

Mycological and Proximate Analysis of Post-Harvest Rice (*Oryza sativa*) Sold in Bida Markets

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Abstract

The study investigated the mycological and proximate composition of post-harvest rice sold in Bida markets, Niger State, Nigeria; Market A: New market, Market B: Small market, Market C: Old market. Samples were collected from different markets and analyzed for fungal contamination and nutrient composition using standard microbiological and chemical methods. The isolated fungi included *Aspergillus flavus* (100%), *Aspergillus niger* (66.4), and *Rhizopus stolonifer* (33.3), which are known to cause spoilage and potential mycotoxin production. Proximate analysis revealed Market A (RNMKT) sample had the highest moisture (12.05%), fat (1.77%), crude fibre (4.31%) and ash (4.63%). Market B (RSMKT) had the highest carbohydrate (72.85%) and market C (ROMKT) had the highest crude protein (8.07). The presence of fungal contaminants suggests poor storage hygiene, which may affect both the safety and nutritional quality of the rice. The study therefore recommends improved storage practices, regular monitoring for fungal contamination, and public awareness to ensure food safety and nutritional integrity of rice sold in Bida markets.

Introduction

BACKGROUND OF THE STUDY

Rice (*Oryza sativa*) is one of the most important staple foods worldwide, especially in developing countries, including Nigeria. It serves as a major source of carbohydrate and contributes significantly to the daily caloric intake of millions (FAO, 2020). In Nigeria, rice consumption has increased dramatically in recent years due to population growth, urbanization, and dietary preferences (Adeyeye *et al.*, 2019). Despite its importance, the quality and safety of rice are often compromised during post-harvest handling, storage, and marketing, particularly in local markets where preservation techniques may be inadequate (Nath *et al.*, 2024).

Post-harvest spoilage of rice is largely influenced by microbial contamination, particularly fungi, which can affect not only the physical quality of the grains but also their nutritional composition and safety for human consumption (Onyedika *et al.*, 2021). Fungal contamination during storage can lead to the production of mycotoxins, which are toxic secondary metabolites with severe health implications, including liver damage, immune suppression, and carcinogenic effects (Okoye *et al.*, 2018). Common fungi associated with stored rice include *Aspergillus*, *Penicillium*, and *Fusarium* species, which thrive in humid and poorly ventilated storage environments (Ezekiel *et al.*, 2017). Alongside microbial quality, the proximate composition of rice comprising moisture, protein, fat, fiber, ash, and carbohydrates is essential for assessing its nutritional value. These parameters can be significantly altered by fungal degradation, affecting the edibility, shelf life, and market value of the grains (Adebayo and Ogunlade, 2019). Therefore, evaluating both the mycological and proximate properties of post-harvest rice offers a comprehensive understanding of its safety and nutritional quality (Dawadi *et al.* 2022).

Bida, a prominent commercial center in Niger State, Nigeria, hosts several markets where rice is sold in large quantities. However, the conditions under which rice is handled and stored in these markets raise concerns about potential microbial contamination and nutrient loss. Despite the growing consumption of rice in this region, there is limited data on the microbial quality and nutritional profile of post-harvest rice sold in Bida markets (Sarfaraz, 2023).

Aim of the study

The aim of this study is to identify the fungal species contaminating post-harvest Rice (*Oryza sativa*) and to determine its proximate composition as sold in selected markets in Bida, Niger State.

Objectives of the study

- i. To enumerate, isolate, and characterize fungi from *Oryza sativa* samples.
- ii. To determine the proximate composition of *Oryza sativa* from the selected markets.

JUSTIFICATION FOR THE STUDY

Despite the high consumption of rice in Bida, there is limited local data on the types of fungi contaminating rice and how this affects its nutritional value. Understanding the level of fungal contamination and the proximate composition of rice sold in these markets is essential for assessing food safety, guiding public health interventions, and promoting better storage practices among seller (Mahunu *et al*, 2024). This study is therefore justified as it provides evidence-based information on the microbial and nutritional quality of rice in Bida markets. The findings from this study will contribute to improving food safety awareness and may encourage the adoption of better storage and handling practices among rice traders (Umaru *et al*, 2022).

