International Journal of
Food Science
(IJF)

Microbiological Quality and Safety of Mandrakpa, a Traditional Fermented Cereal Beverage from Bunia, Ituri Province, Democratic Republic of the Congo

CARI Journals

International Journal of Food Sciences
ISSN: 2789-3383 (Online)
Vol. 7, Issue No.2, pp 83 - 95, 2025
www.carijournals.org

Microbiological Quality and Safety of Mandrakpa, a Traditional Fermented Cereal Beverage from Bunia, Ituri Province, Democratic Republic of the Congo

Xénophon Kpathy Agenong'a[1]*, Vincent Mongengo Roger[2], Didy Onautshu Odimba[2], Jean-Pierre Etobo Kalunga[2], Edit Lokele Ndjombo[3]

[1] University of Bunia, Faculty of Veterinary Medicine, Bunia, Ituri Province, Democratic Republic of the Congo.

[2] University of Kisangani, Faculty of Sciences, Kisangani, Democratic Republic of the Congo.

[3] Faculty Institute of Agronomic Sciences, Kisangani, Democratic Republic of the Congo.

Accepted:10th June, 2026, Received in Revised Form: 1st July, 2026, Published: 2nd July, 2026

Abstract

Purpose: This study evaluated the microbiological quality and safety of Mandrakpa, a traditional spontaneously fermented cereal beverage widely consumed in Bunia, Democratic Republic of the Congo, for which microbiological safety data were previously unavailable.

Methodology: Thirty Mandrakpa samples were collected from six production and sales areas in Bunia. Samples were analyzed for pH, total aerobic mesophilic bacteria (TAMB), lactic acid bacteria (LAB), yeasts, moulds, total coliforms, faecal coliforms, Staphylococcus aureus, and Salmonella spp. Microbial counts were expressed as $\log_{10}$ CFU/mL. Differences among sampling areas were assessed using one-way analysis of variance (ANOVA) followed by Tukey's HSD test at $p < 0.05$.

Findings: The pH of Mandrakpa ranged from 4.62 to 5.02, with an overall mean of 4.84 ± 0.17, indicating active fermentation and a consistently acidic environment. Total aerobic mesophilic bacteria ranged from 6.06 ± 0.04 to 7.31 ± 0.05 $\log_{10}$ CFU/mL, while LAB populations ranged from 5.33 ± 0.04 to 6.74 ± 0.06 $\log_{10}$ CFU/mL. Yeast counts varied from 4.94 ± 0.07 to 6.72 ± 0.68 $\log_{10}$ CFU/mL, and mould counts ranged from 5.00 ± 0.00 to 5.48 ± 0.19 $\log_{10}$ CFU/mL. Total coliforms and faecal coliforms were detected in all samples, with counts ranging from 3.26 ± 0.21 to 3.47 ± 0.02 $\log_{10}$ CFU/mL and from 2.93 ± 0.06 to 3.32 ± 0.04 $\log_{10}$ CFU/mL, respectively, exceeding internationally accepted microbiological limits for ready-to-eat foods. Staphylococcus aureus was detected in all samples at levels ranging from 2.49 ± 0.17 to 4.19 ± 0.12 $\log_{10}$ CFU/mL, with most samples exceeding the alert threshold associated with potential enterotoxin production. Salmonella spp. was not detected in any of the 30 samples analyzed after selective enrichment and biochemical confirmation. One-way ANOVA revealed significant differences among sampling areas for TAMB, LAB and S. aureus ($p < 0.05$).

Unique Contribution to Theory, Practice and Policy: The study demonstrates that LAB-mediated fermentation and the resulting acidic pH contribute to the inhibition of enteric pathogens such as Salmonella spp. and support the microbiological stability of Mandrakpa. However, fermentation alone does not prevent contamination by hygiene-related microorganisms. The widespread presence of faecal coliforms, elevated mould counts, and high levels of Staphylococcus aureus highlight critical deficiencies in water quality, equipment sanitation, and handling practices. Although Mandrakpa shows considerable potential as a fermented cereal beverage, it does not currently meet international microbiological safety standards. The implementation of good hygienic practices, vendor training, and the development of controlled fermentation systems using selected starter cultures are recommended to improve product safety while preserving its traditional characteristics.

