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Review Article

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# Air Quality Assessment of the Fufu Processing Environment in Umucheum Etche, Rivers State, Nigeria: 'Implications for Environmental Health and Community Safety

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**Abstract:** This study assessed the physical, chemical, and microbiological air quality of a traditional fufu-processing environment in Umucheum Etche, Rivers State, Nigeria, with the aim of determining its implications for environmental health and community safety. Traditional cassava processing involves fermentation, sieving, dewatering, and roasting, activities that collectively generate substantial particulate emissions, gaseous pollutants, and microbial aerosols. Using a cross-sectional experimental design, air samples were collected from three major processing zones Fermentation Hall, Drying/Processing Area, and Packaging/Storage Area and compared with a control point. Particulate matter ($PM_{2.5}$ and $PM_{10}$), gaseous pollutants (CO, $CO_2$, $NO_2$, $SO_2$), and airborne microbial loads were quantified using standardized analytical methods, including high-volume air sampling, multi-gas detection, and Andersen air impactor culturing. Results revealed significant spatial variation across the processing environment. The Drying/Processing Area exhibited the highest pollutant burden, with $PM_{2.5}$ (60 µg/m³), $PM_{10}$ (110 µg/m³), CO (3.1 ppm), and peak microbial counts ($3.8 \times 10^4$ CFU/m³ bacteria; $2.1 \times 10^3$ CFU/m³ fungi), corresponding to an Unhealthy Air Quality Index (AQI). The Fermentation Hall demonstrated moderate pollutant and microbial levels, associated with elevated relative humidity, while the Packaging/Storage Area maintained the lowest concentrations and a Good AQI rating. Dominant bacterial isolates included *Bacillus*, *Micrococcus*, and *Staphylococcus*, whereas fungal species were primarily *Aspergillus*, *Penicillium*, and *Mucor*. The findings underscore substantial occupational and public-health risks associated with artisanal fufu processing, particularly in areas of high mechanical activity and biomass combustion. The study recommends the implementation of engineered ventilation, routine air-quality surveillance, and improved hygiene protocols to reduce exposure and enhance environmental safety within cassava-processing communities.

***Keywords:*** *Air quality; Cassava processing; Particulate matter; Microbial aerosols; Environmental health*

## 1. Introduction

Air quality assessment in traditional food-processing environments has gained renewed global relevance due to its implications for environmental hygiene, food safety, and occupational health. Fufu processing, a major cassava-based industry across West Africa, constitutes a complex sequence of operations soaking, fermenting, retting, sieving,



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dewatering, and roasting that collectively release substantial chemical emissions, aerosols, and microbial particulates into the surrounding atmosphere (Okafor & Ogbulie, 2019). These emissions arise from both biological and thermal activities: the fermentative breakdown of cassava liberates carbon dioxide, volatile fatty acids, and sulfur-bearing compounds, while the roasting stage, typically performed over open fires, generates significant quantities of particulate matter (PM2.5 and PM10), carbon monoxide, and polycyclic aromatic hydrocarbons (PAHs) (WHO, 2021).

In communities like Umucheum Etche in Rivers State, processing structures are predominantly informal, lacking engineered ventilation systems, controlled waste-management frameworks, and standardized hygiene protocols. Such infrastructural deficiencies facilitate the accumulation of smoke, combustion residues, and bioaerosols within and around the processing area, thereby posing measurable risks to processors, residents, and consumers (Iwuji et al., 2020). Long-term exposure to these airborne pollutants is associated with respiratory irritation, chronic obstructive pulmonary conditions, ocular discomfort, and potential systemic toxicity from prolonged carbon monoxide inhalation (EPA, 2020). Women who constitute the majority of local fufu processors are particularly susceptible due to prolonged exposure near heat sources and unregulated open-fire cookstoves (Akinbode et al., 2021).

Microbial air quality is an equally pressing concern. Cassava fermentation promotes the proliferation of lactic acid bacteria, coliforms, yeasts, and molds, many of which become aerosolized during sieving and dewatering operations (Ezekiel et al., 2019). High humidity, typical of the Niger Delta region, enhances microbial survival and dissemination, increasing the likelihood of airborne contamination of processing surfaces and finished products (Nweke & Nwachukwu, 2022). Poor wastewater drainage further contributes to odor emissions and reinforces the cyclical release of microbial aerosols. These factors have direct public-health implications, including increased risks of gastrointestinal infections, food spoilage, and opportunistic respiratory infections among processors and nearby residents.

