative to the Equator and 25°11'00'' east longitude relative to the Greenwich Meridian, with an average elevation of 428 m above sea level according to the INSS. The terrain features several variations (Boyoma Plateau, Médical Plateau, etc.) (Ebwa, 2024; Adheka, 2014).

Administratively, Kisangani is divided into six communes: Makiso, Tshopo, Mangobo, Kabondo, Kisangani (on the right bank of the Congo River), and Lubunga (on the left bank).

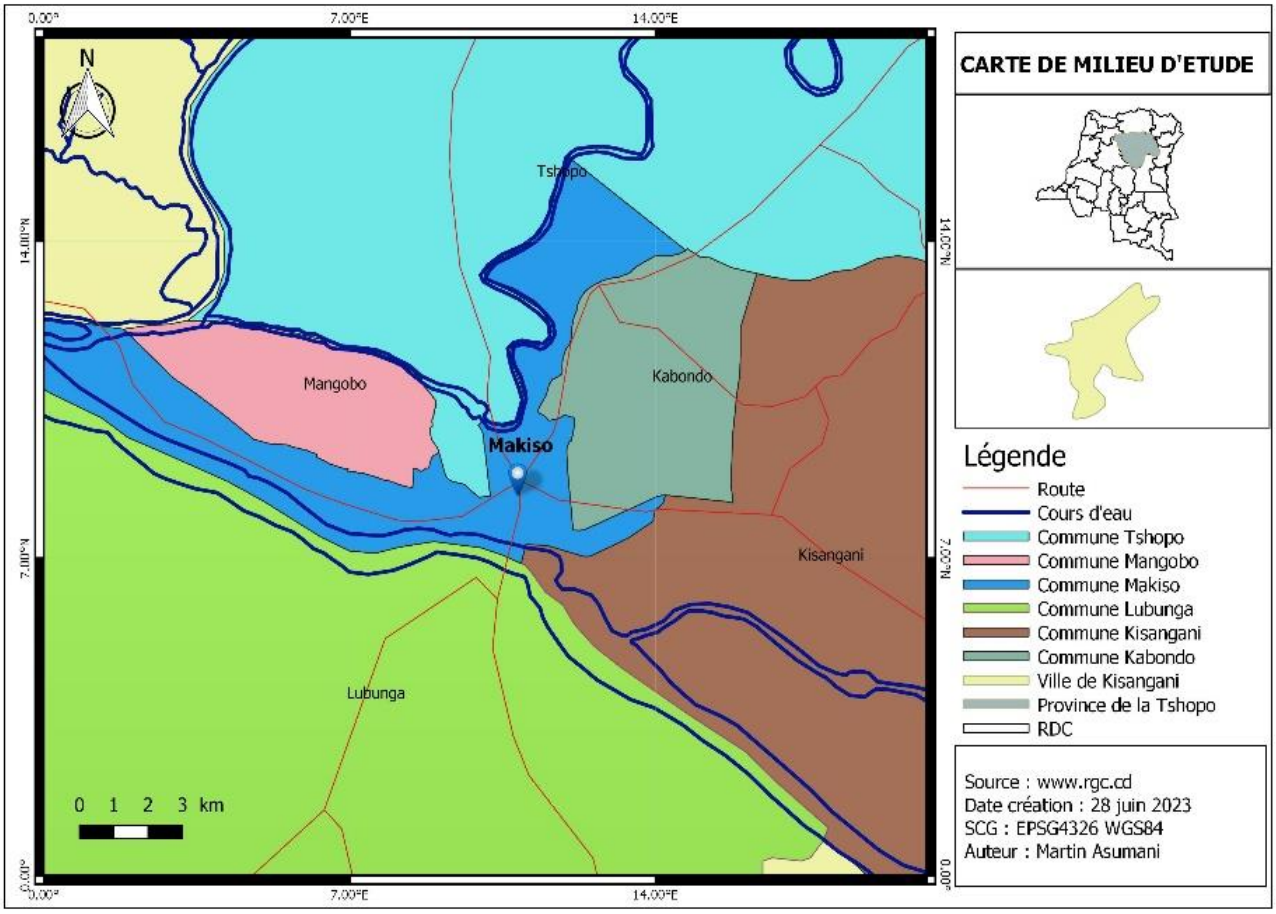

Figure 1: Map of the city of Kisangani

Materials

Samples

The cooked Malewa meals (rice with pondu and beans) sold on the streets served as the samples for this study. These samples were selected using simple random sampling in five different districts (Makiso, Kabondo, Tshopo, Mangobo, and Kisangani) in the city of Kisangani (DRC).