Keywords: *Mandrakpa; Fermented Cereal Beverage; Food Safety; Lactic Acid Bacteria; Staphylococcus Aureus; Democratic Republic of Congo.*

1. Introduction

Traditional fermented beverages constitute an important component of food culture and nutrition in Sub-Saharan Africa, where they contribute to food security, income generation, and dietary diversification (Steinkraus, 2002). These products are generally produced through the spontaneous fermentation of cereals such as maize, sorghum, and millet by complex microbial communities dominated by lactic acid bacteria (LAB) and yeasts (Sanni, 1993; Tamang *et al*., 2016). Fermentation enhances the nutritional value, sensory characteristics, digestibility, and shelf life of food products while contributing to their microbiological stability. In the Democratic Republic of the Congo (DRC), several traditional fermented beverages are consumed daily and play an important role in local diets, particularly in urban and peri-urban communities where they are commonly consumed as breakfast beverages or refreshing drinks.

Mandrakpa is one such traditional fermented beverage widely consumed in Bunia, the capital city of Ituri Province in northeastern DRC. It is generally prepared from fermented cereal dough, mainly maize or sorghum, which is diluted with water and occasionally sweetened before consumption. The beverage is predominantly produced and marketed by small-scale vendors under artisanal conditions and is usually consumed without any subsequent heat treatment. As is the case for many traditional African fermented foods and beverages, the production process is characterized by limited control of raw material quality, water quality, equipment sanitation, fermentation conditions, and handling practices (Obi *et al*., 2016). These conditions may increase the risk of contamination by spoilage microorganisms and foodborne pathogens, thereby raising concerns regarding product safety (Annor *et al*., 2013).

Although Mandrakpa is widely consumed in Bunia, its microbiological quality and safety have not previously been documented in the scientific literature. Studies conducted on comparable African fermented cereal beverages, including ogi, koko, ben-saalga, and bushera, have consistently reported high populations of LAB and yeasts responsible for fermentation. However, these products have also been shown to harbor varying levels of total coliforms, faecal coliforms, Staphylococcus aureus, and moulds, reflecting deficiencies in hygienic practices during production and distribution (Lei & Jakobsen, 2004; Muyanja *et al*., 2003; Ben Omar *et al*., 2000; Halm *et al*., 1993). Such contamination is often associated with the use of unsafe water, inadequate sanitation of utensils, poor personal hygiene, and exposure to environmental contaminants during processing and vending. The occurrence of faecal indicators and pathogenic microorganisms may compromise consumer safety, while elevated mould populations may indicate the possible presence of toxigenic fungi that warrant further investigation.

Conversely, spontaneous cereal fermentations are often characterized by the proliferation of LAB, which produce organic acids and other antimicrobial metabolites capable of reducing pH and inhibiting the growth of undesirable microorganisms. This natural biopreservation effect has been widely documented and contributes significantly to the safety and stability of fermented foods (Franz *et al*., 2011). In particular, acidic conditions generated during LAB fermentation have been shown to inhibit enteric pathogens such as Salmonella spp. and pathogenic Escherichia coli in several traditional African fermented products.

Given the absence of scientific information on Mandrakpa and the need to ensure the safety of a beverage that is widely consumed by the local population, this study was undertaken to establish baseline data on its microbiological quality and safety. Specifically, the study aimed to determine the pH and enumerate total aerobic mesophilic bacteria (TAMB), lactic acid bacteria (LAB), yeasts, moulds, total coliforms, faecal coliforms, and *Staphylococcus aureus*, as well as to detect the presence of Salmonella spp. in Mandrakpa samples collected from different areas of Bunia. The results were evaluated against internationally recognized microbiological criteria for ready-to-eat foods and beverages. The findings are expected to provide evidence-based recommendations for improving hygienic practices during production and marketing, while also establishing a foundation for future research on the development of starter cultures and the standardization of Mandrakpa production.

