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MICROBIAL QUALITY AND CHARACTERIZATION OF BACTERIAL AND FUNGAL CONTAMINANTS IN FERMENTED MILLET PAP SOLD IN KATSINA METROPOLIS, NIGERIA.

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ABSTRACT

Fermented millet pap (akamu) is a popular traditional food in Nigeria, particularly among infants and adults. However, poor hygiene during processing and handling may expose it to microbial contamination, posing potential health risks. This study assessed the microbial quality and characterized bacterial and fungal contaminants in fermented millet pap sold in Unguwar Jaaji, Katsina Metropolis, Nigeria. A total of ten (10) pap samples were collected from different vendors and analyzed using standard microbiological techniques. Bacterial and fungal isolates were identified using Gram staining, biochemical tests, and morphological examination. Data were analyzed using descriptive statistics and expressed as mean ± standard deviation, frequencies, and percentages. The mean aerobic mesophilic bacterial count was $13.34 \pm 3.47 \times 10^8$ CFU/mL, while the mean fungal count was $8.84 \pm 2.08 \times 10^8$ CFU/mL. Staphylococcus aureus (50%) and Penicillium spp. (30%) were the predominant bacterial and fungal isolates, respectively. The high microbial loads and presence of potentially pathogenic organisms indicate poor hygienic practices during production and handling. Improved sanitation, adherence to good manufacturing practices, and routine microbiological monitoring are recommended to ensure the microbiological safety of fermented millet pap.

KEYWORDS: Bacterial load, Characterization, Fungal load, Pap, Katsina state.

1.0 INTRODUCTION

Fermented foods have long been an important component of the diets of many African communities because of their nutritional, sensory, and health benefits. Fermentation enhances food quality by improving digestibility, increasing the bioavailability of nutrients, reducing antinutritional factors, and extending shelf life through the activities of beneficial microorganisms (Karovičová & Kohajdová, 2007). In Nigeria, fermented cereal products constitute a major source of affordable nutrition, particularly among low-income households where access to commercially fortified foods is limited.

Pap (akamu), commonly known as ogi among the Yoruba, akamu among the Igbo, and koko among the Hausa, is one of the most widely consumed fermented cereal foods in Nigeria. Although pap is traditionally prepared from maize, millet (Pennisetum glaucum) and sorghum (Sorghum bicolor) are also commonly used depending on local availability. It is consumed by people of all age groups but is especially important as a complementary food for infants and as a breakfast meal for adults because of its soft texture, ease of digestion, and nutritional value (Kabeer *et al.,* 2024).

The fermentation of pap is largely a spontaneous process driven by naturally occurring microorganisms, particularly lactic acid bacteria and yeasts. These microorganisms contribute to acid production, improve flavour and texture, inhibit the growth of undesirable organisms, and enhance the nutritional quality of the product (Anumudu *et al.,* 2024; Sawant *et al.,* 2025). Despite these benefits, the traditional method of pap production is often carried out under unhygienic conditions that expose the product to contamination during processing, handling, storage, and distribution. The use of contaminated water, poor-quality raw materials, unclean processing equipment, and inadequate personal hygiene among vendors may introduce spoilage microorganisms and foodborne pathogens into the final product.

Microbial contamination of ready-to-eat foods remains a major public health concern because contaminated foods can serve as vehicles for transmitting pathogenic microorganisms. Consumption of contaminated pap may increase the risk of gastrointestinal infections, particularly among infants, young children, older adults, and immunocompromised individuals. The presence of organisms such as Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, and Klebsiella pneumoniae in fermented foods may indicate poor hygienic practices during production and handling, while certain fungal species, including Aspergillus, Penicillium, and Fusarium, are capable of producing mycotoxins that pose additional health risks.

Several studies have investigated the microbiological quality of fermented cereal products in different parts of Nigeria. Afangide (2021) reported the occurrence of Escherichia coli, Staphylococcus aureus, Klebsiella spp., Streptococcus spp., and Pseudomonas spp. in pap sold in Umuahia, with microbial loads exceeding recommended limits. Similarly, Okoli et al. (2023) identified elevated bacterial and fungal counts in stored pap and demonstrated that poor storage conditions significantly increased microbial contamination. Mbochi et al. (2023) also reported high microbial loads in pap sold in the Federal Capital Territory and associated the contamination with poor sanitation, contaminated water, and inadequate handling practices. Collectively, these studies demonstrate that microbial contamination of fermented pap is a persistent food safety challenge across different regions of Nigeria.