LIMITATIONS OF THE STUDY

This study was limited to selected markets in Bida, which may not reflect the broader conditions of rice storage across Nigeria (Adeyeye *et al*, 2019). Additionally, mycotoxin analysis was not conducted, despite the potential presence of toxigenic fungi (Ezekiel *et al*, 2017). Environmental factors such as temperature and humidity during storage were not monitored, which could influence fungal growth and nutrient degradation. Financial and time constraints also limited the sample size and laboratory scope (Umaru *et al*, 2022).

SIGNIFICANCE OF THE STUDY

This study provides essential insight into the fungal contamination and nutritional quality of rice sold in Bida markets. Identifying fungi highlights potential health risks such as exposure to harmful mycotoxins (Ezekiel *et al*, 2017). The proximate analysis informs consumers and public health bodies about the nutritional value of rice commonly consumed in the area (Adeyeye *et al*, 2019). The findings can support food safety policies, improve post-harvest handling, and serve as a baseline for further research on market-sold food products (Ilesanmi and Adeoye, 2020).

OVERVIEW OF *Oryza sativa* (RICE) AS A STAPLE CROP

Rice (*Oryza sativa*) is one of the most important cereal crops globally and serves as a staple food for more than half of the world's population. In Nigeria, it is a central part of the diet and is consumed across various regions and socio-economic groups (Adeyeye *et al*, 2019). The increasing demand for rice has led to intensified local

production and trade, particularly in urban and semi-urban markets such as those in Bida, Niger State.

Rice is broadly classified into two subspecies: Indica and Japonica. Indica varieties are commonly grown in tropical climates, while Japonica types are better suited to temperate regions (FAO, 2019). In Nigeria, the dominant cultivated rice is *Oryza sativa*, although local varieties such as *Oryza glaberrima* are also found in some parts of West Africa (NBS, 2021).

The grain is composed primarily of carbohydrates (70–80%), with modest amounts of protein (6–8%), fiber, lipids, and essential minerals such as iron, zinc, and magnesium (Oko *et al.*, 2016). Rice cultivation is labor-intensive and involves several stages, including land preparation, planting, irrigation, fertilization, pest management, harvesting, and post-harvest processing. Each of these stages significantly affects the final quality and safety of the rice grains (Adeyeye *et al.*, 2019).

Despite its popularity and economic importance, post-harvest losses due to contamination and nutrient degradation remain a significant concern. Improper handling, packaging, and storage expose rice grains to microbial contamination, particularly by fungi, which can compromise both quality and safety (FAO, 2020).

POST-HARVEST HANDLING OF RICE

Post-harvest handling encompasses all the operations that take place immediately after rice is harvested, including threshing, drying, cleaning, storage, milling, and transportation. These steps are critical in maintaining grain quality, nutritional integrity, and market value (IRRI, 2016).

Improper handling during these stages often leads to quantitative and qualitative losses, particularly in developing countries where traditional and manual methods are still widely used (Afolabi *et al.*, 2017). In Nigeria, farmers and traders frequently rely on sun-drying on bare floors, open-air storage, and rudimentary threshing methods, exposing the grains to contamination from dust, insects, rodents, fungi, and physical impurities (Adeyeye *et al.*, 2019).

One major post-harvest concern is inadequate drying, which results in high grain moisture levels. Moist grains are highly susceptible to fungal colonization and mycotoxin production, especially when stored in poorly ventilated environments with high relative humidity (Ezekiel *et al.*, 2017). According to FAO (2019), moisture levels above 14% significantly increase the risk of spoilage during storage.

Storage practices in local Nigerian markets often involve the use of jute bags, polypropylene sacks, or open containers, typically stacked on bare floors or in overcrowded shops. These conditions promote the proliferation of storage fungi such

as *Aspergillus flavus* and *Fusarium spp.*, which not only damage the grains but also compromise their safety for human consumption (Odebode *et al.*, 2020).