Despite the socioeconomic significance of fufu and its widespread consumption, research on environmental air quality within artisanal processing sites in Nigeria remains limited. Existing studies have focused predominantly on water contamination, product microbiology, or occupational safety, with comparatively little empirical work on atmospheric pollutants, exposure pathways, and associated health outcomes in cassava-processing communities. This knowledge gap hinders the development of targeted environmental-health interventions that could mitigate pollution levels, improve hygiene conditions, and enhance consumer safety.

A comprehensive air-quality assessment of the fufu-processing environment in Umucheum Etche is therefore essential. By characterizing chemical pollutants, particulate concentrations, and airborne microbial loads, this study provides an evidence-based foundation for environmental regulations, occupational-safety guidelines, and community health-promotion strategies aimed at reducing exposure risks and promoting safer artisanal food production.

## 1. Materials and Methods

### 2.1 Study Area

The study was conducted in Umucheum Etche, Rivers State, Nigeria, a rural cassava-processing community characterized by humid tropical climatic conditions, informal processing structures, and widespread artisanal fufu production. The site was selected due to its high processing intensity and absence of standardized environmental-health controls.

### 2.2: Study Design

A cross-sectional experimental design was employed to evaluate chemical, physical, and microbiological air-quality parameters within the fufu-processing environment. Sampling was conducted across three major processing points (fermentation area, sieving zone, and frying section) and a control point situated 50 m away from active processing activities.

### 2.3: Sampling Materials and Instruments

- High-volume air sampler
- Portable particulate monitor (PM2.5 and PM10)
- Multi-gas detector (CO, $CO_2$, $NO_2$, $SO_2$, $H_2S$)
- Andersen six-stage microbial air impactor
- Sterile nutrient agar, MacConkey agar, Sabouraud dextrose agar
- Petri dishes, sterile cotton swabs, forceps
- Handheld thermo-hygrometer (temperature and humidity)
- Stopwatches, measuring tapes, sterile sample bags
- Personal protective equipment (PPE)
- GPS device for spatial positioning

### 2.4: Air Sampling Procedure

#### 2.4.1: Particulate Matter (PM) Assessment

Real-time measurements of PM2.5 and PM10 were obtained using a calibrated portable particulate monitor. Readings were taken at a height of 1.5 m and at three 20-minute intervals during peak processing operations. Results were recorded in micrograms per cubic meter (µg/m³).

#### 2.4.2: Gaseous Pollutants Measurement

A multi-gas detector was used to quantify concentrations of carbon monoxide (CO), carbon dioxide ($CO_2$), nitrogen dioxide ($NO_2$), sulfur dioxide ($SO_2$), and hydrogen sulfide ($H_2S$). Measurements were taken at three processing points and at the control site. Each gas was monitored for a 10-minute stabilization period before recording the final concentration.

#### 2.4.3: Microbiological Air Sampling

Airborne microorganisms were sampled using an Andersen impactor positioned 1 m above ground level.

- Nutrient agar was used for total aerobic bacterial counts.
- MacConkey agar for coliform detection.
- Sabouraud dextrose agar for fungi.

Sampling was performed at a flow rate of 28.3 L/min for 10 minutes per site. Plates were transported in insulated sterile carriers to the laboratory within one hour of sampling.

### 2.5: Laboratory Analysis

#### 2.5.1: Bacterial Enumeration and Identification

Plates were incubated at 35 ± 2°C for 24–48 hours. Colony-forming units (CFU/m³) were calculated using standard microbiological formulas. Representative colonies were purified and subjected to:

- Gram staining
- Biochemical tests (catalase, oxidase, coagulase, citrate, indole, urease)

#### 2.5.2: Fungal Identification

Fungal plates were incubated at 25 ± 2°C for 3–5 days. Colony morphology, pigmentation, and microscopic structures (using lactophenol cotton blue staining) were used for identification.

### 2.6 Environmental Parameters

Temperature and relative humidity were recorded using a thermo-hygrometer at each sampling point. Meteorological data were used to interpret pollutant behavior and microbial aerosol dispersion.

### 2.7 Data Analysis

Descriptive statistics were generated for all air-quality parameters. ANOVA was used to

compare pollutant levels across processing sites and the control point. Microbial counts were log-transformed before analysis. Results were evaluated against WHO (2021) and Nigerian Environmental Standards and Regulations Enforcement Agency (NESREA, 2018) guidelines.

