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Research Article

Microbiological characterization of traditional djalaa beer marketed in Sarh (Chad) during the dry and rainy seasons

Emmanuel ben Rangadam Faya ^{1*}, Doloum Gomoung ^{2,3}, Angéline Kemsol Nagorngar ¹, Assadi Michel ¹, Benjamin Tchamagoye Kiddindiwa ¹

¹University of N'Djamena, Doctoral school of Sciences- Technique – Environment, Doctoral Training in Biological Sciences Faculty of Exact and Applied Sciences, Food Science and Nutrition Research Laboratory (LARSAN) P.O. Box 1117, N'Djamena, Chad

²University of Sarh, Faculty of Agronomic and Environmental Sciences, CREFELD, P.O. Box 105, Sarh, Chad

³University of Sarh, Faculty of Science and Technology, Department of Biology–Geology, P.O. Box 105, Sarh, Chad

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For Correspondence:

Faya Ben Rangadam Emmanuel, University of N'Djamena, Doctoral school of Sciences- Technique – Environment, Doctoral Training in Biological Sciences Faculty of Exact and Applied Sciences, Food Science and Nutrition Research Laboratory (LARSAN) P.O. Box 1117, N'Djamena, Chad.

Abstract

Objectives: This study aimed to evaluate the microbiological quality of the traditional beer Djala according to seasonal variations in Sarh, Chad.

Methods: Microbiological analyses were conducted on djalaa beer samples collected during the dry and rainy seasons. Standard microbiological methods based on ISO standards were used for the enumeration and detection of *Escherichia coli*, total coliforms, *Salmonella* spp., and yeasts.

Results: *Escherichia coli* was detected in all analyzed samples, with values ranging from 2 to 10.33 CFU/mL during the dry season and from 70 to 114.3 CFU/mL during the rainy season. Total coliform counts ranged from 70 to 114.33 CFU/mL during the dry season and from 7.7 to 483.33 CFU/mL during the rainy season. *Salmonella* spp. was detected in all samples, with concentrations varying from 0.33 to 3 CFU/mL during the dry season and from 1.33 to 6.1 CFU/mL during the rainy season. Yeast counts were generally higher during the rainy season, reaching 16266.66 ± 4688.81 CFU/mL.

Keywords: djalaa, Microbiological characterization, Traditional beer, Dry and rainy seasons, Chad.

1. INTRODUCTION

Traditional fermented beverages occupy an important place in the dietary habits, cultural heritage, and socio-economic life of many African communities¹. Produced through artisanal processes transmitted across generations, these beverages constitute accessible sources of nutrients and contribute to social cohesion and cultural identity. Among these beverages, djalaa, a traditional sorghum-based beer, is widely consumed in Sarh, southern Chad².

The fermentation process of djalaa mainly depends on microorganisms naturally present in raw materials, water, utensils, and the production environment. Fermentation contributes to the development of organoleptic properties and improves the nutritional value and digestibility of the beverage³. However, this

process is strongly influenced by hygienic conditions, water quality, equipment sanitation, and producers' practices⁴.

Foodborne diseases remain a major public health concern worldwide, particularly in developing countries where traditional foods and beverages are often produced and marketed under inadequate sanitary conditions⁵. Microorganisms such as *Escherichia coli*, total coliforms, and *Salmonella* spp. are commonly used as indicators of hygienic quality and food safety⁶.

Seasonal variations, particularly the alternation between dry and rainy seasons, may significantly influence microbial proliferation due to changes in humidity and temperature. The rainy season is generally associated with increased environmental contamination and may therefore favor microbial

growth and product contamination⁷. In contrast, the dry season is often characterized by lower moisture levels, which may limit microbial development⁸.

In Chad, few studies have investigated the microbiological quality of traditional beers despite their widespread consumption. The presence of contamination indicators such as *Escherichia coli* and total coliforms reflects poor hygienic conditions during production and commercialization⁹. Furthermore, pathogens such as *Salmonella* spp. represent serious public health risks¹⁰.

