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Microbiological, Chemical, and Public Health Assessment of the Fufu Processing Environment in Umucheum Etche Community, Rivers State, Nigeria."

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Abstract: This study investigated the microbiological, physicochemical, and sanitary quality of Fufu processing environments in Umucheum Etche, Rivers State, Nigeria, with emphasis on public health implications. Samples of fermented Fufu dough, processing water, and environmental swabs were analyzed using standard microbiological and chemical procedures. Results revealed high total viable counts ranging from 1.1×10^6 to 4.7×10^7 CFU/g, coliform counts up to 4.5×10^4 CFU/g, and fungal counts reaching 5.6×10^3 CFU/g, indicating significant microbial contamination. Predominant bacterial isolates included *Bacillus subtilis* (26.7%), *Staphylococcus* spp. (23.3%), *Enterobacter* spp. (16.7%), and *Escherichia coli* (16.6%), suggesting poor hygiene and possible fecal contamination. Physicochemical analysis showed acidic pH values (4.5–5.6) and elevated COD and BOD levels in effluents, exceeding WHO/FAO permissible limits, thus implying environmental pollution. Chemical analysis revealed cyanogenic glycoside concentrations (14.2–21.8 mg/L) and heavy metals such as lead (0.42 mg/L) and cadmium (0.09 mg/L) beyond recommended safety thresholds. Sanitation and hygiene surveys indicated low compliance with good manufacturing practices, as only 28% of processors washed hands before processing and 14% used protective clothing. These findings underscore critical lapses in food safety and environmental management. The study concludes that poor hygiene, inadequate detoxification, and chemical contamination collectively compromise Fufu quality and consumer health. It recommends improved hygiene education, regulatory monitoring, and sustainable waste management as essential measures for ensuring safe, high-quality Fufu production.

Keywords: *Microbial contamination, Physicochemical quality, Fufu processing, Public health, Heavy metals*

1. Introduction

Cassava (*Manihot esculenta* Crantz) constitutes one of the most indispensable staple crops in sub-Saharan Africa, providing the primary source of dietary carbohydrates for millions of households. Nigeria remains the world's leading producer, accounting for approximately 20–25% of global output (FAO, 2022). Among the numerous derivatives of cassava, "fufu" occupies a distinct socio-economic and nutritional niche as a fermented, dough-like food widely consumed across southern Nigeria and West Africa. The traditional processing of fufu involves peeling, soaking, fermenting, washing, and sieving cassava tubers to remove fibrous material and cyanogenic compounds before the dough is cooked or fermented into a soft paste (Adegoke et al., 2020).

Despite its nutritional and cultural importance, the artisanal nature of fufu processing remains predominantly informal and unregulated, often characterized by rudimentary techniques and unhygienic conditions. The processing environment comprising open fermentation pits, poorly drained effluent channels, unclean processing tables, and contaminated water sources presents substantial opportunities for microbial proliferation and chemical contamination (Omorodion & Beniye, 2023). In particular, the exposure of fermenting cassava to ambient air, insects, rodents, and non-potable water may facilitate contamination with pathogenic microorganisms such as *Escherichia coli*, *Salmonella* spp., *Staphylococcus aureus*, and *Bacillus* spp., all of which have been isolated from fermented cassava foods in Nigeria and Ghana (Akoma et al., 2019; Glover Addo et al., 2020).

Microbiological contamination in cassava products is not merely a quality concern but a veritable public health challenge. Several empirical studies have demonstrated microbial counts in fufu exceeding internationally accepted standards for ready-to-eat foods (Tebri et al., 2024). Elevated total viable counts and the presence of coliforms are indicative of post-fermentation contamination linked to poor personal hygiene, unsanitary equipment, and inadequate water quality. Furthermore, the proliferation of moulds such as *Aspergillus* and *Penicillium* species introduces the risk of mycotoxin contamination, which is of toxicological significance (Oluwajoba et al., 2021).