FUNGAL CONTAMINATION OF STORED GRAINS

Stored food grains are susceptible to contamination by various fungi, especially under warm and humid conditions. Common fungal genera associated with stored rice include *Aspergillus*, *Penicillium*, *Fusarium*, and *Rhizopus* (Ezekiel *et al.*, 2017). These fungi not only deteriorate the physical and sensory quality of rice but also produce mycotoxins secondary metabolites that are toxic to humans and animals (Awuchi *et al.*).

Aflatoxins (produced by *Aspergillus flavus* and *A. parasiticus*) and fumonisins (produced by *Fusarium verticillioides*) are among the most prevalent mycotoxins found in rice and other grains in Nigeria (Udom *et al.*, 2020). Exposure to these toxins, even in low doses over time, can lead to serious health problems such as hepatocellular carcinoma, immune suppression, stunted growth in children, and birth defects (Okoye *et al.*, 2018).

Environmental conditions, such as high relative humidity, poor aeration, temperature fluctuations, and extended storage periods, significantly influence fungal growth and mycotoxin production. Studies have shown that traditional storage systems used in Nigerian markets, including the use of jute bags and open warehouses, fail to maintain the proper conditions needed to prevent fungal infestation (Umaru *et al.*, 2022).

IMPACT OF FUNGAL CONTAMINATION ON RICE QUALITY

Beyond health concerns, fungal infestation can affect the market value and acceptability of rice. Fungi can cause discoloration, off-odors, and degradation of essential nutrients. As fungi metabolize grain components, they reduce the quality of rice by consuming proteins, fats, and carbohydrates (Onyedika *et al.*, 2021). This reduces both the nutritional and economic value of the grain.

According to Adebayo and Ogunlade (2019), rice samples contaminated with visible molds showed significantly lower protein and fat contents compared to uncontaminated controls. Moreover, high moisture content, often observed in poorly stored rice, creates a favorable environment for mold growth and accelerates spoilage. Additionally, economic losses caused by fungal contamination are significant. Infected rice batches are often rejected by buyers, confiscated by regulators, or sold at lower prices, thereby reducing farmer and trader income. In extreme cases, large quantities of stored rice must be discarded, contributing to post-harvest food waste and food insecurity (Afolabi *et al.*, 2017).

To mitigate the impact of fungal contamination, it is essential to implement good agricultural and storage practices, including thorough drying (to below 14% moisture), use of hermetic storage bags, periodic fumigation, and routine quality monitoring (Bandyopadhyay *et al.*, 2016).

PHYSICAL CONTAMINATION IN MARKET RICE

Physical contamination in rice refers to the presence of foreign or extraneous materials that are not naturally part of the grain and pose potential health risks or reduce grain quality. These contaminants include stones, sand, metal fragments, husks, insect parts, plastic pieces, broken glass, and other debris that may be introduced during harvesting, processing, packaging, transportation, or marketing (Ogunbiyi *et al.*, 2018). Besides reducing the visual and commercial quality, they pose health risks such as dental injuries and gastrointestinal distress (Ilesanmi and Adeoye, 2020).

In local markets, such as those in Nigeria, physical contamination is often linked to poor post-harvest handling practices. For instance, drying rice on bare ground, manual threshing, open-air storage, and multiple rebagging steps expose the grains to foreign materials (Adeyeye *et al.*, 2019). During transportation and marketing, rice bags may be opened and re-sealed multiple times, increasing the likelihood of contamination through contact with dust, rodents, or unclean surfaces (Olatunde *et al.*, 2020).

Efforts to reduce physical contamination in market rice must focus on improved processing infrastructure, better hygiene protocols, and public awareness on safe rice handling. The use of mechanical de-stoners, sealed packaging, and training for vendors can significantly reduce contamination levels and ensure safer products reach consumers (Afolabi *et al.*, 2017).

PROXIMATE ANALYSIS AND ITS IMPORTANCE

Proximate analysis refers to the quantitative assessment of the major nutrient groups in food-moisture, ash, protein, fat, fiber, and carbohydrates. These parameters provide critical information about the nutritional value, processing characteristics, and shelf-life of food products (AOAC, 2015).