Therefore, this study aimed to characterize the microbiological quality of traditional djalaa beer

marketed in Sarh, Chad, during the dry and rainy seasons by determining the occurrence of *Escherichia coli*, total coliforms, *Salmonella* spp., yeasts, and molds.

2. MATERIALS AND METHODS

2.1. Study area selection and stakeholders sampling

The study was conducted in the Moyen-Chari Department, located in southern Chad. The sampling sites were situated in the districts of Barkoh, where traditional djalaa beer is commonly produced and marketed. As shown in Figure 1, the study area lies between 17°00'E and 20°00'E longitude and 8°00'N and 10°00'N latitude.

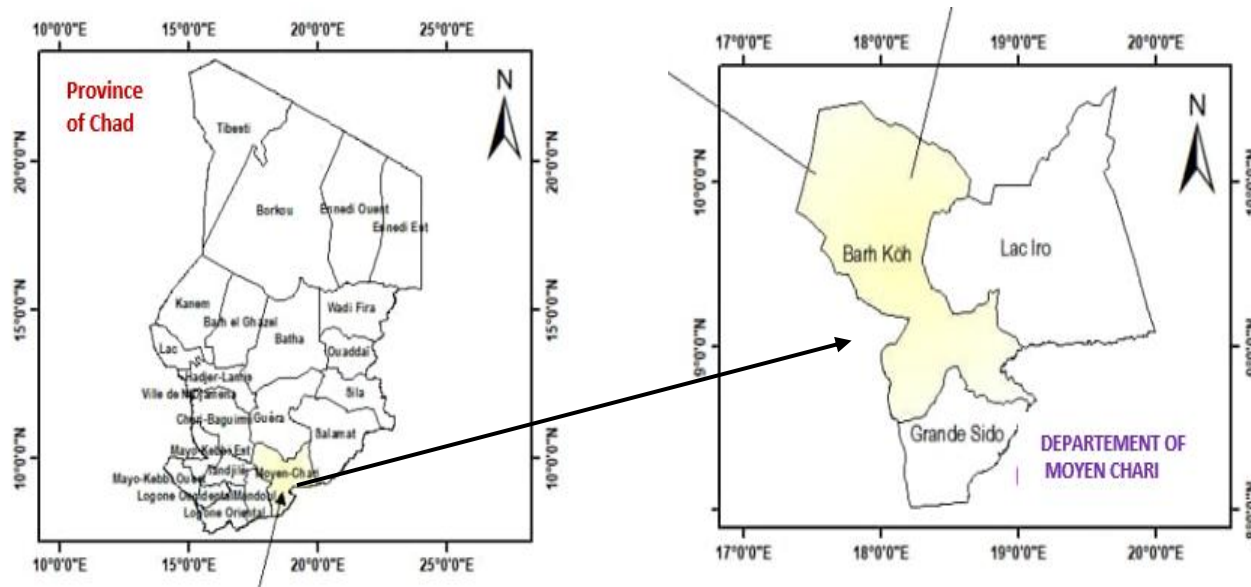


Figure 1: Map of the Study Area

2.2. Beer sampling

Sampling was carried out among producers and, in some cases, sellers in local markets. Due to the clustered distribution of production sites in the Moyen Chari province, a random sampling strategy was applied. A total of 30 samples were collected and divided between two seasons (dry and rainy seasons). The collected samples were placed in sterile, appropriate containers, labeled, and transported in insulated coolers maintained at approximately 4 °C to the laboratory, where microbiological analyses were performed.



Figure 2: Djalaa Samples

2.3. Microbiological analyses

Standard microbiological methods were used to assess the hygienic quality of djalaa beer samples. Serial decimal dilutions (10^{-1} to 10^{-6}) were prepared in triplicate, and only plates containing between 33 and 333 colonies were considered⁷.