Although previous investigations have provided valuable information on the microbiological quality of pap, most were conducted in locations outside Katsina State. Furthermore, the findings of these studies cannot be directly applied to Katsina because microbial contamination is influenced by geographical location, environmental conditions, processing methods, water quality, storage practices, and vendor hygiene. Consequently, there is limited location-specific information on the microbiological quality of fermented millet pap sold in Unguwar Jaaji, Katsina Metropolis. The lack of such data limits evidence-based food safety interventions and public health decision-making in the area.

Therefore, this study was undertaken to evaluate the microbial quality of fermented millet pap sold in Unguwar Jaaji, Katsina Metropolis, Nigeria. Specifically, the study aimed to: To determine the aerobic mesophilic bacterial and fungal loads of fermented millet pap samples; To isolate and identify the bacterial species present using Gram staining and biochemical characterization; To identify the fungal isolates using morphological and microscopic characteristics; and to determine the frequency of occurrence of the identified bacterial and fungal isolates.

To guide the investigation, the following hypotheses were formulated: Null hypothesis (H_0): Fermented millet pap sold in Unguwar Jaaji, Katsina Metropolis, does not contain microbial loads or microbial contaminants of public health significance. Alternative hypothesis (H_1): Fermented millet pap sold in Unguwar Jaaji, Katsina Metropolis, contains microbial loads and contaminants of public health significance that may pose health risks to consumers.

2.0 MATERIALS AND METHODS

2.1 Study Area

This study was conducted in Unguwar Jaaji, Katsina Metropolis, Katsina State, Nigeria. Katsina Metropolis is located in the Sudan Savannah ecological zone of northwestern Nigeria and experiences a tropical continental climate characterized by distinct wet and dry seasons. Unguwar Jaaji is a densely populated urban community where fermented millet pap is commonly produced and sold by numerous roadside vendors and small-scale processors. The area was selected because fermented pap constitutes an important component of the daily diet of residents, particularly infants, children, and adults, thereby making its microbiological safety a significant public health concern.

2.2 Study Design

A cross-sectional descriptive laboratory-based study was conducted to evaluate the microbial quality and characterize bacterial and fungal contaminants in fermented millet pap sold in Unguwar Jaaji, Katsina Metropolis.

2.3 Sample Size Determination

A total of ten (10) fermented millet pap samples were analyzed in this preliminary study. The sample size was selected based on the number of accessible vendors available during the sampling period and the available laboratory resources. Similar microbiological investigations of locally produced ready-to-eat foods have employed comparable sample sizes for preliminary assessments. Although a larger sample size would improve statistical power and generalizability, the present study provides baseline information on the microbiological quality of fermented millet pap sold within the study area.

2.4 Sampling Technique and Sample Collection

A simple random sampling technique was adopted to minimize sampling bias. Ten fermented millet pap samples were purchased from ten different vendors located at different selling points within Unguwar Jaaji, Katsina Metropolis. Only vendors actively selling freshly prepared fermented millet pap during the sampling period were included in the study.

Approximately 250 mL of each sample was aseptically collected into sterile, labeled sample containers. The samples were immediately placed in an insulated ice box and transported to the Microbiology Laboratory, Hassan Usman Katsina Polytechnic, where laboratory analyses commenced within two hours of collection.

2.5 Materials and Equipment

The materials used included Nutrient Agar, MacConkey Agar, Potato Dextrose Agar (PDA), peptone water, sterile distilled water, normal saline, Gram staining reagents, Kovac's reagent,

methyl red reagent, citrate medium, Triple Sugar Iron (TSI) agar, hydrogen peroxide, phenol red indicator, carbohydrate fermentation media, immersion oil, sterile Petri dishes, sterile pipettes, Durham tubes, glass slides, cover slips, conical flasks, beakers, and inoculating loops. Equipment included an autoclave, incubator, hot-air oven, compound light microscope, pH meter, analytical balance, refrigerator, and colony counter.