### 2.8 Ethical Considerations

Approval was obtained from the local ethical review board. Verbal and written consent were secured from processors after explaining the study's purpose, risks, and confidentiality. Participation was voluntary, and no identifying information was recorded.

## 3. Results

### 3.1: Physical and Chemical Air Quality Parameters in Different Sample Areas of the Fufu Processing Environment

The Drying/Processing Area recorded the highest temperature (34.0 °C), $PM_{2.5}$ (60 µg/m³), $PM_{10}$ (110 µg/m³), CO (3.1 ppm), $CO_2$ (425 ppm), $NO_2$ (0.08 ppm), and $SO_2$ (0.03 ppm), indicating the greatest pollutant load due to intensive processing activities. The Fermentation Hall showed the highest relative humidity (78%) and moderate particulate and gas levels, reflecting moisture release during fermentation. The Packaging/Storage Area consistently exhibited the lowest values for most parameters, demonstrating reduced activity and better air stability in this zone.

**Table 1: Physical and Chemical Air Quality Parameters in Different Sample Areas of the Fufu Processing Environment**

| Sample Area | Tempt (oC) | RH (%) | PM2.5 (µg/m³) | PM10 (µg/m³) | CO (ppm) | $CO_2$ (ppm) | $NO_2$ (ppm) | $SO_2$ (ppm) |
|---|---|---|---|---|---|---|---|---|
| Fermentation Hall | 32.2 | 78 | 45 | 82 | 2.3 | 410 | 0.05 | 0.02 |
| Drying/Processing Area | 34.0 | 65 | 60 | 110 | 3.1 | 425 | 0.08 | 0.03 |
| Packaging/Storage Area | 30.8 | 70 | 28 | 55 | 1.9 | 400 | 0.01 | 0.02 |

**Keys:**
**Tempt (°C)= Temperature, RH= Relative Humidity, CO=Carbomonoxide, $CO_2$: Carbon dioxide, $NO_2$: Nitrogen dioxide, $SO_2$: Sulfur dioxide**

### 3.2: Microbial Air Load in Different Sample Areas

The Drying/Processing Area exhibited the highest microbial air load, with bacterial and fungal counts of $3.8 \times 10^4$ CFU/m³ and $2.1 \times 10^3$ CFU/m³, respectively, reflecting intensified activities that promote aerosolization of microbes. The Fermentation Hall showed intermediate levels, influenced by moisture-rich conditions that support microbial proliferation. The Packaging/Storage Area recorded the lowest bacterial ($1.8 \times 10^4$ CFU/m³) and fungal ($0.9 \times 10^3$ CFU/m³) counts, indicating minimal disturbance and better-controlled environmental conditions.

**Table 2: Microbial Air Load in Different Sample Areas**

| Sample Area | Total Bacterial Count(CFU/$m^3$) | Total Fungal Count(CFU/$m^3$) |
|---|---|---|
| Fermentation Hall | 2.5 x $10^4$ | 1.2 x $10^3$ |
| Drying/ Processing Area | 3.8 x $10^4$ | 2.1 x $10^3$ |
| Packaging/ Storage Area | 1.8 x $10^4$ | 0.9 x $10^3$ |

### 3.3: Frequency of Occurrence and Distribution of Bacterial Isolates on Air Quality in Fufu processing Environment in Umucheum Etche, Rivers State, Nigeria

The Drying/Processing Area recorded the highest overall bacterial occurrence (43.5%), with Bacillus and Micrococcus appearing most frequently in this zone, reflecting greater microbial disturbance from active processing. The Fermentation Hall showed moderate bacterial distribution (34.8%), dominated by moisture-favoring genera such as *Bacillus* and *Micrococcus.* The Packaging/Storage Area had the lowest occurrence (21.7%), indicating fewer airborne bacterial contaminants due to reduced human and material activity.

**Table 3: Frequency of Occurrence and Distribution of Bacterial Isolates on Air Quality in Fufu processing Environment in Umucheum Etche, Rivers State, Nigeria**

| Bacterial Isolates | Frequency (%) | Samples Area | | |
|---|---|---|---|---|
| | | F.H | D/P.A | P/S.A |
| *Bacillus* | 10(43.5) | 3 | 5 | 2 |
| *Staphylococcus* | 5(21.7) | 2 | 2 | 1 |
| *Micrococcus* | 8(34.8) | 3 | 3 | 2 |
| **Total** | **23(100)** | **8(34.8)** | **10(43.5)** | **5(21.7)** |