Total coliforms were enumerated using the membrane filtration technique according to ISO 4832⁸. Samples were filtered through sterile membranes (0.45 μ m), placed on TTC-Tergitol agar, and incubated at 36°C for 21 h. Colonies were expressed as CFU/mL.

Escherichia coli detection was performed according to ISO 16649-2⁹ using TBX agar. Plates were incubated at 44°C for 24 h, and characteristic blue-green colonies were counted.

Salmonella spp. detection followed ISO 6579-1¹⁰ procedures, including pre-enrichment, selective enrichment, and isolation on XLD and Hektoen agar media.

Yeasts were enumerated according to ISO 21527-1¹¹ using Sabouraud agar incubated at 25-30°C for 5 days.

3. STATISTICAL ANALYSIS

Data were analyzed using Microsoft Excel 2016 and GraphPad Prism version 8.0.1. Results were expressed as mean $\pm$ standard error of mean (SEM). One-way ANOVA followed by Tukey's post hoc test was used to compare means between groups. Statistical significance was set at $p \leq 0.05$.

4. RESULTS

4.1. *Escherichia coli*

Figure 3A illustrates the levels of *Escherichia coli* in local beer during the dry season. The results show that *E. coli* was detected in all analyzed samples, with marked

variability between sampling sites. The highest concentration was recorded in one site with a value of 10.33 CFU/mL, while the lowest value was 2 CFU/mL, indicating the presence of fecal contamination even during the dry season.

Figure 3B highlights the potential fecal contamination of djala beer during the rainy season through the detection of *Escherichia coli* in all sampling sites. The concentrations varied considerably between locations. The highest level was observed in one site, exceeding 114.3 CFU/mL, whereas the lowest concentration was 70 CFU/mL. Overall, the results indicate a substantial increase in *E. coli* contamination during the rainy season compared to the dry season.

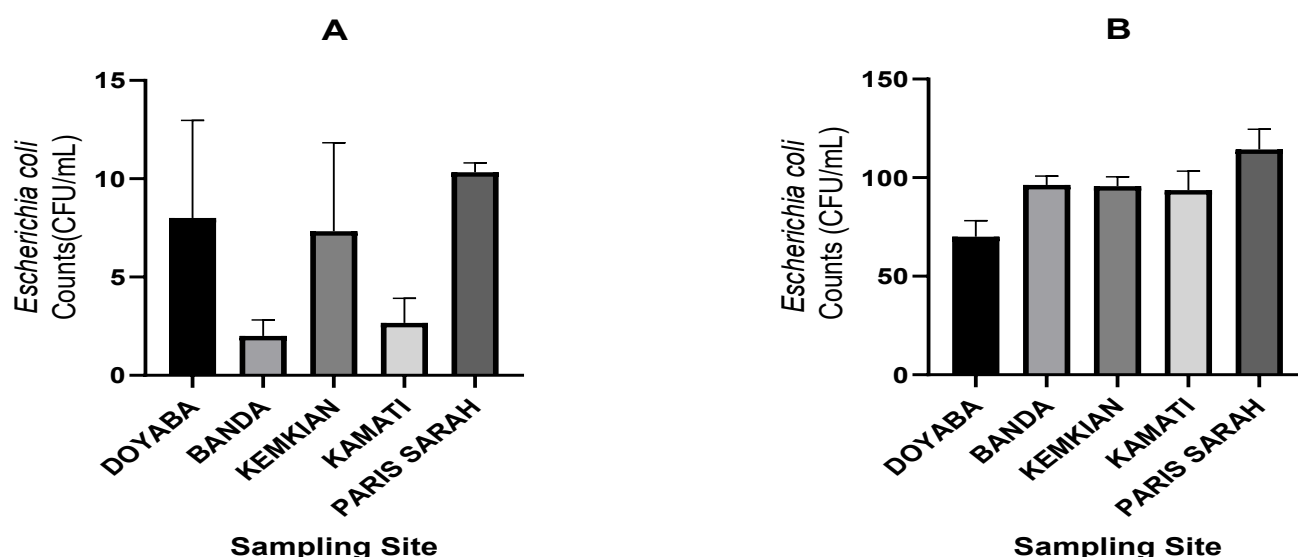


Figure 3: *Escherichia coli* counts during the dry and rainy seasons
Each value represents the mean $\pm$ SEM, $n = 5$. $P < 0.05$. A: dry season; B: rainy season.