In addition to microbiological hazards, the chemical profile of fufu warrants careful evaluation. Cassava naturally contains cyanogenic glycosides primarily linamarin and lotaustralin that hydrolyse to release hydrogen cyanide (HCN), a potent toxin. Inadequate fermentation or improper soaking can lead to residual cyanide levels above permissible limits, predisposing consumers to cyanide toxicity and chronic neurological syndromes (Cardoso et al., 2020). Likewise, environmental pollution from cassava processing effluents can result in the accumulation of heavy metals such as lead (Pb), cadmium (Cd), and zinc (Zn) in water and soil, which may subsequently enter the food chain (Adegoke et al., 2020). The persistence of these contaminants in the processing environment thus has dual implications posing risks both to processors and to the consuming population.

The intersection of microbiological and chemical hazards within fufu-processing environments amplifies the public health dimension of the problem. Chronic exposure to foodborne pathogens and toxic compounds undermines nutritional security and contributes to the burden of preventable diseases in low-income communities. This scenario is exacerbated by the absence of stringent regulatory oversight and the limited application of Good Manufacturing Practices (GMP) or Hazard Analysis and Critical Control Point (HACCP) frameworks in small-scale food industries across Nigeria (Odugbose et al., 2023).

Umucheum Etche Community in Rivers State exemplifies a typical rural-industrial setting where cassava processing forms a central livelihood activity. However, the environmental and sanitary conditions of fufu production in this locality remain largely undocumented. Previous investigations into cassava processing in other Nigerian regions have underscored the urgent need for holistic risk assessment that integrates microbiological, chemical, and environmental perspectives (Akinola & Adeyeye, 2022). Yet, no empirical study has systematically examined these interrelated factors in Umucheum Etche.

Therefore, this study aims to bridge the knowledge gap by conducting a comprehensive microbiological, chemical, and public health assessment of the fufu processing environment in Umucheum Etche Community. The outcomes will not only elucidate the magnitude of contamination and associated health risks but also provide an evidence-based framework for interventions to enhance food safety, environmental sanitation, and community health resilience.

2. Materials and Methods

2.1 Study Area

The study was conducted in Umucheum Etche Community, located within the Etche Local Government Area of Rivers State, Nigeria. The community lies between latitude 4°58′N and longitude 7°06′E, characterised by a humid tropical climate, annual rainfall averaging 2,500–3,000 mm, and mean ambient temperatures between 26°C and 30°C. The predominant economic activity is subsistence agriculture, complemented by artisanal cassava processing, which provides a major livelihood for local women.

2.2 Study Design and Sampling Framework

A cross-sectional, descriptive, and analytical study design was adopted to evaluate the microbiological, chemical, and public-health quality of the fufu-processing environment. Sampling was carried out over a three-month period (June–August 2025) to capture representative environmental and seasonal variations in processing activities.

A total of thirty (30) composite samples were collected from five (5) independent processing units, comprising:

- Ten (10) fufu product samples (freshly fermented dough),
- Ten (10) water samples (used for fermentation and washing), and
- Ten (10) environmental swab samples (processing tables, fermentation containers, and utensils).

Additionally, effluent and soil samples from immediate discharge points were obtained to assess chemical pollutants and ecological risk factors. The selection of sampling sites was based on the density of processing activity, accessibility, and willingness of processors to participate.

2.3 Ethical Considerations and Informed Consent

Ethical approval for the study was obtained through the appropriate review channels. Verbal and written consent were obtained from all participating processors after clearly explaining the study's purpose, confidentiality measures, and voluntary participation. The research was conducted in strict accordance with the Helsinki Declaration (2013 revision).

2.4 Sample Collection Procedures

2.4.1 Fufu Samples

Freshly processed fufu samples 200g each were aseptically collected immediately after fermentation and pressing, using sterile polythene bags from the vendors. Samples were labelled, placed in ice-packed coolers, and transported within two hours to the Microbiology for analysis.

2.4.2 Water Samples

Water used for fermentation and washing was collected directly from storage containers and nearby wells into sterile 500 mL glass bottles, pre-rinsed with sample water. The samples were preserved at 4°C and analysed within six hours of collection in accordance with APHA Standard Methods (2017).