In the context of *Oryza sativa*, proximate analysis is essential because it helps to assess whether rice meets the nutritional standards for human consumption and to detect nutrient degradation caused by spoilage organisms such as fungi. For example, fungal contamination can lead to the loss of essential nutrients, particularly carbohydrates and proteins, as fungi metabolize these components for their growth (Oladipo *et al.*, 2020).

For rice, high moisture content is particularly important as it is directly linked to microbial stability. The acceptable moisture level for safe storage of rice is below 14%,

but levels above this threshold increase the risk of fungal growth (Ezekiel *et al.*, 2017). Determining moisture content therefore helps establish optimal storage and drying conditions to prevent deterioration.

Protein content is another important factor, as it indicates the quality of dietary protein available in rice. Though rice is not typically rich in protein compared to legumes, it remains a significant protein source for millions of people in rice-consuming regions (Nwankwo *et al.*, 2019).

Fat and fiber contents influence both the digestibility and energy density of rice. While rice is relatively low in fat, its lipid content can oxidize if not properly stored, affecting both flavor and nutritional quality. Crude fiber content, though minimal in polished rice, is useful in evaluating how much of the bran and hull remains, which impacts both nutritional value and texture (Sanni *et al.*, 2017).

Ash content reflects the total mineral composition of rice, including essential elements such as iron, zinc, magnesium, and calcium. These minerals are crucial for various metabolic functions in the human body (Oko *et al.*, 2016).

Ultimately, proximate analysis helps in quality control, nutritional labeling, food formulation, and public health monitoring. It is especially important in regions like Bida, where rice sold in open markets may vary widely in quality due to different sources, handling practices, and storage methods (Adeyeye *et al.*, 2019).

PREVIOUS STUDIES ON MARKET RICE IN NIGERIA

Several studies have evaluated the quality, safety, and nutritional composition of market-sold rice in Nigeria, reflecting widespread concerns over microbial contamination, physical adulteration, and nutrient degradation. These studies have provided critical insights into the post-harvest handling challenges, market storage conditions, and the need for regulatory oversight in rice marketing across the country. For instance, Ezekiel *et al.* (2017) conducted a nationwide survey on mycotoxin contamination in market grains and found high levels of *Aspergillus spp.* and *Fusarium spp.* in rice samples, particularly from open-air markets. The authors linked contamination levels to improper drying and storage, as well as the lack of protective packaging.

Adeyeye *et al.* (2019) assessed rice from various markets in Southwest Nigeria and reported significant physical contamination such as stones, husks, and insect fragments. Their study revealed that many vendors lacked basic knowledge of hygienic storage and handling, which contributed to quality deterioration. The findings also indicated that nutrient content, especially protein and fat, was lower in market rice compared to laboratory-stored control samples.

Afolabi *et al.* (2017) focused on storage practices and their impact on rice quality in local markets. They observed that rice stored in open containers or loosely tied bags was more susceptible to fungal and bacterial growth. Their study emphasized the importance of hermetic storage and periodic fumigation in reducing microbial load. More recently, Oladipo *et al.* (2020) analyzed the proximate composition and microbial load of processed rice from three Nigerian states. Their findings showed significant variation in moisture, protein, and fat content, as well as the presence of *Aspergillus niger* and *Penicillium* species in many market samples. The study concluded that proper drying and hygienic handling could mitigate such contamination risks. Collectively, these studies highlight a consistent pattern of substandard post-harvest practices, especially in open markets, and underscore the need for improved storage infrastructure, education of vendors, and regulatory enforcement to ensure rice quality and safety in Nigerian markets.

STUDY AREA

This study was conducted in Bida, a major town in Niger State, Nigeria. Bida is located in the Guinea Savannah region and experiences a tropical climate with high humidity and temperature, especially during the wet season. These environmental conditions contribute to the risk of fungal contamination in stored food commodities (Misiou *et al.*, 2022).