4.2. Total coliforms

Figure 4A shows the variable presence of total coliforms in djala local beer samples during the dry season. The lowest count was recorded at one sampling site with a value of 70 CFU/mL, while the highest value reached 114.33 CFU/mL, indicating a possible deterioration of the microbiological quality of the product.

Figure 4B illustrates the levels of total coliforms in djala beer during the rainy season. The lowest concentration was observed at one site with a value of 7.7 CFU/mL, whereas the highest count reached 483.33 CFU/mL, highlighting a significant increase in microbial contamination during this season.

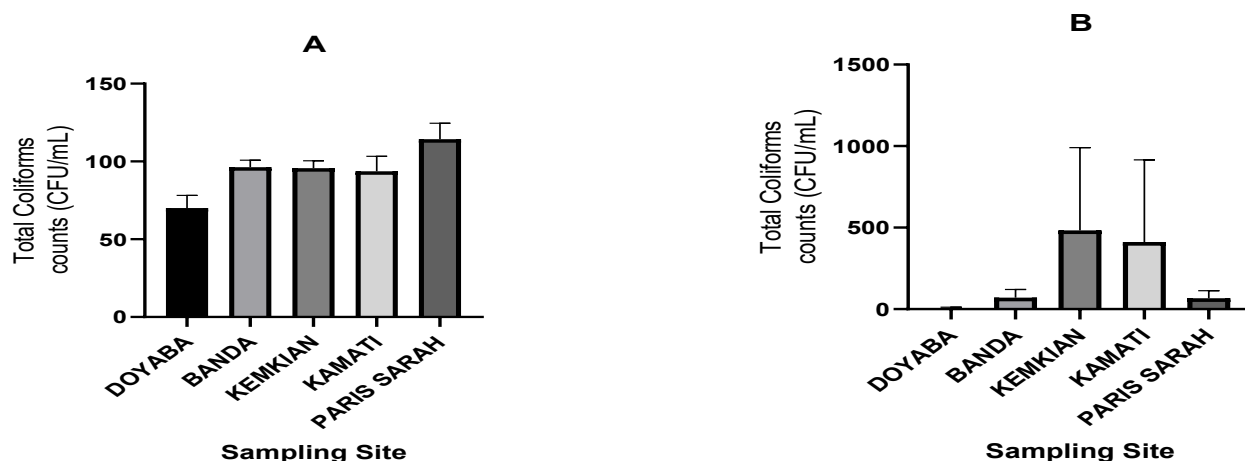


Figure 4: Total Coliforms counts during the dry and rainy seasons
Each value represents the mean $\pm$ SEM, $n = 5$. $P < 0.05$. A: dry season; B: rainy season.

4.3. *Salmonella* spp.

Figure 5A illustrates the levels of *Salmonella* spp. detected in djala local beer samples from the five production sites during the dry season. The results show a generally low average presence of *Salmonella* spp. across all studied sites. However, the lowest mean value was recorded at one site (0.33 CFU/mL), while the highest mean value was observed at another site, reaching 3 CFU/mL.