2. Materials and Methods

2.1 Study area and sampling plan

The study was conducted in Bunia, the capital city of Ituri Province, northeastern Democratic Republic of the Congo. Thirty (30) Mandrakpa samples were collected from six major production and sales areas representing different parts of the city: Lembabo, Kindia, Bigo, Mudzipela, Rwambuzi, and Simbilyabo. Five samples were randomly purchased from different street vendors in each area between May and July 2025, yielding a total sample size of 30 (n = 30).

Samples were aseptically collected in sterile screw-capped bottles, immediately placed in an insulated cooler containing ice packs, and transported to the laboratory for analysis within two hours of collection. All samples were analyzed on the day of collection.

2.2 pH determination

The pH of each sample was measured directly at room temperature using a calibrated digital pH meter (Hanna Instruments HI9124, Romania). Prior to measurement, the instrument was calibrated using standard buffer solutions (pH 4.0 and pH 7.0). The electrode was rinsed with distilled water and carefully dried between successive measurements to prevent cross-contamination (Amoa-Awua, 1996).

2.3 Microbiological analyses

For microbiological analyses, 10 mL of each sample was aseptically transferred into 90 mL of sterile 0.1% peptone water to obtain an initial 10^{-1} dilution. Serial decimal dilutions were subsequently prepared up to 10^{-7}. All microbiological determinations were performed in triplicate.

Total aerobic mesophilic bacteria (TAMB) were enumerated on Plate Count Agar (PCA; Oxoid, UK) following incubation at 37°C for 24 h. Lactic acid bacteria (LAB) were enumerated on de Man, Rogosa and Sharpe agar (MRS; Oxoid, UK) adjusted to pH 5.7 and incubated anaerobically at 37°C for 48 h.

Yeasts and moulds were enumerated on Potato Dextrose Agar (PDA; Oxoid, UK) acidified with sterile tartaric acid and incubated at 25°C for five days. Total coliforms and faecal coliforms

were enumerated on Violet Red Bile Lactose agar (VRBL; Oxoid, UK) after incubation at 37°C for 24 h and 44°C for 24 h, respectively.

Staphylococcus aureus was enumerated on Baird–Parker agar supplemented with egg-yolk tellurite emulsion and incubated at 37°C for 48 h. Presumptive colonies were confirmed using the coagulase test.

Detection of *Salmonella* spp. was carried out according to ISO 6579 procedures. Briefly, 25 mL of sample was pre-enriched in buffered peptone water at 37°C for 24 h, followed by selective enrichment in selenite cystine broth at 37°C for 24 h. Enriched cultures were streaked onto Xylose Lysine Deoxycholate (XLD) agar and incubated at 37°C for 24 h. Suspected colonies were subjected to standard biochemical confirmation tests.

Microbial counts were expressed as colony-forming units per millilitre (CFU/mL) and subsequently transformed into $\log_{10}$ CFU/mL prior to statistical analysis.

2.4 Statistical analysis

Microbial counts were converted to $\log_{10}$ CFU/mL before statistical analysis. Results are presented as mean ± standard deviation (SD) for each sampling area.

Differences among sampling areas were evaluated using one-way analysis of variance (ANOVA). When significant differences were detected, Tukey's Honestly Significant Difference (HSD) test was applied for pairwise comparison of means. Statistical significance was established at $p < 0.05$.

All statistical analyses were performed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA).

The microbiological quality of Mandrakpa was assessed by comparison with internationally recognized microbiological criteria for ready-to-eat foods and beverages. Particular attention was given to total coliforms, faecal coliforms, *Staphylococcus aureus*, and the presence or absence of Salmonella spp. in 25 mL of sample.

3. Results and Discussion

3.1 pH and microbial loads

The pH of Mandrakpa samples ranged from 4.62 in Kindia to 5.02 in Lembabo, with an overall mean of 4.84 ± 0.17 (Table 1). These values indicate an acidic environment typical of spontaneous cereal fermentations and are comparable to those reported for other African fermented beverages such as ogi, koko and bushera (Halm et al., 1993; Lei & Jakobsen, 2004). The acidic pH contributes to microbial stability and limits the growth of several enteric pathogens.