2.6 Sterilization of Materials

All glassware was washed thoroughly with laboratory detergent, rinsed with distilled water, and sterilized in a hot-air oven at 180°C for two hours. Culture media and heat-resistant materials were sterilized in an autoclave at 121°C under 15 psi pressure for 15 minutes before use. Working surfaces were disinfected with 70% ethanol before and after laboratory procedures.

2.7 Preparation of Culture Media

Culture media were prepared according to the manufacturers' instructions. Nutrient Agar and MacConkey Agar were used for bacterial isolation, while Potato Dextrose Agar supplemented with chloramphenicol was used for fungal isolation. Prepared media were sterilized by autoclaving, cooled to approximately 45–50°C, and aseptically dispensed into sterile Petri dishes.

2.8 Sample Preparation and Serial Dilution

One gram (1 g) of each pap sample was aseptically transferred into 9 mL of sterile peptone water to obtain the stock suspension (10^{-1} dilution). Serial ten-fold dilutions were subsequently prepared up to 10^{-6} by transferring 1 mL of the previous dilution into 9 mL of sterile diluent. Appropriate dilutions (10^{-5} and 10^{-6}) were used for microbial enumeration.

2.9 Enumeration of Aerobic Mesophilic Bacteria and Fungi

Aliquots of 0.1 mL from appropriate dilutions were inoculated onto duplicate Nutrient Agar and Potato Dextrose Agar plates using the spread plate technique. Nutrient Agar plates were incubated at 37°C for 24 hours, while PDA plates were incubated at 28 ± 2°C for 72–120 hours.

After incubation, colonies were counted using a digital colony counter, and microbial counts were expressed as colony-forming units per millilitre (CFU/mL) using:

$$\text{CFU/mL} = \frac{\text{Number of colonies} \times \text{Dilution factor}}{\textit{Volume plated}}$$

2.10 Isolation and Identification of Bacterial Isolates

Following incubation, morphologically distinct bacterial colonies were aseptically selected from the primary culture plates and repeatedly subcultured on freshly prepared Nutrient Agar plates using the streak plate technique to obtain pure cultures. The purified isolates were subsequently maintained on sterile Nutrient Agar slants at 4°C until further characterization. Identification of bacterial isolates was carried out based on colony morphology, Gram staining, and standard biochemical tests following established microbiological procedures.

2.10.1 Gram Staining

Gram staining was performed to differentiate bacterial isolates into Gram-positive and Gram-negative organisms based on the structural characteristics of their cell walls. A thin smear of each pure isolate was prepared on a clean grease-free microscope slide using sterile normal saline. The smear was air-dried and heat-fixed before staining.

The fixed smear was flooded with crystal violet for 60 seconds and rinsed gently with distilled water. Lugol's iodine solution was applied as a mordant for one minute, followed by decolorization with 95% ethanol for approximately 20 seconds. The smear was immediately rinsed with distilled water to stop the decolorization process and counterstained with safranin for 30 seconds. After air drying, the stained smear was examined microscopically using the oil immersion objective (×100). Purple-stained cells were recorded as Gram-positive, whereas pink or red-stained cells were recorded as Gram-negative.

2.10.2 Catalase Test

The catalase test was performed to determine the ability of bacterial isolates to produce the enzyme catalase, which decomposes hydrogen peroxide into water and oxygen. A drop of 3% hydrogen peroxide was placed on a clean microscope slide, and a small portion of a 24-hour-old bacterial colony was emulsified in the reagent using a sterile inoculating loop. Immediate production of effervescence (oxygen bubbles) was interpreted as a positive reaction, whereas the absence of bubbles indicated a negative reaction.

2.10.3 Motility Test

The motility test was conducted to determine whether the bacterial isolates possessed flagella responsible for active movement. A loopful of each overnight culture was suspended in a drop of sterile peptone water placed on a clean microscope slide and covered with a cover slip. The preparation was examined microscopically under high-power magnification. Directional movement of bacterial cells indicated a positive motility test, while organisms exhibiting only Brownian motion were regarded as non-motile.

2.10.4 Carbohydrate Fermentation Test

Carbohydrate fermentation tests were carried out using glucose, lactose, sucrose, and mannitol to evaluate the fermentative ability of the bacterial isolates. Individual carbohydrate media were prepared by dissolving the appropriate sugar in sterile peptone water containing phenol red indicator. Sterile inverted Durham tubes were inserted into each test tube before sterilization by autoclaving.