**Key: F.H=Fermentation Hall, D/PA=Drying/ Processing Area, P/SA=Packaging/ Storage Area**

### 3.4: Frequency of Occurrence and Distribution of Fungal Isolates on Air Quality in Fufu processing Environment in Umucheum Etche, Rivers State, Nigeria

The Drying/Processing Area recorded the highest fungal occurrence (56.3%), with dominant isolates such as *Aspergillus*, *Penicillium*, and *Mucor*, reflecting increased aerosolization during active processing. The Packaging/Storage Area showed moderate fungal presence (25%), while the Fermentation Hall had the lowest occurrence (18.7%), with only a few genera detected. Overall, fungal distribution was greatest where mechanical disturbance and particulate generation were highest.

**Table 4: Frequency of Occurrence and Distribution of Fungal Isolates on Air Quality in Fufu processing Environment in Umucheum Etche, Rivers State, Nigeria**

| Fungal Isolates | Frequency (%) | Samples Area | | |
|---|---|---|---|---|
| | | F.H | D/P.A | P/S.A |
| *Aspergillus* | 5(31.3) | 1 | 3 | 1 |
| *Penicillium* | 4(25) | 1 | 2 | 1 |
| *Mucor* | 3(18.7) | 0 | 2 | 1 |
| *Rhizopus* | 2(12.5) | 0 | 2 | 0 |
| *Fusarium* | 2(12.5) | 1 | 0 | 1 |
| **Total** | **16(100)** | **3(18.7)** | **9(56.3)** | **4(25)** |

**Key: F.H=Fermentation Hall, D/PA=Drying/ Processing Area, P/SA=Packaging/ Storage Area**

### 3.5: Combined Air Quality Index (AQI) Assessment

The Drying/Processing Area showed the highest pollutant levels ($PM_{2.5}$ = 60 µg/m³, $PM_{10}$ = 110 µg/m³, CO = 3.1 ppm) and high microbial load**,** resulting in an overall Unhealthy AQI**.** The Fermentation Hall displayed moderate pollutant concentrations and microbial load, giving it a Moderate AQI. The Packaging/Storage Area recorded the lowest values across all parameters**,** corresponding to a Good AQI, indicating the cleanest air quality among the three zones.

**Table 5: Combined Air Quality Index (AQI) Assessment**

| Sample Area | PM2.5 (µg/m³) | PM10 (µg/m³) | CO (ppm) | CO2 (ppm) | Microbial Load | AQI Category |
|---|---|---|---|---|---|---|
| F.H | 45 | 82 | 2.3 | 410 | Moderate | Moderate |
| D/P A | 60 | 110 | 3.1 | 425 | High | Unhealthy |
| P/SA | 28 | 55 | 1.9 | 400 | Low | Good |

**Key: F.H=Fermentation Hall, D/PA=Drying/ Processing Area, P/SA=Packaging/ Storage Area**

## 4. Discussion

The assessment of physical, chemical, and microbiological air quality parameters across the Fufu processing environment revealed distinct variations that reflect the intensity and nature of activities in each sampled zone. Across all parameters, the Drying/Processing Area consistently exhibited the highest pollutant and microbial loads, whereas the Packaging/Storage Area recorded the lowest values, with the Fermentation Hall occupying an intermediate position.

### 4.1 Physical and Chemical Air Quality Parameters

The Drying/Processing Area recorded elevated concentrations of particulate matter ($PM_{2.5}$ = 60 µg/m³; $PM_{10}$ = 110 µg/m³), gaseous pollutants (CO = 3.1 ppm; $NO_2$ = 0.08 ppm; $SO_2$ = 0.03 ppm), and the highest temperature (34.0 °C). These findings align with those of Adebayo et al. (2019), who reported that agro-processing environments with intense mechanical activities and biomass combustion typically exhibit higher PM and gaseous emissions. Similarly, Odonkor & Mahami (2020) observed that particulate emissions in traditional food-processing facilities rise substantially due to the grinding, roasting, and drying operations supporting the current study's results.

The Fermentation Hall presented the highest relative humidity (78%), consistent with the moisture released from fermenting cassava. Earlier research by Okareh & Erhahon (2015) also noted that fermentation rooms exhibit elevated humidity and moderate $CO_2$ due to biological activity. The relative humidity values recorded in the present study therefore agree with previous findings.

Conversely, the Packaging/Storage Area showed lower PM, gas concentrations, and temperature, consistent with reduced mechanical disturbance and limited human activity. Similar trends were documented by Chiemela et al. (2021), who found that storage areas in cassava-based processing facilities typically maintain more stable and cleaner air conditions due to controlled movement.

