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# Characterization of Aflatoxin-Producing Fungi on Postharvest Quality of Stored Sorghum (*Sorghum bicolor* L.) Grains in Makurdi, Benue State

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## Abstract

*Characterization of aflatoxin-producing fungi on postharvest quality of stored Sorghum (Sorghum bicolor L.) grains in Makurdi, Benue State, was carried out. Sorghum samples were collected from storehouses in Wurukum, Yaikyo market and Northbank, respectively, using the sampling probe method. The samples were taken to Botany Laboratory of Rev. Fr. Moses Orshio Adasu University for isolation of aflatoxin-producing fungi, while samples were sent to the Institute for Agricultural Research, Zaria, Kaduna State, for aflatoxin analysis. Fungal isolation from Sorghum seeds were carried out using the Standard Blotter Method, while aflatoxin analysis was done using the Enzyme-Linked Immunosorbent Assay (ELISA) technique. The collected data were subjected to statistical analysis using the chi-square ($\chi^2$) test, t-test, and analysis of variance (ANOVA). Where significant differences occurred, mean values were compared using Fisher's least significant difference (LSD) test at the 5% probability level. The mycological assessment of Sorghum grains resulted in the identification of three fungal genera/species, namely Aspergillus niger, Penicillium sp., and Aspergillus flavus. Statistical analysis indicated that the average fungal load of Sorghum grains did not differ significantly among the stores from which the samples were collected. Among the fungi detected, Aspergillus flavus showed the greatest frequency of occurrence, accounting for 8 isolates (50.0%), followed by Penicillium sp. with 7 isolates (36.8%). Aspergillus niger was recorded at the lowest frequency, comprising 4 isolates (21.1%). Sorghum grains from a storehouse in Northbank had higher fungi occurrence, 7 (36.8%), followed by those in Wurukum and Yaikyo market, each with 6 (31.6%), respectively. There was no significant relationship in fungal occurrence based on location ($\chi^2$= 2.45; df= 4; P= 0.65). There was no significant difference in seed germination. Grains from the storehouse in Yaikyo market and Northbank had higher germination, each with (7.33), and the least was that from Wurukum (7.00). Sorghum grains from the storehouse in Yaikyo market had a higher vigour index (820.00), followed by grains from the storehouse in Wurukum (743.80) and Northbank (526.70), respectively. Aflatoxin B1 was identified in Sorghum samples collected from the different storehouses. Aflatoxin level in Sorghum grains obtained from Northbank (6.85) µg/kg was significantly higher compared with aflatoxin levels in Sorghum from Yaikyo market (1.34) µg/kg and Wurukum (0.00) µg/kg, respectively. Aflatoxin B1 was detected in all Sorghum samples collected from the different storehouses in Makurdi. The levels of aflatoxin in Sorghum from Yaikyo market and Northbank stores were below the permissible limit by the Standard Organisation of Nigeria, but the level of aflatoxin in Sorghum from the store in Northbank exceeded the permissible limit by the European Union. Farmers within and outside Makurdi, Benue State, should source high-quality Sorghum grains from non-aflatoxin-contaminated stores for planting.*

**Keywords:** *Fungi, Aflatoxin, quantification, identification, Sorghum, storehouses, Makurdi.*

## INTRODUCTION

*Sorghum* (*Sorghum bicolor* (L.) Moench) is among the major cereal crops cultivated worldwide and represents an important indigenous cereal in Africa. In Nigeria, it is considered one of the principal staple cereals, with an estimated annual production of approximately 8 million tonnes. The crop has diverse applications, serving as a source of human food and livestock feed and as a raw material for the preparation of both alcoholic and non-alcoholic traditional beverages [1]. Across tropical and semi-tropical regions, *Sorghum* contributes substantially to the dietary supply of energy, protein, vitamins, and essential minerals for both human populations and livestock. Its grains are particularly valued as a carbohydrate-rich food ingredient, while the seeds are also utilized in agricultural production.