Following cooling, each medium was inoculated with a pure bacterial culture and incubated at 37°C for 24 hours. A change in the colour of the medium from red to yellow indicated acid production resulting from carbohydrate fermentation, while gas accumulation within the Durham tube indicated gas production.

2.10.5 Indole Test

The indole test was performed to determine the ability of bacterial isolates to hydrolyse tryptophan into indole using the enzyme tryptophanase. Each isolate was inoculated into sterile peptone water and incubated at 37°C for 48 hours. Following incubation, 0.5 mL of Kovac's reagent was carefully added to each culture tube. Development of a distinct cherry-red ring at the surface of the medium indicated a positive indole reaction, whereas the absence of a coloured ring indicated a negative result.

2.10.6 Methyl Red Test

The methyl red test was carried out to determine the ability of bacterial isolates to produce stable acidic end products from glucose fermentation. Each isolate was inoculated into sterile MR-VP broth and incubated at 37°C for 48 hours. Following incubation, several drops of methyl red indicator were added to each culture. Development of a bright red colour indicated a positive reaction, whereas a yellow or orange colour indicated a negative reaction.

2.10.7 Voges–Proskauer Test

The Voges–Proskauer (VP) test was performed to detect acetoin production during glucose metabolism through the butylene glycol fermentation pathway. Following incubation of bacterial isolates in MR-VP broth at 37°C for 48 hours, Barritt's reagent A (α-naphthol) and Barritt's reagent B (40% potassium hydroxide) were added sequentially to the culture tubes. The tubes were gently shaken and allowed to stand for 15–30 minutes. Development of a pink to deep red colour indicated a positive VP reaction, while no colour change indicated a negative reaction.

2.10.8 Citrate Utilization Test

The citrate utilization test was performed using Simmons Citrate Agar to determine the ability of bacterial isolates to utilize citrate as their sole carbon source. Pure bacterial cultures

were lightly streaked onto the surface of Simmons Citrate Agar slants and incubated aerobically at 37°C for 24–48 hours. Development of visible bacterial growth accompanied by a colour change of the medium from green to blue was interpreted as a positive reaction, while no growth and no colour change indicated a negative result.

2.10.9 Coagulase Test

The coagulase test was performed to differentiate coagulase-positive Staphylococcus aureus from coagulase-negative staphylococci. A small quantity of each bacterial isolate was emulsified in a drop of sterile normal saline on a clean microscope slide. A drop of plasma was added and gently mixed with the bacterial suspension. Formation of visible clumping or agglutination within 10–15 seconds indicated a positive coagulase reaction, whereas absence of agglutination indicated a negative reaction.

2.10.10 Triple Sugar Iron (TSI) Test

The Triple Sugar Iron (TSI) test was performed to evaluate carbohydrate fermentation patterns, gas production, and hydrogen sulfide (H_2S) production by bacterial isolates. Each isolate was inoculated into TSI agar slants by stabbing the butt and streaking the slant surface with a sterile inoculating needle. The inoculated tubes were incubated at 37°C for 20 hours. Reactions were interpreted based on changes in the slant and butt colours, gas formation, and black precipitate formation. An alkaline slant with an acidic butt (K/A) indicated glucose fermentation only, while an acidic slant and butt (A/A) indicated fermentation of glucose and one or more additional sugars. Blackening of the medium indicated hydrogen sulfide production.

2.11 Identification of Fungal Isolates

Fungal isolates were purified on Potato Dextrose Agar and identified based on colonial morphology and microscopic characteristics using lactophenol cotton blue staining. Identification was performed with reference to standard fungal identification manuals, considering colony texture, pigmentation, hyphal characteristics, conidiophore arrangement, and spore morphology.

2.12 Quality Assurance and Quality Control

To ensure the reliability of laboratory results, all microbiological analyses were conducted under strict aseptic conditions. Culture media were quality-checked before use, and sterility controls were included for each batch of prepared media. Laboratory equipment was calibrated according to manufacturers' recommendations before analysis. All microbiological exami

nations were performed in duplicate, and the average values were reported. Standard operating procedures were followed throughout the study to minimize analytical errors and cross-contamination.