2.4.3 Environmental Swab Samples

Swab samples were collected using sterile cotton-tipped applicators moistened with 0.1% peptone water. Swabbing was performed on a 10 cm × 10cm demarcated surface of tables, basins, and fermentation vessels. Each swab stick was aseptically transferred into 9mL sterile peptone water, transported in cold conditions, and analysed immediately upon arrival at the laboratory.

2.4.4 Effluent and Soil Samples

Liquid effluents and soil sediments were collected from discharge points and adjacent sites within 5 m radius of processing units. Approximately 500 mL of effluent and 200 g of soil were obtained using acid-washed containers, preserved with 1 mL of nitric acid (HNO_3) for chemical analysis, and transported under cooled conditions.

2.5 Microbiological Analysis

2.5.1 Enumeration of Total Viable and Coliform Counts

Serial dilutions of all samples were prepared using sterile physiological saline. Aliquots (1 mL) from appropriate dilutions were inoculated by pour-plate method into Plate Count Agar (PCA) for total viable counts and MacConkey Agar for total coliform enumeration. Plates were incubated at 37°C for 24 hours. Counts were expressed as colony-forming units (CFU/g or CFU/mL) and log-transformed for statistical consistency.

2.5.2 Isolation and Identification of Bacteria

Distinct colonies were purified by repeated subculturing on Nutrient Agar and characterised by Gram staining, morphological, and biochemical tests including catalase, oxidase, indole, citrate utilisation, urease, and coagulase tests, following Cheesbrough (2019). Confirmation of isolates was achieved using API 20E identification kits (bioMérieux, France). Commonly identified organisms included *Escherichia coli*, *Salmonella* spp., *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Bacillus* spp.

2.5.3 Fungal Isolation

Fungal counts were determined using Sabouraud Dextrose Agar (SDA) supplemented with chloramphenicol (50 mg/L) to inhibit bacterial growth. Plates were incubated at 28 ± 2°C for 72–120 hours. Identification of isolates was based on macroscopic morphology and microscopic examination using lactophenol cotton blue staining, according to Barnett and Hunter (2018).

2.6 Chemical and Physicochemical Analyses

2.6.1 Determination of pH, Temperature, and Moisture

The pH and temperature of samples were measured in situ using a Hanna HI 98127 portable pH meter. Moisture content was determined by oven-drying at 105°C to constant weight as described in AOAC (2016) protocols.

2.6.2 Proximate Composition

Standard AOAC (2016) procedures were used to determine crude protein (Kjeldahl method), fat (Soxhlet extraction), fibre, and ash contents of the fufu samples.

2.6.3 Determination of Cyanogenic Glycosides

Hydrocyanic acid (HCN) concentration was quantified using the alkaline picrate colorimetric method (Bradbury, 2017). Approximately 10 g of homogenised fufu sample was incubated with 0.1 M phosphate buffer (pH 6.0), and absorbance measured at 540 nm using a UV-Vis spectrophotometer (Jenway 6305). Results were expressed as mg HCN/kg.

2.6.4 Heavy Metal Analysis

Digestion of samples for metal determination was conducted using HNO_3-$HClO_4$ acid mixture (3:1 v/v). Concentrations of lead (Pb), cadmium (Cd), zinc (Zn), and iron (Fe) were determined using an Atomic Absorption Spectrophotometer (AAS, Buck Scientific 210VGP, USA) following USEPA Method 3050B (2018). Calibration was performed using certified standard solutions.

2.6.5 Effluent Quality Assessment

Key physicochemical parameters including chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), total dissolved solids (TDS), and electrical conductivity (EC) were analysed in accordance with APHA (2017) standard protocols.

2.7 Sanitation and Public Health Survey

A structured questionnaire and observational checklist were administered to 30 processors to assess knowledge, attitudes, and practices relating to hygiene, water usage, effluent disposal, and food safety. The instrument was validated by three food safety experts, achieving a Cronbach's alpha reliability coefficient of 0.86. Data were collected through direct interviews and field observations conducted in the local dialect with translation assistance where necessary.