In Nigeria, *Sorghum* grains are processed into a variety of traditional foods. In southwestern communities, the grain may be milled and processed into pastes and pap, which is commonly consumed as a complementary food for children. Throughout different parts of Africa, *Sorghum* is incorporated into traditional products including tuwo and molded grain products such as *fura*. It is also used in the preparation of fermented alcoholic beverages, including burukutu and pito, as well as non-alcoholic beverages such as *kunu zaki* [2].

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Beyond its traditional uses, *Sorghum* has gained considerable nutritional interest because it is naturally gluten-free and contains several phytochemicals with potential health-promoting properties. Among its bioactive constituents are phenolic compounds such as vanillic acid, gallic acid, and ferulic acid, which have been associated with antioxidant and anti-inflammatory activities [3].

The nutritional profile of *Sorghum* grains varies considerably depending on cultivar, environmental conditions, and processing practices. Reported ranges include approximately 1.4–26.1% dietary fibre, 54.6–85.2% carbohydrates, 0.9–4.2% ash, 1.3–10.5% fat, and 6.2–14.9% protein [4]. These nutritional attributes make *Sorghum* an important component of food systems, particularly in regions where cereals constitute a major proportion of the daily diet. However, despite its nutritional and economic importance, maintaining grain quality after harvest remains a major challenge.

## STATEMENT OF THE PROBLEM

Post-harvest deterioration is one of the major factors responsible for losses in cereal production. In many parts of sub-Saharan Africa, inadequate drying, handling, transportation, and storage facilities contribute substantially to post-harvest losses and consequently aggravate existing food-security challenges [5]. *Sorghum* grains that are harvested with excessive moisture or exposed to unsuitable storage conditions provide favourable conditions for the development of moulds and other spoilage microorganisms [6]. Prolonged exposure to moisture and elevated temperatures can therefore compromise grain quality and increase the likelihood of fungal contamination.

Several fungal genera, particularly *Aspergillus*, *Penicillium*, and *Fusarium*, are capable of colonising improperly stored cereal grains and may produce toxic secondary metabolites known as mycotoxins [7]. Species belonging to *Aspergillus* are associated with the production of aflatoxins, including aflatoxins B1, B2, G1, and G2, whereas *Fusarium* species may produce important mycotoxins such as fumonisins, trichothecenes, and zearalenone. The occurrence of aflatoxin-producing fungi is not restricted to a single commodity; these organisms have been reported in several major African food crops, including maize, *Sorghum*, millet, rice, oilseeds, groundnuts, spices, tree nuts, and cassava [8].

The risk of aflatoxin contamination may arise at different stages of crop production and post-harvest management. Since *Aspergillus* species are commonly associated with soil and plant environments, contamination may begin during crop establishment and subsequently increase as a result of poor harvesting, handling, drying, transportation, processing, and storage practices. Environmental factors, particularly elevated temperature and moisture availability, strongly influence fungal growth and toxin production both before and after harvest [9]. Among the principal aflatoxin-producing fungi are *Aspergillus flavus* and *Aspergillus parasiticus*, which can synthesize aflatoxins B1, B2, G1, and G2 [10].

Aflatoxin B1, which is recognized by the International Agency for Research on Cancer (IARC) as a potent naturally occurring carcinogenic compound [11]. Human and animal exposure to contaminated food and feed can therefore present significant food-safety and public-health concerns. Following harvest, inadequate drying, excessive grain moisture, high storage temperatures, and poor storage conditions may create an environment conducive to fungal proliferation and subsequent mycotoxin formation [9].

Benue State is one of Nigeria's important *Sorghum*-producing regions. Given the importance of *Sorghum* as a food and feed resource in the area, the occurrence of fungal contaminants in stored grains warrants systematic investigation. Therefore, assessing the fungal contamination of stored *Sorghum* grains is important for determining the prevalence of potentially toxigenic fungi and for generating information that can support improved post-harvest handling and storage practices in the region.