2.13 Statistical Analysis

Data were entered into Microsoft Excel 2021 and analyzed using IBM SPSS Statistics version 27.0. Microbial counts were expressed as mean ± standard deviation (SD). Frequencies and percentages were calculated for bacterial and fungal isolates. Where appropriate, one-way analysis of variance (ANOVA) was used to compare microbial counts among samples, with statistical significance set at $p < 0.05$.

3.0 RESULTS

3.1 Biochemical Characterization of Bacterial Isolates

The biochemical characteristics of bacterial isolates recovered from fermented millet pap samples are presented in Table 1. Gram staining showed that five isolates (S1, S2, S4, S6, and S7) were Gram-positive, while the remaining isolates were Gram-negative. All isolates exhibited positive catalase reactions, indicating their ability to produce catalase enzyme. Most isolates utilized citrate as the sole carbon source, whereas indole production was observed only in isolates S5 and S10. Voges–Proskauer-positive reactions were recorded for isolates S3 and S9, while the remaining isolates were negative.

Triple Sugar Iron (TSI) reactions demonstrated predominantly alkaline slant/acid butt (K/A) reactions, indicating glucose fermentation. Based on the combined results of Gram staining and biochemical characterization, the bacterial isolates were provisionally identified as Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli, and Klebsiella pneumoniae (Table 1).

Table 1: Summary of Biochemical tests and Gram staining from the Samples Collected.

Samples	G.Stain	indole	Catalase	VP	coagulase	MR	citrate	TSI	H_2S	INFERENCE
S1	+	-	+	-	+	+	+	K/A	+	*S.aureus*
S2	+	-	+	-	+	+	+	K/A	+	*S. aureus*
S3	-	-	+	+	-	-	+	K/A	-	*P. aeroginosa*
S4	+	-	+	-	+	+	+	K/A	-	*S. aureus*
S5	-	+	+	-	-	+	-	K/A	-	*E. coli*

S6	+	-	+	-	+	+	+	K/A	-
	S. aureus								
S7	+	-	+	-	+	+	+	K/S	-
	S. aureus								
S8	+	-	+	-	+	+	+	K/S	-
	E. coli								
S9	-	-	+	+	-	-	+	K/S	
	- *P.aeruginosa*								
S10	-	+	+	-	-	+	-	K/S	-
	K. pneumonia								

KEY: Positive (+), Negative (-), K (Basic), A (Acidic), S (Neutral)

3.2 Morphological Characterization of Fungal Isolates

The macroscopic and microscopic characteristics of fungal isolates are presented in Table 2. Identification was based on colony morphology, pigmentation, hyphal structure, conidiophore arrangement, and spore morphology. Five fungal genera were identified: Aspergillus spp., Penicillium spp., Fusarium spp., Candida albicans, and Saccharomyces cerevisiae. Penicillium spp. were the most frequently encountered fungal isolates, whereas Candida albicans was detected least frequently among the samples analyzed.

Table 2: Macroscopic and Microscopic of fungal isolates.

Isolates	Macroscopic characteristics	Microscopic characteristics	Inference
S1	Large black colonies	Septate hyphae, non septate conidiosphore	*Aspergillus spp*
S2	White colonies with cotton like appearance	Repeatedly branched conidiophore and septate hyphae	*Penicillium spp*
S3	least abundant, elongated, cylindrical, slightly curved,	Branched conidiosphore	*Fusarium spp*
S4	Small, oval, measuring 2-4 µm in diameter.	Septate hyphae	*C. albicans*
S5		Oval, cylindrical, or ovoid blastopores that vary in length, appearing either short or elongated based on the strain.	*S. cerevisiae*
S6	White colonies with cotton like appearance	Repeatedly branched conidiophore and septate hyphae	*Penicillium spp*
S7	Large black colonies	Septate hyphae, non septate conidiosphore	*Aspergillus spp*
S8		Oval, cylindrical, or ovoid blastopores that vary in size and length according to the strain.	*S. cerevisiae*
S9	White colonies with cotton like appearance	Repeatedly branched conidiophore and septate hyphae	*Penicillium spp*
S10	least abundant, elongated, cylindrical, slightly curved,	Branched conidiosphore	*Fusarium* spp