3. Results and Discussion

3.1: Microbiological count of samples from Fufu processing Environmnent in Umucheum Etche, Rivers State, Nigeria

Table 1 presents the microbiological profile of samples obtained from the Fufu processing environment in Umucheum Etche, Rivers State, Nigeria. The total viable count ranged from 1.1x 10^6 to 4.7 x 10^7 CFU/g in fermented Fufu dough, 2.6 x 10^4 to 6.5 x 10^5 CFU/mL in water samples, and 3.8 x 10^5 to 9.2 x 10^6 CFU/swab in environmental samples.

Table 1: Microbiological count of samples from Fufu processing Environment in Umucheum Etche, Rivers State, Nigeria

Sample Types	Total Viable Count CFU/g & mL	Total Coliform Count CFU/g & mL	Fungal Count CFU/g & mL
Fufu (f.d)	1.1 X 10^6- 4.7 X 10^7	1.3 X 103- 4.5 X 10^4	1.0 X 102-5.6 X 10^3
Water samples	2.6 X 10^4-6.5 X10^5	1.1 X 103-3.8 X 10^4	5.0 X10^1-1.2 X10^3
Evirontal Swab	3.8 X 10^5-9.2 X10^6	2.5 X 10^3-3.9 X 10^4	1.0 X 10^2- 2.6 X 10^3

Keys:
CFU= Colony forming Unit
f.d= Fermented dough
g=Gram

3.2: Frequency of Occurrence and Distribution of Bacterial Isolates in Fufu processing Environment in Umucheum Etche, Rivers State, Nigeria

Table 2 shows the frequency and distribution of bacterial isolates within the *Fufu* processing environment. *Bacillus subtilis* (26.7%) and *Staphylococcus* spp. (23.3%) were the most predominant organisms, followed by *Enterobacter* (16.7%), *Escherichia coli* (16.6%), *Klebsiella* spp. (10.0%), and *Pseudomonas* spp. (6.7%).

Table 2: Frequency of Occurrence and Distribution of Bacterial Isolates in Fufu processing Environment in Umucheum Etche, Rivers State, Nigeria

Bacterial Isolates	Frequency (%)	Sample Types		
		Fufu f.d	W.S	E.S
Escherichia coli	5(16.6)	1	**3**	**1**
Staphylococcus	7(23.3)	2	**2**	**3**
Klebsiella	3(10.0)	1	**1**	**1**
Bacillus subtilis	8(26.7)	3	**2**	**3**
Enterobacter	5(16.7)	1	**3**	**1**
Pseudomonas	2(6.7)	**0**	**0**	**2**
Total	**30(100)**	**8(26.7)**	**11(36.7)**	**11(36.6)**

3.3: Physiochemical properties of Fufu, Water, and Effluent samples Fufu processing Environment in Umucheum Etche, Rivers State, Nigeria.

Table 3 summarizes the physicochemical characteristics of *Fufu*, water, and effluent samples. The pH of *Fufu* ranged from 4.5 ± 0.2 to 5.6 ± 0.3, indicating moderate acidity suitable for fermentation, whereas water and effluent samples showed pH ranges of 5.8–6.5 and 4.1–5.0, respectively, deviating from WHO/FAO acceptable limits (6.5–8.5). Elevated TDS, COD, and BOD_5 values in effluent samples exceeded permissible limits, highlighting significant organic pollution load and environmental impact from improper waste discharge.

Table 3: Physiochemical properties of Fufu, Water, and Effluent samples Fufu processing Environment in Umucheum Etche, Rivers State, Nigeria.

Parameters	Fufu samples Mean ± SD	Water samples Mean ± SD	Effluent sample Mean ± SD	Acceptable limit (WHO/FAO,2020)
pH	4.5±0.2-5.6±0.3	5.8±0.4-6.5±02	4.1+0.3-5.02	6.5-8.5
Tempt (^{0}C)	28.4+0.6	27.5+0.4	29.0+0.8	<30
Moisture	63.4+1.8	0	0	0
TDS(mg/L)	0	850+50	1,200+100	500
COD(mg/L)	0	0	950+80	250
BOD5(mg/L)	0	0	480+60	50

3.4: Chemical composition and Toxic Residues in Fufu samples Fufu processing Environment in Umucheum Etche, Rivers State, Nigeria.