SAMPLE COLLECTION

Rice samples were randomly purchased from three major markets in Bida: New Market, Small Market, and Old Market. Approximately 500 g of rice was collected from each market, packaged in sterile polyethylene bags, labeled, and transported to the laboratory for analysis (Dessi *et al.*, 2021).

MATERIALS AND EQUIPMENT

Post-harvest cereal grains (*Oryza sativa*), sterile containers, sterile gloves, Analytical balance, sterile distilled water, glass slides, coverslip, chloramphenicol, lactophenol cotton blue, Petri dishes, cotton wool, matches, razor, syringe, inoculating needle, test tubes, Potato Dextrose Agar (PDA), conical flask, Beaker, filter paper, Bunsen burner and Foil paper

Samples were collected randomly from the markets Sample A: New market; Sample B: Old market; Sample C: Small market, and stored at 4°C. Ten grams of the sample was weighed for analysis. Surface was sterilize using 1% Sodium hydrochlorite for 1-2 minutes, then rinse with sterile distilled water three times.

Preparation of Culture Media

Potato Dextrose Agar (PDA) was prepared according to manufacturer instructions and sterilized at 121°C for 15 minutes. Chloramphenicol (50 mg/L) was added after cooling to inhibit bacterial growth.

Inoculation and Incubation

Inoculation and incubation of fungi associated with post-harvest Rice samples were carried out using standard microbiological methods as described by Oyeleke and Manga (2018) with slight modifications.

Ten grams of each Rice sample were aseptically weighed and homogenized in 90 mL of sterile distilled water to obtain a 10^{-1} dilution. Serial dilutions were prepared up to 10^{-4} , and 0.5 mL aliquots from appropriate dilutions were inoculated onto Potato Dextrose Agar (PDA) supplemented with chloramphenicol (50 mg/L) to suppress bacterial contamination. The inoculated plates were incubated at $25 \pm 2^\circ\text{C}$ for 5–7 days to allow fungal growth (Ahmed *et al.*, 2021).

Isolation and Identification of Fungi

After incubation, colonies differing in color, texture, and growth pattern were sub-cultured on fresh PDA plates to obtain pure isolates. Fungal isolates were examined and identified based on their macroscopic (colony morphology) and microscopic features, such as spore type and hyphal arrangement, using lactophenol cotton blue staining (Hassan *et al.*, 2020).

Common fungal species isolated from Rice samples include *Aspergillus flavus*, *A. niger*, *Penicillium spp.*, and *Rhizopus spp.*, which are recognized as major post-harvest contaminants of grains in tropical environments (Ezeonu *et al.*, 2022).

Moisture Content

The moisture content of the Rice was ascertained by applying a technique suggested by the Association of Official Analytical Chemists (AOAC, 2015). 2g of the Rice sample were dried in a vacuum oven at 105°C for 1 hour in a Petri dish of a predefined weight. After weighing and recording W_0 for a dry petri dish, W_1 for the sample was inserted and recorded without any adjustments. After that, the sample was placed in a desiccator and cooled at 105°C for an hour to achieve complete dryness. After removing the sample using tongs and letting it cool in the desiccator, it was weighed again and the new result was noted as W_2 . The following formula was used to estimate the moisture content:

$$\% \text{ Moisture content} = \frac{W_2 - W_1}{W_1 - W_0} \times 100$$

Where W_0 = Weight of crucible, W_1 = weight of crucible + sample, W_2 = weight after heat treatment.

Determination of Ash Percentage

The guidelines provided by the Association of Official Analytical Chemists (AOAC, 2015) were adhered to. 1g of dry material was placed in duplicate crucibles and incinerated for 5 hours at 550°C in a muffle furnace. The samples were removed after reaching a consistent weight and turning a light gray ash. Without making any adjustments, the sample was inserted, weighed, and recorded as W_1 after the dry crucible had been weighed and recorded as W_0 . After being moved to a muffle furnace, the sample was burned for six hours at 600°C. To reduce moisture absorption, the samples were cooled in desiccators and weighed as W_2 .