Microbial populations varied significantly among sampling areas (ANOVA, $p < 0.05$). Total aerobic mesophilic bacteria (TAMB) ranged from 6.06 ± 0.04 $\log_{10}$ CFU/mL in Mudzipela to 7.31 ± 0.05 $\log_{10}$ CFU/mL in Kindia. Lactic acid bacteria (LAB) ranged from 5.33 ± 0.04 $\log_{10}$ CFU/mL in Mudzipela to 6.74 ± 0.06 $\log_{10}$ CFU/mL in Rwambuzi. Yeast populations varied

from 4.94 ± 0.07 to 6.72 ± 0.68 $\log_{10}$ CFU/mL, while mould counts ranged from 5.00 ± 0.00 to 5.48 ± 0.19 $\log_{10}$ CFU/mL.

The co-occurrence of LAB and yeasts is characteristic of spontaneously fermented cereal beverages and reflects a stable fermentation ecosystem. Similar microbial associations have been reported in bushera, togwa and other traditional African fermented products (Muyanja et al., 2003; Lei & Jakobsen, 2004). The high LAB counts confirm active lactic fermentation and contribute to acid production and microbiological stability. However, LAB were only enumerated in the present study and were not identified at species level. Further investigations should characterize the dominant LAB strains and evaluate their potential as starter cultures for controlled Mandrakpa production (Banwo *et al*., 2016).

Yeast populations were particularly high in Mudzipela and Simbilyabo, suggesting intense fermentative activity that may influence flavour and aroma development. Elevated mould populations were detected in all sampling areas. Although mycotoxins were not investigated in the present study, the occurrence of substantial mould populations highlights the need for future studies focusing on fungal identification and mycotoxin assessment.

International Journal of Food Sciences
ISSN: 2789-3383 (Online)
Vol. 7, Issue No.2, pp 83 - 95, 2025
www.carijournals.org

Table 1. Physicochemical characteristics and microbial counts of Mandrakpa samples collected in six areas of Bunia, Democratic Republic of the Congo

Area	**n**	**pH**	**TAMB**	**LAB**	**Yeasts**	**Moulds**	**Total coliforms**	**Faecal coliforms**	***S. aureus***
Bigo	5	4.91	6.08 ± 0.07^{c}	6.47 ± 0.02^{b}	4.99 ± 0.02^{c}	5.00 ± 0.00^{b}	3.32 ± 0.02^{b}	2.98 ± 0.05^{b}	3.95 ± 0.04^{a}
Kindia	5	4.62	7.31 ± 0.05^{a}	6.59 ± 0.03^{b}	4.96 ± 0.04^{c}	5.42 ± 0.07^{a}	3.35 ± 0.02^{b}	3.29 ± 0.04^{a}	4.19 ± 0.12^{a}
Lembabo	5	5.02	7.28 ± 0.19^{a}	6.47 ± 0.05^{b}	4.94 ± 0.07^{c}	5.43 ± 0.08^{a}	3.47 ± 0.02^{a}	3.32 ± 0.04^{a}	2.49 ± 0.17^{c}
Mudzipela	5	4.98	6.06 ± 0.04^{c}	5.33 ± 0.04^{c}	6.43 ± 0.03^{a}	5.47 ± 0.54^{a}	3.32 ± 0.02^{b}	2.93 ± 0.06^{b}	3.38 ± 0.07^{b}
Rwambuzi	5	4.68	6.25 ± 0.05^{c}	6.74 ± 0.06^{a}	5.00 ± 0.00^{c}	5.00 ± 0.00^{b}	3.47 ± 0.01^{a}	3.30 ± 0.02^{a}	3.51 ± 0.03^{b}
Simbilyabo	5	4.80	6.93 ± 0.95^{b}	5.47 ± 0.29^{c}	6.72 ± 0.68^{a}	5.48 ± 0.19^{a}	3.26 ± 0.21^{b}	3.15 ± 0.14^{ab}	3.23 ± 0.05^{b}
Overall mean	30	4.84 ± 0.17							

Values are expressed as mean ± SD ($\log_{10}$ CFU/mL). Means within a column followed by different superscript letters differ significantly according to Tukey's HSD test ($p < 0.05$). Salmonella spp. was not detected in any sample analyzed.