Figure 2: Various samples from Malewa (rice, beans, and pondu)

Methods

We conducted five field visits per site, with a one-week interval between each sampling. The purchased samples were placed in sterile jars, then stored in a portable cooler, and subsequently transported to the Microbiology and Plant Pathology Laboratory at the Faculty of Sciences, UNIKIS, for analysis.

Preparation of Dilutions, Inoculation, and Bacterial Counting

For bacteriological analyses, the stock solution was prepared aseptically by weighing 25 g of food, emulsifying it in 225 ml of sterile peptone water, and homogenizing the solution. Perform successive dilutions (10^{-2}; 10^{-3}; 10^{-4}; 10^{-5}) by diluting 1 ml of the stock solution in 9 ml of sterile peptone water.

From the successive dilutions, inoculate 1 ml of the inoculum into the appropriate medium to detect the microorganisms.

Counting of Pathogenic Bacteria

The bacteria sought in food are FMAT, Staphylococci, Salmonella, and Enterobacteria.

Take 1 mL of each dilution and aseptically pour it into a sterile Petri dish. Next, aseptically pour 15 ml of nutrient agar for FMAT, Chapman's agar for Staphylococci, SS Agar for Salmonella, and MacConkey's agar for Enterobacteria into the plates containing the inoculum, then let stand for at least 15 minutes to allow the medium to solidify completely. Place the plates upside down in the incubator at 37°C for 24 to 48 hours, depending on the target microorganisms.

After bacterial enumeration, the number of microorganisms (CFU/g) was determined using the following formula:

$$\mathbf{N} = \frac{\sum colonies}{V(ml) \times (n1+0,1 \times n2) \times d1}$$

Method for Interpreting Results

The interpretation of microbiological results was based on French standards for prepared foods, as defined in the decree of December 21, 1979, published in the Official Journal on January 10, 1980.

These standards establish microbiological criteria (m) used to assess the quality of prepared foods:

- FMAT: Maximum of 3.105 colonies per gram of food.
- Enterobacteria: Maximum of 10 colonies per gram of food.
- Pathogenic staphylococci: Maximum of 100 colonies per gram of food.
- Salmonella: Absent in 25 grams of food.

For solid-medium analyses, results were interpreted using a three-class system:

- ✓ Satisfactory: when the number of colonies is less than or equal to 3m.
- ✓ Acceptable: when the number of colonies is greater than 3m but less than or equal to 10m.
- ✓ Unsatisfactory: when the colony count is greater than 10 CFU.

This system allows microbiological samples to be classified based on the critical value m determined according to the established microbiological criterion. Here is how the quality classes are distributed for each microbial group studied:

Table 1: Food Safety Quality Criteria

Microbial group	Satisfactory	Acceptable	Unsatisfactory
TAMF	CB <9.10^5	CB : 9.10^5-90.10^5	CB >90.10^5
Enterobacteria	CB < 30	CB : 30-100	CB >100
Staphylococci	CB <300	CB : 300-1000	CB >1000
Salmonella	Absence	Absence	Presence

Legend: CB: bacterial concentration

RESULTS AND DISCUSSION

Total Aerobic Mesophilic Flora (TAMF) Count

The TAMF bacterial load in samples analyzed from five sites is presented in Table 2.

Table 2: TAMF bacterial load in samples analyzed from five sites

Site	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Kabondo	$404,54.10^2$	$264,09.10^2$	$3,35.10^4$	$83,18.10^2$	$359,09.10^2$
Kisangani	$141,36.10^2$	$129,54.10^2$	$1,9.10^4$	$81,81.10^2$	$117,72.10^2$
Makiso	$31181,81.10^2$	$4,45.10^4$	$24,13.10^2$	$744,16.10^2$	$1,85.10^3$
Mangobo	$1,39.10^3$	$8,14.10^2$	$3,65.10^2$	$1,05.10^3$	$63,75.10^4$
Tshopo	$317,14.10^2$	$15,57.10^2$	$1,9.10^2$	$4,72.10^2$	$3686,36.10^2$

Table 2 shows that all samples analyzed from five sites contain FMATs. These levels range from 83.18 × 10^2 to 404.54 × 10^2 CFU/g in the Kabondo district; 81.81 × 10^2 to 1.9 × 10^4 CFU/g in the Kisangani district; 1.85 × 10^3 to 31,181.81 × 10^2 CFU/g in the Makiso commune; 3.65 × 10^2 to 63.75 × 10^4 CFU/g in the Mangobo commune; and 1.9 × 10^2 to 3,686.36 × 10^2 CFU/g in the Tshopo commune.

The highest bacterial counts were found in the communes of Makiso (Ech1, 2, 4), Mangobo (Ech5), and Kabondo (Ech3).