### Significance of the Study

The stakeholders likely to benefit from this study include students, researchers, farmers, and consumers. For farmers, it will guide them on adopting better postharvest handling, drying and storage practices to reduce contamination. For researchers, it will provide baseline data for further research in this area of study. For policymakers, it will provide scientific evidence to support policies on food safety, grain quality control and aflatoxin regulation in Nigeria. For students, it will provide relevant research data for academic research projects. Therefore, the aim of the study was to isolate, identify fungi and quantify aflatoxins in *Sorghum* (*Sorghum bicolor* L.) grains in some storehouses in Makurdi.

## MATERIALS AND METHODS

### Experimental location

The study was carried out in the Institute for Agricultural Research, Zaria, Kaduna state and the Botany laboratory of Rev. Fr. Moses Orshio Adasu University, Makurdi, Benue State. *Sorghum* samples were sent to the Institute for Agricultural Research, Zaria, Kaduna State, for aflatoxin analysis, while *Sorghum* samples were brought to the Botany laboratory of Rev. Fr. Moses Orshio Adasu University, Makurdi for isolation of aflatoxin-producing fungi.

### Collection of *Sorghum* grain samples

*Sorghum* grains were collected from three major storehouses. One each from Wurukum, Northbank and Yaikyo markets in Makurdi Local Government Area of Benue State. The samples were collected from the storehouses using the sampling probe. The sampling probe was inserted horizontally into the bag and withdrawn slowly in order to collect a uniform sample from each bag. Three samples were collected from each storehouse. Approximately 500g samples were purchased from each storehouse and placed separately in clean containers and labelled appropriately. They were transported to the Botany laboratory of the Rev. Fr. Moses Orshio Adasu University, Makurdi, for further studies.

**EXPERIMENT I:** Analysis of *Sorghum* Grains for Aflatoxin Levels

### Sample Extraction for Aflatoxin Analysis

A representative 50 g portion of each *Sorghum* grain sample was randomly selected and pulverized into a fine powder. From the homogenized material, 20 g was transferred into a 250 mL conical flask, followed by the addition of 100 mL of 70% methanol. The suspension was thoroughly mixed using an orbital shaker operated at 150 rpm for 30 min to facilitate the extraction of aflatoxins. Following agitation, the extract was filtered, and the resulting filtrate was collected and used for the determination of aflatoxin B1 concentration.

**Quantification of Aflatoxin B1**

Aflatoxin B1 was quantified by an indirect enzyme-linked immunosorbent assay (ELISA) following the established immunoassay procedure. Initially, 150 µL of appropriately diluted toxin–bovine serum albumin (BSA) conjugate was introduced into each well of an ELISA microplate. The plate was incubated at 37 °C for 1 h with continuous shaking. Following incubation, the contents of the wells were discarded into an appropriate waste container, and the plate was washed three times with phosphate-buffered saline containing Tween 20 (PBST), allowing approximately 3 min for each washing cycle.

Subsequently, 150 µL of 0.2% BSA solution was added to each well, and the plate was incubated at 37 °C for 30 min under shaking conditions. After incubation, the contents were removed and the wells were washed using the same PBST washing procedure. Thereafter, 150 µL of the prepared antiserum solution was added to each well, followed by incubation at 37 °C for 30 min. The plate was subsequently emptied and washed three times with PBS-Tween at 3-min intervals.

For preparation of the aflatoxin standard, 1.5 µL of the aflatoxin standard was diluted in 0.6 mL of a 1:1 methanol–PBST mixture. Serial dilutions of the prepared standard were subsequently made using the same methanol–PBST mixture as the diluent. For sample preparation, 20 µL of each extracted sample was mixed with 180 µL of 0.2% BSA solution and thoroughly homogenized using a vortex mixer.

Aliquots of 100 µL of the standards and prepared samples were dispensed into the appropriate ELISA wells in duplicate. Subsequently, 50 µL of antiserum was added to each well. The plate was incubated at 37 °C for 1 h with shaking. Following incubation, the contents were discarded and the wells were washed three times with PBST.