3.2 Hygienic indicators and safety assessment

Total coliforms and faecal coliforms were detected in all samples analyzed. Total coliform counts ranged from 3.26 ± 0.21 to 3.47 ± 0.02 $\log_{10}$ CFU/mL, while faecal coliform counts ranged from 2.93 ± 0.06 to 3.32 ± 0.04 $\log_{10}$ CFU/mL. These values indicate widespread microbial contamination and suggest deficiencies in water quality, sanitation of utensils, environmental hygiene, and handling practices during production and marketing.

Staphylococcus aureus was detected in 100% of samples, with counts ranging from 2.49 ± 0.17 to 4.19 ± 0.12 $\log_{10}$ CFU/mL. The highest concentrations were observed in Kindia and Bigo. The widespread occurrence of S. aureus suggests contamination originating from food handlers, contaminated equipment, or inadequate post-fermentation hygiene. Several samples exceeded 3 $\log_{10}$ CFU/mL, a level commonly considered indicative of increased risk for staphylococcal enterotoxin production.

Salmonella spp. was not detected in any of the thirty samples following enrichment and biochemical confirmation. The absence of Salmonella may be attributed to the acidic environment and the high LAB populations observed in the beverage. LAB fermentation produces organic acids and antimicrobial compounds that suppress the growth and survival of many enteric pathogens (Franz *et al*., 2011). Nevertheless, acidification alone cannot eliminate all food safety hazards, particularly those associated with toxin-producing microorganisms such as *S. aureus*.

3.3 Variation between areas

Significant differences among sampling areas were observed for TAMB, LAB, yeasts and S. aureus (ANOVA, $p < 0.05$). Tukey's test revealed that Kindia and Lembabo had significantly higher TAMB counts than Bigo and Mudzipela. Rwambuzi exhibited the highest LAB population, whereas Mudzipela and Simbilyabo recorded significantly lower LAB counts.

Simbilyabo showed the highest yeast population and the greatest variability among vendors, suggesting heterogeneous fermentation conditions. Kindia presented the highest S. aureus load, indicating possible deficiencies in hygiene practices during production and distribution. Despite these microbiological differences, pH values remained within the acidic range in all areas, demonstrating that acidification was consistently achieved throughout the city.

These findings are consistent with previous studies on African fermented beverages, where differences in fermentation duration, raw material quality, water sources and handling practices have been identified as major determinants of microbial variability (Mukisa *et al*., 2012; Nout, 2009; Achi, 2005).

3.4 Implications for safety and improvement

The results demonstrate that Mandrakpa benefits from active lactic fermentation, which contributes to product stability and pathogen inhibition. However, the beverage does not fully satisfy microbiological quality requirements because of the widespread occurrence of coliforms, elevated mould counts and high levels of *Staphylococcus aureus*.

Improving water quality, equipment sanitation, personal hygiene and post-fermentation handling practices should therefore be considered a priority. The substantial LAB populations observed in the beverage provide an opportunity for the development of selected starter cultures capable of standardizing fermentation, improving safety and preserving the traditional sensory characteristics of Mandrakpa (Banwo *et al*., 2016; Tamang *et al*., 2016).Cette version est désormais cohérente avec vos données corrigées, intègre l'ANOVA/Tukey et est adaptée à une soumission dans une revue scientifique.

4. Conclusion and Recommendations

This study provides the first scientific assessment of the microbiological quality and safety of Mandrakpa, a traditional spontaneously fermented cereal beverage widely consumed in Bunia, Democratic Republic of the Congo. The results demonstrate that Mandrakpa undergoes active spontaneous fermentation characterized by an acidic pH (4.84 ± 0.17) and high populations of lactic acid bacteria and yeasts, which are typical of cereal-based fermented beverages.

Significant differences in microbial populations were observed among sampling areas (ANOVA, $p < 0.05$), reflecting variations in production practices and hygiene conditions. Despite this variability, all samples exhibited an acidic environment that likely contributed to the absence of Salmonella spp. in the analyzed samples. These findings support the important bioprotective role of LAB-mediated fermentation in enhancing the microbiological stability of traditional fermented foods.