3.3 Aerobic Mesophilic Bacterial and Fungal Counts

The aerobic mesophilic bacterial counts varied among the ten fermented millet pap samples, ranging from 9.6 × 10^8 to 20.3 × 10^8 CFU/mL. Sample S5 recorded the highest bacterial count (20.3 × 10^8 CFU/mL), followed by S7 (17.7 × 10^8 CFU/mL), whereas S8 had the lowest count (9.6 × 10^8 CFU/mL). The fungal counts ranged from 5.4 × 10^8 to 12.5 × 10^8 CFU/mL. Sample S3 recorded the highest fungal count (12.5 × 10^8 CFU/mL), while S7 had the lowest fungal count (5.4 × 10^8 CFU/mL). Descriptive statistical analysis showed an overall mean aerobic mesophilic bacterial count of 13.34 ± 3.47 × 10^8 CFU/mL, while the mean fungal count was 8.84 ± 2.08 × 10^8 CFU/mL.

Table 3. Aerobic mesophilic bacterial and fungal counts of fermented millet pap samples.

Pap sample	AMBC (×10^8 CFU/mL)	Fungal count (×10^8 CFU/mL)
S1	15.7	6.1
S2	10.7	9.1
S3	13.9	12.5
S4	10.2	8.4
S5	20.3	11.1
S6	11.7	9.2
S7	17.7	5.4
S8	9.6	8.3
S9	12.7	10.1
S10	10.9	8.2
Mean ± SD	**13.34 ± 3.47**	**8.84 ± 2.08**
Minimum	**9.6**	**5.4**
Maximum	**20.3**	**12.5**

Key: AMBC = aerobic mesophilic bacterial count; CFU/mL = colony-forming units per millilitre; SD = standard deviation

3.4 Frequency of Occurrence of Bacterial Isolates

Four bacterial species were recovered from the ten fermented millet pap samples. Staphylococcus aureus had the highest frequency of occurrence, being detected in five of the ten samples (50%). Pseudomonas aeruginosa and Escherichia coli were each detected in two samples (20%), while Klebsiella pneumoniae was detected in one sample (10%).

Table 4. Frequency and percentage occurrence of bacterial isolates.

Isolates	Frequency of occurrence	Percentage (%)
S.aureus	5	50
P. aeruginosa	2	20
E. coli	2	20
K. pneumonia	1	10
Total	**10**	**100**

3.5 Frequency of Occurrence of Fungal Isolates

Five fungal taxa were recovered from the ten fermented millet pap samples. *Penicillium* spp. had the highest frequency of occurrence, being detected in three samples (30%). *Aspergillus* spp., *Fusarium* spp., and *Saccharomyces cerevisiae* were each detected in two samples (20%), while *Candida albicans* was detected in one sample (10%).

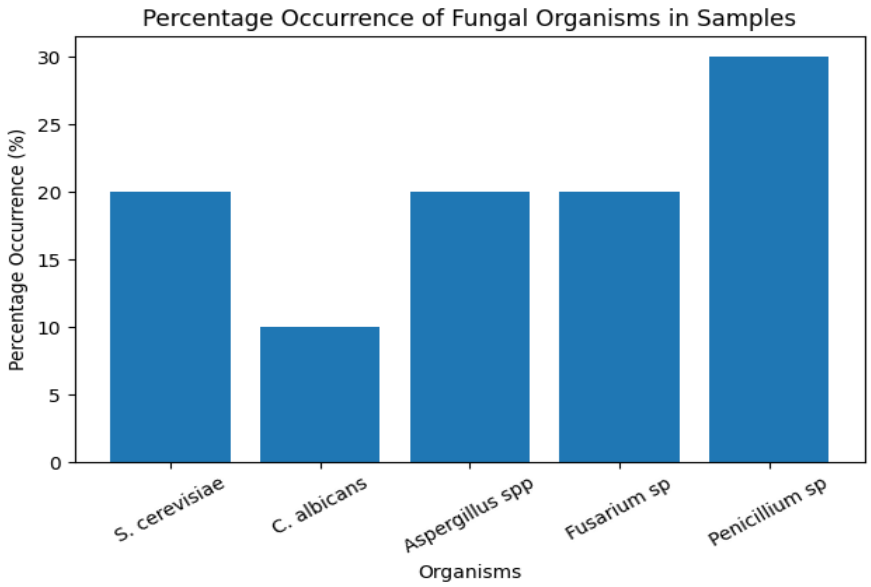

Figure 1: Percentage occurrence of Fungal isolates from the Samples.