Next, 150 µL of goat anti-rabbit antibody was added to each well, and the plate was incubated under the same conditions (37 °C for 1 h with shaking). After incubation, the contents were removed, and the wells were washed three times with PBST. For colour development, 5 mg of *p*-nitrophenyl phosphate was dissolved in 10 mL of 10% diethanolamine solution. A volume of 150 µL of the prepared substrate solution was added to each well, and the plate was incubated at 37 °C for 30 min under the same shaking conditions. The absorbance of the standards and samples was subsequently determined at 405 nm using an ELISA plate reader. Aflatoxin B1 concentrations in the tested *Sorghum* grain samples were calculated automatically using the software integrated with the ELISA reader.

**EXPERIMENT II:** Isolation of Aflatoxin-Producing Fungi from *Sorghum* Grains Collected from Makurdi Local Government Area, Benue State.

**Preparation of Culture Medium**

Potato Dextrose Agar (PDA) was used as the culture medium for the isolation and growth of fungal pathogens. The medium was prepared in accordance with the manufacturer's instructions. Briefly, 39.6 g of powdered PDA was suspended in 1,000 mL of sterile distilled water and thoroughly mixed to obtain a homogeneous suspension. The mixture was heated on a heating mantle with continuous agitation until the medium became clear. The flask was subsequently covered with aluminium foil and sterilized in an autoclave at 121 °C for 15 min under a pressure of 760 mmHg.

Following sterilization, the medium was allowed to cool to a temperature suitable for handling. Two to three drops of streptomycin sulfate were aseptically incorporated into the cooled medium to suppress bacterial contamination. The prepared PDA was then dispensed aseptically into sterile Petri dishes and allowed to solidify under aseptic conditions before inoculation.

**Detection and Isolation of Fungi from *Sorghum* Seeds**

The presence of seed-associated fungi was assessed using the standard blotter method described by [12]. Three layers of sterile Whatman filter paper were placed in sterile Petri dishes measuring 9 cm in diameter and adequately moistened with sterile distilled water. Ten *Sorghum* seeds from each sample were surface-disinfected by immersion in 5% sodium hypochlorite solution for 1 min. The seeds were subsequently rinsed three consecutive times with sterile distilled water to remove residual disinfectant, following the procedure reported by [13].

After surface sterilization, the seeds were aseptically transferred onto the moistened filter papers, ensuring adequate spacing between individual seeds. The inoculated Petri dishes were incubated at ambient laboratory temperature for 5–7 days. At the end of the incubation period, the seeds were carefully examined for the development of visible fungal colonies. Emerging fungi were identified based on their macroscopic characteristics and, where necessary, further cultured on PDA for subsequent examination.

**Data Collection and Assessment of Fungal Occurrence**

***i. Mean Fungal Occurrence***

*Sorghum* seed samples were collected in triplicate from each sampling location and transported to the laboratory for analysis. Following incubation, the number of fungal colonies or infected seeds was recorded for each sample. The mean fungal occurrence for each location was calculated from the observations obtained from the three replicate samples.

***ii. Percentage Occurrence of Individual Fungal Species***

The frequency of occurrence of each fungal species was determined by examining the incubated seeds for characteristic fungal growth. The number of occurrences recorded for each individual fungal species was expressed relative to the total number of fungal occurrences and converted to a percentage using the formula described by [14]:

$$\frac{\text{Number of times each fungus occurred}}{\text{Total number of fungi per plate}} \times 100$$

**i. Percentage Seed Germination**

This was calculated by counting the number of seeds with seed leaf and the percentage seed germination was calculated using the formula adopted by [14].

$$\frac{\text{Number of seeds with seed leaf}}{\text{Total number of seeds per plate}} \times 100$$

**ii. Vigour index:** This refers to the properties of the seed which determine the health/quality, level of activity and performance of the seed during germination and seedling emergence. The seedling vigour index was calculated using the formula reported by [15];

Vigour index = Germination (%) per treatment x Seedling length

**Sub-culturing of Fungal Isolates**

Following the emergence of fungal colonies, a small portion of each distinct colony was carefully collected using a sterile inoculating needle and transferred onto freshly prepared Potato Dextrose Agar (PDA) plates. The inoculated plates were maintained under ambient laboratory conditions and monitored daily for 5–7 days to observe fungal development. To obtain uncontaminated cultures, successive sub-culturing was performed. Briefly, a small portion of fungal growth from the developing culture was aseptically transferred with a sterilized inoculating needle to the centre of a fresh PDA plate. This procedure was repeated as necessary until morphologically uniform and pure cultures of the individual fungal isolates were obtained.