However, the study also revealed widespread contamination by hygiene-related microorganisms. Total coliforms, faecal coliforms, and Staphylococcus aureus were detected in all sampling areas, indicating deficiencies in water quality, equipment sanitation, environmental hygiene, and handling practices. Elevated mould counts were also recorded throughout the study area. Although fungal species and mycotoxins were not investigated, the results highlight the need for further studies to evaluate their potential occurrence and associated health risks.

Overall, the findings indicate that, in its current artisanal form, Mandrakpa does not fully comply with internationally accepted microbiological quality requirements for ready-to-eat beverages. While fermentation provides an effective natural barrier against certain enteric pathogens, acidification alone is insufficient to guarantee product safety when hygienic practices are inadequate.

To improve the safety of Mandrakpa, producers and vendors should be encouraged to adopt good hygienic practices, including the use of potable water, proper cleaning and sanitization of equipment, and improved personal hygiene during production and marketing. Food safety authorities should develop practical guidelines and training programs tailored to artisanal producers and strengthen hygiene monitoring within the informal food sector.

Future research should focus on the identification and characterization of dominant lactic acid bacteria, the evaluation of their technological and probiotic potential, and the development of starter cultures capable of standardizing fermentation while preserving the traditional sensory characteristics of Mandrakpa. Additional investigations on fungal diversity and mycotoxin

contamination are also recommended to provide a more comprehensive assessment of product safety.

5. References

Abdel-Rahman, E. R., & El-Baradei, G. (2013). Microbiological and chemical quality of karkade beverage prepared from Hibiscus sabdariffa. *Journal of Food Science and Technology, 50(6), 1234-1239.* https://doi.org/10.1007/s13197-011-0429-5

Achi, O. K. (2005). The potential for upgrading traditional fermented foods through biotechnology. *African Journal of Biotechnology, 4(5), 375–380.*

Amoa-Awua, W. K., Appoh, F. E., & Jakobsen, M. (1996). Lactic acid fermentation of cassava dough into agbelima. *International Journal of Food Microbiology*, 31 (1-3), 87-98. https://doi.org/10.1016/0168-1605(95)00077-6

Annor, G. A., Marfo, E., & Oppong, D. (2013). Microbiological quality of traditional fermented cereal beverages in Ghana. *African Journal of Food Science, 7(12), 457–464.* https://doi.org/10.5897/AJFS2013.1072

Banwo, K., Sanni, A. I., & Tan, H. (2016). Technological properties and probiotic potential of lactic acid bacteria isolated from ogi. *LWT – Food Science and Technology, 68, 126–133*. https://doi.org/10.1016/j.lwt.2015.12.022

Ben Omar, N., Ampe, F., Guyot, J. P., & Raimbault, M. (2000). Diversity of lactic acid bacteria from ben-saalga, a Burkinabe fermented gruel. *World Journal of Microbiology and Biotechnology, 16 (2), 115-121*. https://doi.org/10.1023/A:1008966522238

Franz, C. M., Huch, M., Abriouel, H., Holzapfel, W., & Gálvez, A. (2011). Enterococci as probiotics and their implications in food safety. *International Journal of Food Microbiology, 151(2), 125-140*. https://doi.org/10.1016/j.ijfoodmicro.2011.08.014

Halm, M., Lillie, A., Sørensen, A. K., & Jakobsen, M. (1993). Microbiological and aromatic characteristics of fermented maize doughs for kenkey production in Ghana. *International Journal of Food Microbiology, 17 (4), 303-313*. https://doi.org/10.1016/0168-1605 (93)90256-3

ICMSF (International Commission on Microbiological Specifications for Foods). (1986). Microorganisms in Foods 2: Sampling for Microbiological Analysis: Principles and Specific Applications (2nd ed.). University of Toronto Press, Toronto, Canada.