4.0 DISCUSSION

The present study revealed considerable bacterial and fungal contamination in fermented millet pap sold in Unguwar Jaaji, Katsina Metropolis. The mean aerobic mesophilic bacterial

count was **13.34 ± 3.47 × 10^8 CFU/mL**, while the mean fungal count was **8.84 ± 2.08 × 10^8 CFU/mL**. The variation among samples suggests differences in processing, handling, storage, and environmental conditions.

The bacterial counts observed were generally higher than those reported by Afangide (2021) and were within the broad range documented for fermented pap by Mbochi et al. (2023). Differences between studies may reflect variations in sampling locations, raw materials, water quality, processing practices, storage conditions, and microbiological methods. These findings emphasize the importance of location-specific assessment of traditionally processed foods.

Staphylococcus aureus was the predominant bacterial isolate (50%), followed by *Escherichia coli* and *Pseudomonas aeruginosa* (20% each), and *Klebsiella pneumoniae* (10%). Similar organisms have been reported in previous studies of pap (Afangide, 2021; Okoli et al., 2023). The frequent occurrence of *S. aureus* may be associated with handling contamination, while the detection of *E. coli* suggests possible deficiencies in sanitation or water quality. However, these potential contamination sources were not directly investigated in the present study and should therefore be interpreted cautiously.

Five fungal taxa were identified, with *Penicillium* spp. being the most frequent (30%). *Aspergillus*, *Fusarium*, *Saccharomyces cerevisiae*, and *Candida albicans* were also recovered. The occurrence of *Aspergillus*, *Penicillium*, and *Fusarium* is of food safety interest because some species within these genera can produce mycotoxins. However, the present study did not determine mycotoxin production; therefore, their detection should not be interpreted as evidence of mycotoxin contamination.

Overall, the findings are consistent with previous reports that fermented pap can be exposed to substantial microbial contamination. The study provides useful location-specific information for Unguwar Jaaji, where limited microbiological data are available. Nevertheless, the small sample size and reliance on culture-based identification limit the generalization of the findings. Further studies involving larger sample sizes, direct assessment of hygiene practices, molecular identification, and mycotoxin analysis are recommended.

The presence of potentially pathogenic bacteria and relatively high microbial loads highlights the need for improved hygiene during pap production, handling, storage, and sale. Good manufacturing practices and regular microbiological monitoring could help improve the safety of fermented millet pap.

5.0 CONCLUSION

This study demonstrated that fermented millet pap sold in Unguwar Jaaji, Katsina Metropolis, harboured considerable bacterial and fungal loads. The bacterial isolates included *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Klebsiella pneumoniae*, while the fungal isolates included *Penicillium* spp., *Aspergillus* spp., *Fusarium* spp., *Saccharomyces cerevisiae*, and *Candida albicans*. The occurrence of potentially pathogenic bacteria indicates that the microbiological quality of the pap requires attention. Although some fungi may be associated with fermentation, the detection of filamentous fungi of food safety concern warrants further investigation. Overall, the findings highlight the need for improved hygienic control during the production, handling, storage, and sale of fermented millet pap.

6.0 RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made:

Improved hygiene: Pap producers and vendors should maintain proper personal hygiene and ensure that processing utensils, containers, and vending environments are kept clean.

Safe water supply: Clean and microbiologically safe water should be used during pap processing to minimize contamination.

Good manufacturing practices: Appropriate hygienic practices should be adopted throughout fermentation, handling, packaging, storage, and distribution.

Proper storage: Fermented pap should be stored under conditions that minimize microbial growth and prevent post-processing contamination.

Food safety monitoring: Relevant public health and regulatory authorities should conduct periodic microbiological monitoring of commercially sold pap to identify potential food safety problems.

Further research: Future studies should involve larger sample sizes and directly assess processing and handling practices. Molecular identification of isolates and mycotoxin analysis should also be considered to provide a more comprehensive assessment of microbiological and toxicological risks.