Overall, the physical and chemical parameters align closely with established knowledge that zones with more mechanical operations generate more pollutants, while areas with limited activity remain comparatively cleaner.

### 4.2 Microbial Air Load Distribution

Microbial counts followed a pattern consistent with pollutant load, with the

Drying/Processing Area showing the highest bacterial ($3.8 \times 10^4$ CFU/m³) and fungal ($2.1 \times 10^3$ CFU/m³) concentrations. This agrees with the findings of Oluwafemi & Simisaye (2019), who reported microbial aerosolization during cassava peeling, sieving, and drying processes. Mechanical disturbance, increased particulate levels, and elevated temperature create favorable conditions for microbial spread, which mirrors the findings in this study.

The Fermentation Hall exhibited moderate microbial levels, which is consistent with the moisture-rich environment that supports microbial proliferation but lacks the vigorous mechanical disturbance observed in the processing area. Earlier studies by Egbuta et al. (2018) similarly indicated that fermentation-dominant areas show moderate microbial loads due to humidity and biochemical activity.

The Packaging/Storage Area presented the lowest microbial counts, aligning with findings from Nimzing & Orokpo (2014) that low-activity storage rooms typically harbor fewer airborne microbes due to reduced movement and stable environmental conditions.

### 4.3 Bacterial Isolate Distribution

The predominance of *Bacillus*, *Micrococcus*, and *Staphylococcus* across all zones is consistent with reports from similar agro-processing settings. *Bacillus* spp., being spore-formers, are commonly reported in dry and dusty environments (Adekunle & Akinola, 2020), explaining their high frequency (43.5%) in the Drying/Processing Area.

The presence of *Micrococcus* spp. and *Staphylococcus* spp. agrees with the findings of Awan & Rahman (2017), who noted that these genera are typical human-associated and dust-associated microorganisms frequently detected in food-processing environments. Their distribution across all zones, though highest in the processing area, is consistent with their known ubiquity.

### 4.4 Fungal Isolate Distribution

Fungal isolates followed similar patterns, with *Aspergillus*, *Penicillium*, and *Mucor* dominating in the Drying/Processing Area (56.3%). This finding corresponds with previous studies by Nafisa et al. (2020), who reported that fungal spores readily aerosolize during cassava drying and milling. The high particulate environment enhances spore suspension, aligning with the elevated $PM_{10}$ levels observed.

The lower fungal presence in the Fermentation Hall (18.7%) agrees with reports by Afolabi et al. (2015), indicating that high humidity environments may suppress airborne fungal dispersal due to spore clumping and reduced aerosolization.

### 4.5 Air Quality Index (AQI) Categorization

The Air Quality Index (AQI) assessment revealed marked spatial disparities across the processing environment, with the Drying/Processing Area classified as Unhealthy owing to its elevated particulate matter concentrations, heightened gaseous emissions, and substantial microbial burden findings consistent with Udemezue and Abah (2021), who documented significant air-quality deterioration associated with cassava-processing activities. The Fermentation Hall attained a Moderate AQI rating, attributable to intermediate pollutant levels and comparatively regulated operational conditions, while the Packaging/Storage Area achieved a Good AQI status, reflecting minimal human disturbance and stable environmental parameters. Collectively, these AQI categorizations corroborate established environmental-health models that identify particulate matter as the principal determinant of indoor air-quality degradation within traditional food-processing settings.

## 5. Conclusion

Conclusively, air quality assessment in the Fufu processing environment revealed distinct spatial variations, with the Drying/Processing Area exhibiting the highest levels of

particulate matter, gaseous pollutants, and microbial load, the Fermentation Hall showing moderate contamination due to elevated humidity, and the Packaging/Storage Area maintaining relatively clean and stable conditions. These results highlight that operational intensity, environmental parameters, and human activity are major determinants of airborne contaminant distribution in cassava-processing facilities.

## 6. Recommendations

**We therefore recommend the following:**

1. There should an Installation of effective local exhaust ventilation and dust suppression systems in the Drying/Processing Area to mitigate particulate and microbial emissions.
2. Establishment of routine air quality monitoring and rigorous cleaning protocols should be encouraged, particularly in high-activity zones, to limit microbial proliferation.
3. Also, to maintain controlled environmental conditions, including humidity and airflow management, in the Fermentation Hall and Packaging/Storage Area to preserve air quality and prevent contamination.

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