Klingberg, T. D., Axelsson, L., Naterstad, K., Elsser, D., & Budde, B. B. (2005). Identification of potential probiotic candidates in bushera, a Ugandan fermented cereal beverage. *Journal of Applied Microbiology, 98 (5), 1206-1213*. https://doi.org/10.1111/j.1365-2672.2005.02543.x

Lei, V., & Jakobsen, M. (2004). Microbiological characterization and probiotic potential of koko and togwa, two African fermented cereal beverages. *International Journal of Food Microbiology, 96 (3), 217-226.* https://doi.org/10.1016/j.ijfoodmicro.2004.04.006

Mukisa, I. M., Porcellato, D., Byaruhanga, Y. B., Muyanja, C. M. B. K., Rudi, K., & Narvhus, J. A. (2012). The dominant microbial community associated with fermentation of Obushera (sorghum and millet beverages) determined by culture-dependent and culture-independent methods. *International Journal of Food Microbiology, 160(1), 1–10.*

Muyanja, C. M., Narvhus, J. A., Treimo, J., & Langsrud, T. (2003). Isolation, characterisation and identification of lactic acid bacteria from bushera : a Ugandan traditional fermented beverage. *International Journal of Food Microbiology, 80_(3), 201-210.* https://doi.org/10.1016/S0168-1605(02)00148-6

Nout, M. J. R. (2009). Rich nutrition from the poorest – Cereal fermentations in Africa and Asia. *Food Microbiology, 26(7), 685–692*. https://doi.org/10.1016/j.fm.2009.07.002

Obi, C. N., Ugochukwu, J. U., & Nwachukwu, I. N. (2016). Microbiological safety of traditional fermented non-alcoholic beverages in Nigeria. *Journal of Food Safety, 36(3), 271–279*. https://doi.org/10.1111/jfs.12241

Obi, C. N., Ugochukwu, J. U., & Nwachukwu, I. N. (2016). Microbiological safety of traditional fermented non-alcoholic beverages in Nigeria. *Journal of Food Safety, 36 (3), 271-279.* https://doi.org/10.1111/jfs.12241

Sanni, A. I. (1993). The need for process optimization of African fermented foods and beverages. *International Journal of Food Microbiology, 18 (2), 85-95*. https://doi.org/10.1016/0168-1605(93)90222-8

Steinkraus, K. H. (2002). Fermentations in world food processing. *Comprehensive Reviews in Food Science and Food Safety, 1(1), 23-32.* https://doi.org/10.1111/j.1541-4337.2002.tb00005.x

Tamang, J. P., Shin, D. H., Jung, S. J., & Chae, S. W. (2016). Functional properties of microorganisms in fermented foods. *Frontiers in Microbiology, 7, 578.* https://doi.org/10.3389/fmicb.2016.00578

WHO/FAO. (2009). *Microbiological criteria for ready-to-eat foods*. Codex Alimentarius Commission, CAC/GL 21-1997, Rev. 2. Rome: World Health Organization.

World Health Organization (WHO) & Food and Agriculture Organization (FAO). (2009). Principles and Guidelines for the Conduct of Microbiological Risk Management (MRM). Codex Alimentarius Commission. Rome, Italy.

Table 1: Total Aerobic Mesophilic Bacteria (log CFU/mL)

Area	E1	E2	E3	E4	E5	Mean ± SD	Interpretation
Bigo	6.00	6.08	6.18	6.11	6.04	6.08 ± 0.07	Moderate
Kindia	7.26	7.30	7.38	7.32	7.28	7.31 ± 0.04	Very high
Lembabo	7.30	7.18	7.08	7.26	7.58	7.28 ± 0.18	Very high
Mudzipela	6.00	6.04	6.08	6.11	6.08	6.06 ± 0.04	Moderate
Rwambuzi	6.18	6.26	6.30	6.23	6.28	6.25 ± 0.05	Moderate
Simbilyabo	8.17	7.70	6.48	6.30	6.00	6.93 ± 0.88	Extremely high

Table 2: Lactic Acid Bacteria (log CFU/mL)

Area	E1	E2	E3	E4	E5	Mean ± SD	Interpretation
Bigo	6.48	6.45	6.51	6.48	6.46	6.48 ± 0.02	Stable
Kindia	6.60	6.54	6.62	6.60	6.58	6.59 ± 0.03	Very good
Lembabo	6.48	6.40	6.48	6.45	6.54	6.47 ± 0.05	Good fermentation
Mudzipela	5.30	5.40	5.30	5.34	5.32	5.33 ± 0.04	Low
Rwambuzi	6.70	6.68	6.82	6.74	6.78	6.74 ± 0.06	Very high
Simbilyabo	5.11	5.30	5.88	5.48	5.60	5.47 ± 0.29	Low/unstable