REFERENCES

1. Al-Joda, B. M. S., & Jasim, A. H. (2021). Biochemical testing revision for identification of several kinds of bacteria. *Journal of University of Babylon for Pure and Applied Sciences, 29*(2), 168–176.
2. Anumudu, C. K., Miri, T., & Onyeaka, H. (2024). Multifunctional applications of lactic acid bacteria: Enhancing safety, quality, and nutritional value in foods and fermented beverages. *Foods, 13*(23), Article 3714. https://doi.org/10.3390/foods13233714
3. El-Sayed, H., Osman, M. E., Abdelsalam, A., Boroujerdi, A., Sonbol, H., & Elsaba, Y. M. (2022). Morphological, molecular and metabolic characterization of the pigmented fungus *Subramaniula asteroids*. *Journal of Fungi, 8*(11), Article 1149. https://doi.org/10.3390/jof8111149
4. Food and Drug Administration. (2005). *Bacteriological analytical manual*. U.S. Department of Health and Human Services.
5. Ibanga, A. N. (2021). *Microbial quality of "ogi" (pap) sold in Umuahia market*. Michael Okpara University of Agriculture. https://repository.mouau.edu.ng/works/microbial-quality-of-ogi-pap-sold-in-umuahia-market-7-2
6. Kabeer, S., Mary, S. J., Govindarajan, N., Essa, M. M., & Qoronfleh, M. W. (2024). Traditional weaning foods and processing methods with fortification for sustainable development of infants to combat zero hunger: A review. *Journal of Food Science and Technology, 61*(12), 2263–2274. https://doi.org/10.1007/s13197-024-06065-2
7. Karovičová, Z. K. J., & Kohajdová, J. (2007). Fermentation of cereals for specific purpose. *Journal of Food and Nutrition Research, 46*(2), 51–57.
8. Kato, S., Yamagishi, A., Daimon, S., Kawasaki, K., Tamaki, H., Kitagawa, W., & Kamagata, Y. (2018). Isolation of previously uncultured slow-growing bacteria by using a simple modification in the preparation of agar media. *Applied and Environmental Microbiology, 84*(19), e00807-18. https://doi.org/10.1128/AEM.00807-18
9. Kurtzman, C. P., Fell, J. W., & Boekhout, T. (Eds.). (2011). *The yeasts: A taxonomic study* (5th ed.). Elsevier.
10. Mbochi, C. A., Shanu, M. A., Egbulefu, C. S., Makanjuola, D. O., Adeoye, B. A., Ahmadu, J. H., Nyam, P. N., Fadesire, A. K., Olukotun, G. B., & Labbo, Z. (2023). The hygiene and microbial quality of pap sold in Mandalla Market, Federal Capital Territory, Nigeria. *Global Scientific Journal, 11*(6).
11. Okoli, F. A., Okonkwo, N. N., Agu, K. C., Nwobu, W. C., Uwanta, L. I., Ifediegwu, M. C., & Umeoduagu, N. D. (2023). Identification of potential microbial contaminants from

stored pap. *International Journal of Progressive Research in Engineering Management and Science, 3*(9), 409–415. https://doi.org/10.58257/IJPREMS32060

12. Ojodomo, B., & Ashar, S. J. (2023). Isolation and identification of possible pathogenic bacteria on carrots sold at community market, Ahmadu Bello University, Zaria. *bioRxiv*.
13. Oyeleke, S. B., & Manga, S. B. (2008). *Essentials of laboratory practicals in microbiology*. Tobest Publishers.
14. Patra, J. K., Das, G., Das, S. K., & Thatoi, H. (2020). Isolation, culture, and biochemical characterization of microbes. In *A practical guide to environmental biotechnology* (pp. 83–133). Springer. https://doi.org/10.1007/978-981-15-6252-5_4
15. Salwan, R., Rana, A., & Sharma, V. (2023). Basic experiments in microbial biochemistry. In *Laboratory methods in microbiology and molecular biology: Methods in molecular microbiology* (Vol. 87). Springer.
16. Sawant, S. S., Park, H.-Y., Sim, E.-Y., Kim, H.-S., & Choi, H.-S. (2025). Microbial fermentation in food: Impact on functional properties and nutritional enhancement—A review of recent developments. *Fermentation, 11*(1), Article 15. https://doi.org/10.3390/fermentation11010015
17. Talaiekhozani, A. (2013). Guidelines for quick application of biochemical tests to identify unknown bacteria. *Account of Biotechnology Research, 2*(2), 65–82.