Percentage ash was calculated using the formula: $\frac{W_2 - W_1}{W_1 - W_0} \times 100$

Where; W_0 = Weight of crucible, W_1 = weight of crucible + sample, W_2 = weight of crucible and ash.

Determination of Crude Protein

The micro-Kjeldahl method, which was published by the Association of Official Analytical Chemists Association (AOAC, 2015), was used to determine the protein concentration.

Protein% = % total nitrogen x 6.25.

Determination of Fat Content

The AOAC (2015) established procedures for determining the quantity of fat in the samples.

After being weighed on a chemical balance, a ten-gram (10g) sample of Rice was placed in a filter paper envelope for storage. It was cleaned, dried in an oven, and allowed to cool in desiccators before being placed in an extraction thimble and weighed. The fat was extracted after 25 milliliters of petroleum ether solvent were added to the flask. To extract the solvent after the extraction, the sample was dried in an oven for a few hours. The container and its contents were cooled, then placed in desiccators and weighed. To calculate the percentage of fat content, the following formula was applied:

$\frac{\text{The weight of the extracted}}{\text{Weight of sample}} \times 100$

Determination of Crude Fiber

AOAC method (2015) was used to determine the Rice's fiber content. 2g of the Rice sample was boiled in a 1.25% sulfuric acid (H₂SO₄) solution for 30 minutes, this is done to break down soluble carbohydrate, proteins and other acid-soluble components. After acid treatment, the mixture was filtered using crucible to remove the liquid. The residue was meticulously returned to the flasks and washed multiple times with hot (boiling) water to remove the remaining acid. A two-fold muslin towel was used to catch any particles as 200ml of 1.25% NaOH solution was carefully put into each flask. The flasks were then allowed to boil for 30 minutes. To get rid of fat and other soluble materials, the solution was then carefully filtered once more, and the residue was extensively cleaned with hot water before being cleaned with ethanol. The leftover residue, which is crude fiber, was dried for three hours at 105°C in an oven until its weight remained constant. After cooling in desiccators, the samples were put in a muffle furnace and burned for two hours at 550 degrees Celsius until they were reduced to ash. The crude fiber content of each sample was determined using the following gravimetric formula:

$$\text{Crude fiber\%} = \frac{\text{Weight of Dried Residue} - \text{Weight of Ash}}{\text{Original Sample Weight}} \times 100$$

Determination of Carbohydrate Content

By subtracting the total of the percentages of crude protein, crude fat, moisture, ash, and fiber from 100, the available carbohydrate was calculated. The nitrogen-free extractive (NFE) was used to calculate the carbohydrate content. The extractive free of nitrogen would be computed as % NFE = 100 – % (Moisture + Ash + Protein + Fat + Fiber).

Mycological Analysis

The mycological analysis of the post-harvest rice samples collected from three major markets in Bida; New Market, Small Market, and Old Market, revealed the presence of several fungal species. The isolates were identified based on their cultural characteristics on Potato Dextrose Agar (PDA), colony morphology, spore structures, and microscopic observations. The fungal species identified include *Aspergillus flavus*, *Aspergillus niger*, and *Rhizopus stolonifer*. Among these, *Aspergillus* species were the most frequently isolated, followed by *Rhizopus stolonifer*.

The predominance of *Aspergillus* species may be due to their xerophilic nature, enabling them to thrive in low moisture environments typical of stored grains. According to Adedeji *et al.* (2017), *Aspergillus spp.* is among the most common

contaminants of stored cereals in tropical regions due to their tolerance for warm temperatures and dry storage conditions.

Aspergillus flavus is particularly significant because it is known to produce aflatoxins, secondary metabolites that are carcinogenic and can cause liver damage in humans and animals (Adebayo *et al.*, 2018; Umeh *et al.*, 2020). The presence of such fungi suggests that improper drying, unhygienic handling, and storage under humid conditions could be contributing factors to contamination (Ibrahim *et al.*, 2021).

Table 1: Frequency of occurrence of fungi isolated from rice samples in Bida markets.