This can be explained by: prolonged exposure of food to room temperature, an unsanitary environment (dust, traffic), frequent handling without proper hygiene, and inadequate storage.

These values generally exceed the recommended standards for ready-to-eat foods, suggesting insufficient microbiological quality.

Enterobacteria Count

The enterobacteria bacterial load in samples analyzed from five sites is presented in Table 3.

Table 3: Enterobacteria bacterial load in samples analyzed from five sites

Site	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Kabondo	$12,72.10^2$	0	0	$3,63.\ 10^2$	$2,72.\ 10^2$
Kisangani	0	$24,09.10^2$	0	0	$16,36.\ 10^2$
Makiso	0	0	0	$1,5.\ 10^2$	0
Mangobo	$8,61.10^2$	$3,8.10^2$	0	0	$2,55.\ 10^2$
Tshopo	$3,66.10^2$	$2,1.10^2$	0	0	$8,68.\ 10^2$

Table 3 shows that samples 1, 4, and 5 from the Kabondo district are contaminated with Enterobacteria, as are samples 1, 2, and 5 from the Mangobo and Tshopo districts. Furthermore, in the Makiso commune, only sample 4 is contaminated with Enterobacteria, while for the samples from the Kisangani commune, contamination is observed in samples 2 and 5.

Taken together, these results show that sample 3 from all sites is not contaminated with Enterobacteria. Thus, high bacterial loads of Enterobacteria were observed in the Kabondo commune, with 12.72 × 10^2 and 3.63 × 10^2 CFU/g in samples 1 and 4, respectively, and in the Kisangani commune with 24.09 × 10^2 and 16.36 × 10^2 10^2 CFU/g in samples 2 and 5, respectively.

The presence of Enterobacteriaceae is an indicator of contamination of environmental (soil, water) or fecal origin. This contamination in food could be explained by: the use of contaminated water, poor hand hygiene, or cross-contamination between raw and cooked foods.

In contrast, the low value observed in Makiso (30 CFU/g) may indicate relatively better conditions for this specific parameter, even though the total flora remains high.

Salmonella Count

The Salmonella bacterial loads in the analyzed samples from five sites are presented in Table 4.

Table 4: Salmonella bacterial load in samples analyzed from five sites

Site	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Kabondo	0	$83,18.10^2$	0	0	0
Kisangani	0	$9,54.10^2$	$4,09.10^2$	$1,36.10^2$	$0,9.10^2$
Makiso	0	0	0	0	0
Mangobo	$2,15.10^2$	$1,9.10^2$	0	0	0
Tshopo	$1,8.10^2$	0	0	0	$7,13.10^2$

Table 4 shows that several samples from the Kisangani district are contaminated with Salmonella, specifically samples 2, 3, 4, and 5. Furthermore, two contaminated samples were found in the Mangobo and Tshopo districts, respectively, and one sample in the Kabondo district, while no samples in the Makiso district were contaminated with Salmonella.

This number ranges from 0 to 2.15 × 10^2 CFU/g; 0 to 83.18 × 10^2 CFU/g; 0 to 4.09 × 10^2 CFU/g; 0 to 1.36 × 10^2 CFU/g and 0 to 7.13 × 10^2 CFU/g, respectively, in samples 1, 2, 3, 4, and 5.

The presence of Salmonella in ready-to-eat foods is a serious concern, as these bacteria cause severe foodborne illnesses.

The high bacterial load observed in Kabondo suggests: improper cooking of food, cross-contamination, use of contaminated water, or improper storage.

The absence of Salmonella in Makiso could indicate: better food cooking practices, or conditions that limit the survival of this bacterium.

Staphylococcus Count

The bacterial load of Staphylococcus in samples analyzed from five sites is presented in Table 5.

Table 5: Bacterial load of Staphylococcus in samples analyzed from five sites

Site	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Kabondo	0	0	0	0	0
Kisangani	0	0	0	0	0
Makiso	0	0	0	0	0
Mangobo	0	0	0	0	0
Tshopo	0	0	0	0	0

In this table, we observed a complete absence of staphylococci (0 CFU/g) at all sites.

This can be explained by: thorough cooking of the food (heat destroys these bacteria), or the absence of direct contamination by food handlers. However, this absence should be interpreted with caution because: it may also be related to methodological limitations or suboptimal detection conditions.