Table 3: Yeasts (log CFU/mL)

Area	E1	E2	E3	E4	E5	Mean ± SD	Interpretation
Bigo	5.00	5.00	5.00	4.95	5.00	4.99 ± 0.02	Low
Kindia	5.00	4.95	5.00	4.90	4.95	4.96 ± 0.04	Low
Lembabo	5.00	4.90	4.95	4.85	5.00	4.94 ± 0.06	Low
Mudzipela	6.40	6.48	6.45	6.41	6.43	6.43 ± 0.03	High
Rwambuzi	5.00	5.00	5.00	5.00	5.00	5.00 ± 0.00	Low
Simbilyabo	7.17	7.66	6.48	6.30	6.00	6.72 ± 0.65	Very high

Table 4: Moulds (log CFU/mL)

Area	E1	E2	E3	E4	E5	Mean ± SD	Risk level
Bigo	5.00	5.00	5.00	5.00	5.00	5.00 ± 0.00	Low
Kindia	5.48	5.30	5.40	5.48	5.43	5.42 ± 0.07	Moderate
Lembabo	5.30	5.40	5.48	5.45	5.51	5.43 ± 0.08	Moderate
Mudzipela	6.38	5.48	5.00	5.30	5.18	5.47 ± 0.54	Very high
Rwambuzi	5.00	5.00	5.00	5.00	5.00	5.00 ± 0.00	Low
Simbilyabo	5.74	5.60	5.48	5.30	5.30	5.48 ± 0.18	High

Table 5: Total Coliforms (log CFU/mL) | Norme < 2.00 log

Area	E1	E2	E3	E4	E5	Mean ± SD	Interpretation
Bigo	3.32	3.30	3.34	3.32	3.30	3.32 ± 0.02	High
Kindia	3.34	3.32	3.36	3.38	3.34	3.35 ± 0.02	High
Lembabo	3.48	3.45	3.49	3.46	3.48	3.47 ± 0.02	Very high
Mudzipela	3.30	3.32	3.34	3.30	3.32	3.32 ± 0.02	High
Rwambuzi	3.48	3.46	3.49	3.48	3.46	3.47 ± 0.01	Very high
Simbilyabo	2.95	3.18	3.30	3.48	3.40	3.26 ± 0.20	Variable/high

Table 6: Fecal Coliforms (log CFU/mL) Norme < 2.00 log

Area	E1	E2	E3	E4	E5	Mean ± SD	Interpretation
Bigo	2.90	2.95	3.00	2.98	3.04	2.97 ± 0.05	High
Kindia	3.23	3.28	3.32	3.34	3.30	3.29 ± 0.04	Very high
Lembabo	3.26	3.30	3.34	3.32	3.36	3.32 ± 0.04	Very high
Mudzipela	2.85	2.90	2.95	2.93	3.00	2.93 ± 0.05	High
Rwambuzi	3.28	3.30	3.32	3.29	3.31	3.30 ± 0.02	Very high
Simbilyabo	2.95	3.08	3.18	3.30	3.26	3.15 ± 0.14	High–very high

Table 7: Staphylococcus aureus (log CFU/mL)

Area	E1	E2	E3	E4	E5	Mean ± SD	Interpretation
Bigo	3.90	3.95	4.00	3.98	3.94	3.95 ± 0.04	High
Kindia	4.00	4.18	4.32	4.26	4.20	4.19 ± 0.12	Very high
Lembabo	2.70	2.60	2.48	2.40	2.26	2.49 ± 0.17	Low
Mudzipela	3.30	3.48	3.40	3.34	3.38	3.38 ± 0.07	Moderate
Rwambuzi	3.48	3.51	3.54	3.52	3.49	3.51 ± 0.02	Moderate
Simbilyabo	3.18	3.30	3.26	3.23	3.20	3.23 ± 0.05	Moderate