Fungal Isolates	Market A	Market B	Market C	Frequency (%)
<i>Aspergillus flavus</i>	+	+	+	100
<i>Aspergillus niger</i>	-	+	+	66.7
<i>Rhizopus stonolifer</i>	+	-	-	33.3

Note: Market A= New Market; Market B = Small Market; Market C= Old Market.

Key: + =Present; - = Absent.

Morphological Characteristics of Fungal Isolates from the sample locations

The fungal isolates recovered from rice samples collected across Bida markets were identified based on their macroscopic and microscopic features. Colony color, texture, growth rate, and spore morphology were examined using standard taxonomic keys as described by Barnett and Hunter (2006) and Samson *et al.* (2019).

The isolates showed distinct characteristics that allowed identification at the genus level. Colonies of *Aspergillus flavus* colonies were greenish-yellow with granular textures while *Aspergillus Niger* appeared black with powdery surfaces whereas *Rhizopus* appeared as white, cottony growths that later darkened with age.

Microscopically, *Aspergillus species* exhibited septate hyphae and radiating conidial heads, while *Rhizopus* was recognized by non-septate hyphae and spherical sporangia. These distinct traits confirmed that rice samples were contaminated by common storage fungi capable of surviving under fluctuating humidity and temperature conditions (Adebayo *et al.*, 2018).

The summarized characteristics of the isolated fungi are presented in Table 4.2.

Table 2. Morphological Characteristics of Fungal Isolates from the sample locations

Fungal isolates	Cultural Characteristics	Microscopic Characteristics
<i>Aspergillus flavus</i>	Olive-green to yellowish colonies with granular surface; reverse side pale to golden. Moderate growth rate.	Septate hyphae with globose vesicles; conidia rough and spiny; phialides arranged in radiating form.

Fungal isolates	Cultural Characteristics	Microscopic Characteristics
<i>Aspergillus niger</i>	Black to dark brown colonies with a rough, powdery texture and distinct reverse coloration. Rapid growth observed within 3–4 days	Septate hyphae with large, dark conidial heads; conidiophores long and smooth; conidia spherical and black.
<i>Rhizopus stonolifer</i>	White cottony colonies turning grayish-black as sporangia mature; rapid spreading growth.	Broad, non-septate hyphae with rhizoids; sporangia round and black; sporangiophores unbranched.

Proximate Composition of Rice Samples

The proximate composition of rice samples was analyzed to determine their nutritional quality and to assess if fungal contamination had any impact on nutrient composition. The parameters determined include moisture, ash, crude protein, crude fiber, crude fat, and carbohydrate contents.

The moisture content ranged from 11.4% to 12.2%, which is within the recommended safe limit for stored rice (FAO, 2020). However, samples with slightly higher moisture content, especially from the Small Market, also showed higher fungal loads. This agrees with Ibrahim *et al.* (2021), who reported that elevated moisture promotes fungal proliferation and leads to nutrient degradation.

The crude protein content averaged 7.3%, which aligns with earlier findings by Oko *et al.* (2016), who reported 7–8% protein content for most Nigerian rice varieties. Carbohydrate values were high, accounting for over 77% of total composition, consistent with rice being a carbohydrate-rich staple (Eke-Ejiofor *et al.*, 2019).

Table 3: Proximate composition (%) of post-harvest rice samples from Bida markets

Samples	Moisture %	Fat %	Crude Protein %	Crude Fibre %	Ash %	Cho %	Energy Kj	Value Kcal
Market A	12.05	1.77	7.16	4.31	4.63	70.06	324.73	1,298.92
Market B	11.11	1.24	7.66	3.58	3.52	72.85	333.20	1332.80
Market C	11.29	1.53	8.07	4.02	3.33	71.76	333.09	1332.36

Key: Market A: New Market; Market B: Small Market, Market C: Old Market

Discussion

The isolation of *Aspergillus*, and *Rhizopus species* from the rice samples confirms that fungal contamination remains a major post-harvest issue in the storage and marketing of rice in Bida. Similar fungal genera have been reported in studies of stored cereals in Nigeria and other tropical regions (Adebayo *et al.*, 2018; Umeh *et al.*, 2020; Adedeji *et al.*, 2017).