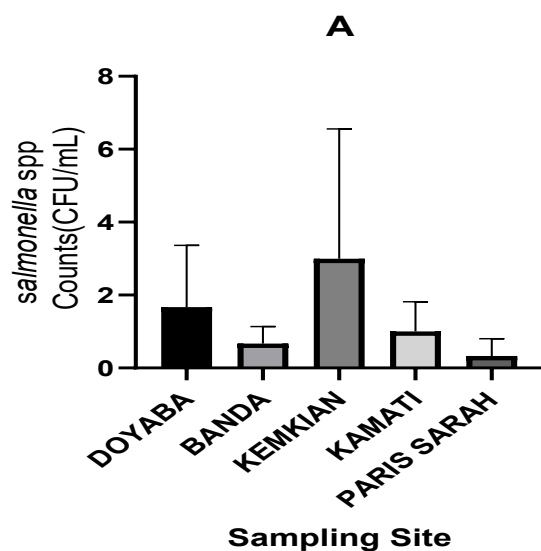


Figure 5B shows that *Salmonella* spp. was detected in all production sites during the rainy season. The highest mean concentration was observed at one site, reaching 6.1 CFU/mL, whereas the lowest mean value was recorded at another site with 1.33 CFU/mL. Overall, the results indicate an increase in *Salmonella* spp. contamination during the rainy season compared to the dry season.

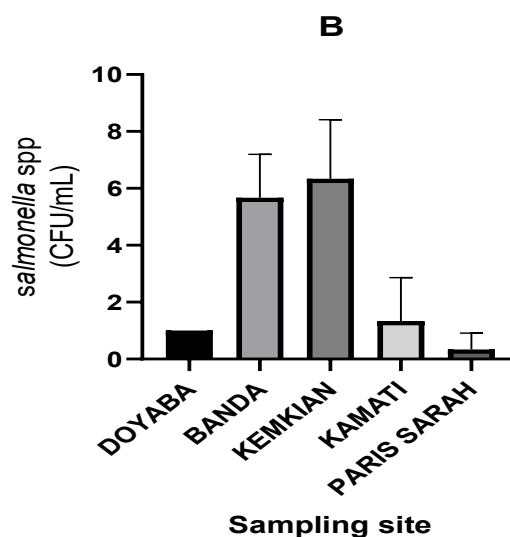


Figure 5: *Salmonella* spp counts during the dry and rainy seasons

Each value represents the mean $\pm$ SEM, $n = 5$. $P < 0.05$. A: dry season; B: rainy season.

4.4. Yeast evaluation during dry and rainy seasons

The table below presents yeast counts in djala local beer during the dry and rainy seasons. The results show that yeast concentrations varied between sampling sites within each season, as well as between seasons. The highest yeast count was observed during the rainy season at one site, reaching $16,266.66 \pm 4,688.81$

CFU/mL, while the lowest value was recorded at another site with $10,001 \pm 0.67$ CFU/mL. In the dry season, the highest count was $10,666.67 \pm 888.9$ CFU/mL, whereas the lowest value was 9.33 ± 0.4 CFU/mL. Overall, the results indicate higher yeast loads during the rainy season compared to the dry season, suggesting a seasonal influence on microbial proliferation in djala beer.

Table 1: Determination of yeast counts during the dry and rainy seasons

Sampling sites	Rainy season	Dry season
DOYABA	$10001 \pm 0,67$	70 ± 40
BANDA	$11433,33 \pm 955,56$	$10,33 \pm 0,4$
KEMKIAN	$12100 \pm 133,33$	$10666,67 \pm 888,9$
KAMATI	$16266,66 \pm 4688,81$	3340 ± 440
PARIS SARAH	$8440 \pm 5546,67$	$9,33 \pm 0,4$

Each value represents the mean $\pm$ SEM

5. DISCUSSION

The present study revealed significant seasonal variations in the microbiological quality of djala beer. *Escherichia coli* contamination was substantially higher during the rainy season, suggesting increased fecal contamination associated with environmental

conditions such as rainfall, humidity, and runoff^{4,12}. Increased precipitation may facilitate the transfer of fecal microorganisms from surrounding environments into water sources and raw materials used during the brewing process. According to World Health Organization reports, inadequate sanitation and poor

access to clean water remain major factors contributing to the contamination of traditional foods and beverages in developing countries¹⁷. Similar observations have been documented in studies of traditional cereal-based fermented beverages in West and Central Africa, where seasonal fluctuations strongly influenced microbial contamination levels¹⁸.