Average bacterial counts of isolated microorganisms

Table 6: Average bacterial count of all microorganisms isolated from the analyzed samples at five sites

Site	TAMF	Enterobacteria	Salmonella	Staphylococci
Kabondo	28918,18	381,82	1663,64	0
Kisangani	13209,09	809,09	318,18	0
Makiso	648272,42	30	0	0
Mangobo	128224,04	299,57	81	0
Tshopo	80514,10	288,97	178,73	0

The results in Table 6 show that the average bacterial counts range from 13,209.09 to 648,272.42 CFU/g for FMAT; from 30 to 809.09 CFU/g for Enterobacteria; and from 0 to 1,663.64 CFU/g for Salmonella. Furthermore, Staphylococci were not detected at any of the sites. Thus, high levels of FMAT, Enterobacteria, and Salmonella were observed in the municipalities of Makiso, Kisangani, and Kabondo, respectively.

Overall, these results show that: Makiso has the highest overall contamination (high FMAT), Kabondo poses the greatest health risk (high presence of Salmonella), Kisangani has high contamination with Enterobacteriaceae, Mangobo and Tshopo have intermediate levels.

These results reflect inadequate hygiene conditions in food preparation and sales at several sites.

Health Implications

The presence of high bacterial counts, particularly Salmonella, exposes consumers to: diarrhea, vomiting, intestinal infections, and food poisoning.
These risks are particularly high among: children, the elderly, and immunocompromised individuals.

CONCLUSION OF THE DISCUSSION

The various findings show that food sold on the streets in the areas studied exhibits significant microbiological contamination, which varies by location. The presence of Salmonella and Enterobacteriaceae, combined with high levels of total coliforms, indicates a real risk to public health.

These findings underscore the urgent need to improve food hygiene conditions in these areas.

Assessment of Food Safety

Table 7: Assessment of food safety for samples collected by municipality and by pathogen

Site	FMAT					Entérobactéries					Salmonelles					Staphylocoques				
	E1	E2	E3	E4	E5	E1	E2	E3	E4	E5	E1	E2	E3	E4	E5	E1	E2	E3	E4	E5
Kabondo	S	S	S	S	S	NS	S	S	NS	NS	S	NS	S	S	S	S	S	S	S	S
Kisangani	S	S	S	S	S	S	NS	S	S	NS	S	NS	NS	NS	NS	S	S	S	S	S
Makiso	A	S	S	S	S	S	S	S	NS	S	S	S	S	S	S	S	S	S	S	S
Mangobo	S	S	S	S	S	NS	NS	S	S	NS	NS	NS	S	S	S	S	S	S	S	S
Tshopo	S	S	S	S	S	NS	NS	S	S	NS	NS	S	S	S	NS	S	S	S	S	S

Legend: S: Satisfactory; A: Acceptable; NS: Not Satisfactory; E: Sample

This table shows that 100% of the samples tested for FMAT are satisfactory according to the established evaluation criteria, whereas for Enterobacteria, 50% of the samples are satisfactory and 50% are unsatisfactory; for Salmonella, 65% of the samples are satisfactory and 35% are unsatisfactory; finally, for Staphylococci, all samples are satisfactory.

Statistical Analysis

All of these experiments were repeated five times. However, the analysis of variance was performed using R Studio version 4.1.1. This test was applied to verify differences in the results of the counts of the target bacteria.

ANOVA results for each bacterium

- **FMAT**
  - ANOVA: F = 1.23, p = 0.34
  - No significant difference between municipalities (p > 0.05)
- **Enterobacteria**
  - ANOVA: F = 2.56, p = 0.08
  - No significant difference (but a trend, p close to 0.05)
- **Salmonella**
  - ANOVA: F = 3.42, p = 0.03
  - Significant difference between municipalities!
  - Post-hoc (Tukey): Kabondo vs. Makiso (p = 0.02), Kabondo vs. Mangobo (p = 0.04)

N.B.: In summary, only Salmonella shows a significant difference between municipalities, with Kabondo being more contaminated than Makiso and Mangobo.

CONCLUSION

This study on the microbiological analysis of food sold on the streets of Kisangani (DRC) revealed that these foods are largely unfit for consumption and pose a significant risk of food poisoning to consumers. The results showed high bacterial counts of FMAT, Enterobacteria, and Salmonella, indicating significant food contamination.

Factors contributing to this contamination include:

- Poor hygiene during food preparation and service
- Inadequate storage conditions
- Unsanitary conditions around street food vendors
- Low level of training for vendors in food hygiene

To reduce the risk of food poisoning and improve public health, the following is recommended:

- Implement a food hygiene training program for street vendors
- Ensure regular quality control of the food sold
- Raise consumer awareness of the risks associated with consuming contaminated food
- Take measures to improve food preparation and storage conditions
- In summary, this study highlights the importance of taking concrete measures to improve the hygienic quality of food sold on public streets and thereby protect consumer health.

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