The predominance of *Aspergillus flavus* and *A. niger* in this study aligns with reports by Ezeonu *et al.* (2019), who found these species to be common in rice and maize grains stored under ambient market conditions. Their persistence is linked to their ability to produce spores that resist desiccation and survive long-term in storage environments. The proximate analysis results showed that rice sold in Bida markets retains significant nutritional value but may experience mild nutrient loss due to fungal activity. For instance, samples with visible fungal contamination recorded slightly lower protein and fat levels. This observation supports the findings of Nwankwo *et al.* (2018), who reported that fungal metabolism during storage causes a decrease in nutrient content through enzymatic degradation.

Moreover, the observed moisture levels were close to the threshold where fungal growth can begin. FAO (2020) recommends that the moisture content of stored rice should not exceed 12%, to prevent microbial deterioration. Hence, markets with average values around this limit may be at risk if storage conditions remain humid or aeration is poor.

The presence of toxigenic fungi such as *Aspergillus flavus* and *Fusarium spp.* also raises food safety concerns, as they are capable of producing aflatoxins and fumonisins, respectively both of which are known to cause chronic health effects, including liver cancer and immune suppression (Okeke and Nwankwo, 2020; Ibrahim *et al.*, 2021). Therefore, strict post-harvest management practices are necessary to minimize contamination and ensure consumer safety.

Overall, the findings suggest that post-harvest handling practices particularly drying, bagging, and storage play a crucial role in determining the microbial quality and nutritional integrity of rice grains. Proper drying before storage, use of moisture-proof bags, and storage in clean, dry environments can greatly reduce fungal incidence and maintain the proximate quality of rice (Eke-Ejiofor *et al.*, 2019; Adebayo *et al.*, 2018).

Conclusion

The findings of this study indicate that post-harvest rice grains sold in Bida markets are contaminated with storage fungi, particularly *Aspergillus species*, which are known producers of mycotoxins that can pose health risks to consumers (Bhat and Reddy, 2017). Although the proximate composition remains within standard nutritional ranges, fungal contamination could compromise both quality and safety if appropriate control measures are not taken.

Thus, the study concludes that the quality of rice sold in Bida markets depends significantly on post-harvest handling and storage conditions. Preventive measures such as proper drying, use of clean storage bags, and regular inspection of grains are crucial to minimize fungal growth and nutrient loss.

Recommendation

1. **Improved Storage Practices:** Rice traders and farmers should ensure proper drying of rice before storage and maintain storage environments with low humidity and good aeration to reduce fungal proliferation.
2. **Public Awareness:** Market vendors should be educated on the dangers of fungal contamination and mycotoxin exposure through local agricultural extension services.
3. **Regular Monitoring:** Periodic microbial assessment of stored and sold rice grains should be conducted by relevant food safety authorities to ensure compliance with quality standards.
4. **Use of Antifungal Treatments:** The application of safe natural antifungal agents (e.g., neem extract or clove oil) could help reduce fungal growth during storage.
5. **Further Research:** Future studies should focus on molecular identification of the fungi and quantitative analysis of mycotoxins to assess the actual food safety risks associated with post-harvest rice in Bida markets.

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Appendix



Plate I: *Aspergillus flavus* on PDA

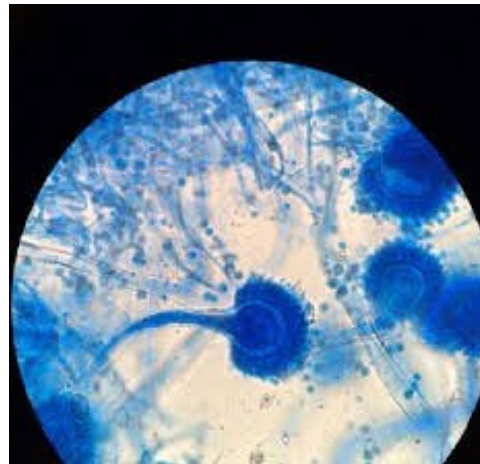


Plate II: *Aspergillus flavus* under microscope