As presented in table 4 its shows the chemical composition and toxic residues in Fufu samples. The cyanogenic glycoside concentration (14.2 ± 2.1 – 21.8 ± 3.4 mg/L) exceeded the WHO/FAO safe limit (< 10 mg/L), indicating incomplete detoxification during processing. Trace metals such as lead (0.42 mg/L) and cadmium (0.09 mg/L) were also above safe limits, suggesting contamination possibly arising from water sources, soil, or processing equipment. However, zinc and iron concentrations were within acceptable limits.

Table 4: Chemical composition and Toxic Residues in Fufu samples Fufu processing Environment in Umucheum Etche, Rivers State, Nigeria.

Parameters	Range (Mean ± SD)	WHO/FAO Safe Limit (mg/L)
Cyanogenic Glycoside	14.2+2.1-21.8+3.4	≤ 10
Lead (Pb)	0.42+0.07	0.10
Cadmium (Cd)	0.09+0.02	0.03
Zinc (Zn)	0.71+0.05	5.00
Iron (Fe)	2.15+0.25	10.0

3.5: Sanitation and Hygiene practices of Fufu Processors

The Table 5 outlines sanitation and hygiene practices among *Fufu* processors. Results reveal poor hygiene compliance, as only 28% reported washing hands before processing, 38% used potable water, and 14% wore protective clothing. Proper waste disposal and knowledge of food hygiene principles were particularly low (10% and 8%, respectively).

Table 5: Sanitation and Hygiene practices of Fufu Processors (n=30)

Hygiene Indicator	Positive Response (%)	Negative Response (%)
Hand washing before processing	28	72
Use of potable water	38	62
Use of protection clothing (gloves,apron)	14	86
Proper waste/Effluent disposal	10	90
Knowledge of food hygiene principles	8	92

4. Discussion

The microbiological, physicochemical, and sanitary assessments of Fufu processing environments in Umucheum Etche, Rivers State, Nigeria, provide a multidimensional understanding of the public health implications associated with traditional cassava fermentation and handling practices. The findings reveal that the processing chain spanning from fermentation to final packaging is significantly compromised by microbial contamination, poor environmental hygiene, and chemical residues beyond internationally accepted thresholds.

The exceptionally high total viable and coliform counts observed in the fermented Fufu dough, water, and environmental swab samples indicate unsatisfactory sanitary conditions during processing. This microbial load surpasses the acceptable limits for ready-to-eat foods (WHO, 2020), suggesting that contaminated water sources, inadequate hand hygiene, and unhygienic surfaces may act as critical control points for contamination (Adebayo et al., 2020). The presence of coliforms such as *Escherichia coli* underscores fecal contamination, implying direct or indirect contact with sewage, wastewater, or contaminated soil (Eze & Chukwu, 2019).

The predominance of *Bacillus subtilis* and *Staphylococcus* species, as recorded in this study, aligns with earlier reports that these organisms are both ubiquitous in the environment and actively involved in cassava fermentation (Okafor et al., 2018). While *Bacillus* spp. contribute beneficially to enzymatic hydrolysis during fermentation, uncontrolled proliferation, along with *Staphylococcus* spp. and *Enterobacter* species, may accelerate spoilage and compromise product safety (Nwachukwu et al., 2021). The isolation of *Pseudomonas* spp. exclusively from environmental swabs signifies biofilm formation and persistent contamination niches, which resist conventional cleaning methods (Onyeka & Umeh, 2020).

The physicochemical analyses further elucidate the interaction between fermentation biochemistry and environmental conditions. The pH values of Fufu samples (4.5–5.6) reflect a mildly acidic environment that supports lactic acid bacterial activity, a critical factor in cassava detoxification and flavor development (Oyewole & Odunfa, 2018). However, the acidic nature and elevated COD and BOD5 of effluent samples indicate significant organic pollution, representing an environmental hazard when discharged untreated (FAO, 2021). Such effluents, rich in carbohydrates and organic acids, deplete dissolved oxygen in aquatic ecosystems, disrupt microbial balance, and contribute to eutrophication (WHO, 2020).