The presence of total coliforms also indicated poor hygienic practices during production and handling. Total coliforms are widely recognized as indicators of sanitary quality and environmental contamination. Their occurrence in fermented beverages generally reflects deficiencies in equipment sanitation, water quality, handling practices, and storage conditions^{5,13}. In traditional brewing systems, the use of non-sterilized utensils and open fermentation vessels increases the risk of contamination by environmental microorganisms. Previous studies on traditional sorghum beers have demonstrated that inadequate hygiene during processing significantly increases coliform counts and reduces product safety^{19,20}.

The detection of *Salmonella* spp. in all samples represents a major public health concern due to its high pathogenic potential, even at low infectious doses. Even at low concentrations, *Salmonella* spp. remains a dangerous pathogen due to its infectious potential^{6,14}. The presence of this pathogen may be associated with contaminated water, poor personal hygiene among handlers, or cross-contamination during processing and marketing. Salmonellosis remains one of the leading causes of foodborne illnesses worldwide and is particularly problematic in regions where food safety control measures are limited²¹. The persistence of *Salmonella* in fermented beverages has been reported in several studies and highlights the need for improved hygienic practices and effective microbial monitoring systems²².

Yeast proliferation was more pronounced during the rainy season due to favorable environmental conditions such as humidity and moderate temperatures^{15,16}. Environmental humidity enhances microbial growth and may accelerate fermentation processes. Although yeasts play a fundamental role in ethanol production and flavor development, excessive proliferation may negatively affect the organoleptic characteristics of fermented beverages, leading to undesirable flavors, excessive gas production, and reduced shelf life. Similar findings have been reported in studies investigating traditional African fermented beverages, where seasonal climatic conditions significantly influenced yeast dynamics and fermentation performance²³.

Furthermore, the elevated microbial loads observed during the rainy season may reflect the combined effects of increased environmental contamination, poor storage conditions, and the absence of standardized production practices. Traditional brewing processes often rely on spontaneous fermentation, which, although culturally important, may expose the product

to diverse microbial contaminants. The implementation of good manufacturing practices (GMP), good hygienic practices (GHP), and hazard analysis critical control point (HACCP) principles could significantly improve the microbiological safety of djalaa beer²⁴.

Overall, these findings indicate insufficient hygienic conditions during production, storage, and marketing of djalaa beer. The results emphasize the necessity for regular microbiological monitoring, producer training programs, improved sanitation measures, and the adoption of standardized fermentation procedures to ensure consumer safety and enhance the quality of this traditional beverage.

6. CONCLUSION

This study demonstrated significant microbiological contamination of traditional djalaa beer sold in Sarh, Chad, with higher contamination levels observed during the rainy season. The detection of *Escherichia coli*, total coliforms, and *Salmonella* spp. indicates inadequate hygienic conditions during the production, handling, and storage processes. Seasonal environmental factors significantly influenced microbial loads, leading to increased contamination risks during the rainy period. The results obtained confirm that djalaa beer may constitute a potential public health risk when produced and marketed under uncontrolled sanitary conditions. All these findings highlight the necessity of implementing Good Manufacturing Practices (GMP), Good Hygienic Practices (GHP), and regular microbiological quality control measures to improve the safety and quality of this traditional beverage. These measures would contribute to consumer protection and promote the sustainable production of djalaa beer.

Conflicts of interest: The authors declare that they have no conflicts of interest.

Author Contributions: FBRE designed the study, conducted field sampling, performed laboratory analyses, analyzed the data, and drafted the manuscript. AKN, BTK, and BH contributed to laboratory analyses, data interpretation, and manuscript revision. DG supervised the study, provided scientific guidance, reviewed the manuscript, and coordinated the overall research activities. All authors read and approved the final version of the manuscript.

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