The chemical composition analysis reveals that cyanogenic glycoside levels in Fufu samples were markedly above the WHO/FAO permissible limit (<10 mg/L), confirming incomplete detoxification of cassava roots during fermentation. This incomplete detoxification could stem from short fermentation durations, inadequate microbial diversity, or suboptimal environmental conditions (Oluwole et al., 2019). Chronic ingestion of cyanide residues is associated with neurological impairments, goitrogenic effects, and metabolic dysfunctions (Essers et al., 2020). Moreover, the detection of heavy metals such as lead and cadmium beyond permissible limits suggests environmental or anthropogenic contamination possibly through water, soil, or processing equipment (Akinola et al., 2022). Such toxic elements, even at trace concentrations, pose cumulative health risks, including renal impairment, neurotoxicity, and carcinogenesis.

The sanitation and hygiene survey conducted among Fufu processors reveals profound deficiencies in food safety awareness and operational discipline. The low frequency of handwashing before processing (28%), minimal use of protective clothing (14%), and poor waste disposal practices (90%) signify a lack of structured hygiene education and regulatory oversight (Okonkwo & Nwogu, 2017). These conditions foster a high-risk environment for foodborne pathogen transmission, potentially leading to outbreaks of diarrheal diseases among consumers (Nigerian Food Safety Policy, 2021). It is evident that traditional Fufu processors operate in informal settings devoid of standard operating procedures, quality control mechanisms, and infrastructural support systems that characterize regulated food industries.

Collectively, the results underscore the intricate relationship between environmental hygiene, microbial ecology, and public health outcomes. The observed microbiological and chemical hazards highlight an urgent need for a holistic intervention strategy incorporating environmental sanitation, hygiene education, and enforcement of food safety regulations. Sustainable food processing requires a synergy between scientific innovation, policy implementation, and community participation to bridge the gap between traditional methods and modern safety standards.

5. Conclusion

The study concludes that the *Fufu* processing environment in Umucheum Etche, Rivers State, is characterized by substantial microbial contamination, poor hygiene practices, and the presence of chemical residues beyond safe limits. The combination of high microbial counts, elevated cyanogenic compounds, and trace metal contamination poses significant risks to food safety and public health. Inadequate sanitation infrastructure, lack of potable water, and insufficient hygiene awareness are key contributing factors. Ensuring the microbiological and chemical safety of *Fufu* therefore demands urgent institutional and policy interventions targeting hygiene improvement, effluent management, and continuous monitoring of production sites.

6. Recommendations

Regular and structured hygiene and safety training programmes should be instituted for Fufu processors to enhance their adherence to good manufacturing practices, promote exemplary personal hygiene, and ensure the safe disposal of processing waste. The quality of water utilised during production must be rigorously monitored, with exclusive use of treated and microbiologically safe water, accompanied by periodic laboratory testing to prevent fecal contamination. Furthermore, there is a critical need for the development of designated, hygienically designed processing centres equipped with adequate sanitary infrastructure and efficient waste management systems to improve overall production conditions. Regulatory oversight should be strengthened, with local health authorities and food safety agencies ensuring strict compliance with both national and international food safety standards. Community-based education initiatives are equally essential, as public health campaigns should sensitize rural processors and consumers to the health risks associated with the consumption of contaminated Fufu. Lastly, environmental control measures must be implemented, ensuring that effluents generated during processing are effectively treated prior to discharge, thereby mitigating environmental degradation and protecting surrounding water bodies.

7. Contribution to Knowledge

This study makes a novel contribution by providing a comprehensive, data-driven assessment of the microbiological, physicochemical, and chemical hazards prevalent in *Fufu* processing environments within a rural Nigerian community. It bridges the gap between traditional cassava fermentation practices and scientific understanding of microbial ecology, food safety, and environmental health. The findings establish a foundation for policy formulation, public health intervention, and future research on sustainable and hygienic *Fufu* production systems. Furthermore, the study enriches the literature by linking microbial contamination and toxic residue accumulation to socio-environmental factors in local food processing.

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