**Identification of Fungi**

The fungal isolates were identified using both macroscopic and microscopic characteristics. Macroscopic identification was based on observable features of the colonies, including colony colour, texture, growth pattern, and general morphology on PDA. For microscopic examination, a drop of Lactophenol Cotton Blue stain was placed on a clean glass slide. A small portion of the fungal colony was gently transferred onto the stained area using a sterile inoculating needle and covered with a coverslip. The prepared slides were examined under the ×40 objective of a light microscope. Microscopic features such as the nature of the hyphae, conidiophores, spores, and other reproductive structures were observed and used for identification [14]. The morphological characteristics obtained from both macroscopic and microscopic examinations were compared with standard taxonomic identification references [16].

**Data Analysis**

The experimental data were subjected to statistical analysis using the chi-square ($\chi^2$) test and analysis of variance (ANOVA). Where significant differences were detected, treatment means were compared using Fisher's least significant difference (LSD) test at the 5% level of significance.

## RESULTS

The morphological features of *Aspergillus niger*, *Penicillium* sp. and *Aspergillus flavus* isolated from *Sorghum* seeds is presented in Plates 1a-3b. The colony of *Penicillium* sp. on PDA was powderish green in colour with white edges (Plate 1a). When viewed under the microscope, the conidiophores produced brush-like structures (Plate 1b). The colony of *A. niger* on PDA was black in colour (Plate2a). Microscopically, the conidia of *A. niger* were dark in colour borne on smooth, long and transparent conidiophores (Plate 2b). The colony of *Colletotrichum* sp was white in colour with wooly appearance (Plate 3a). Microscopically, the conidia were hyaline, smooth-walled and ovoid in shape (Plate 3b)

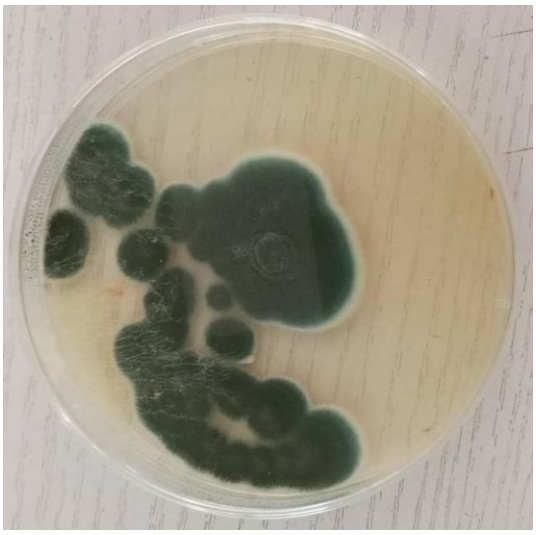

*Plate 1a. Macroscopic view of Penicillium sp*

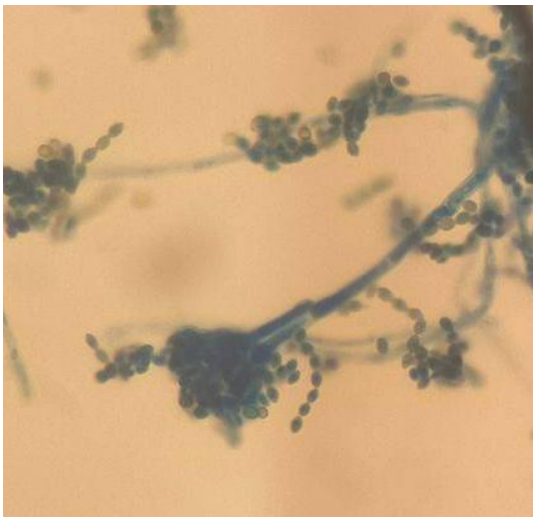

*Plate 1b. Microscopic view of Penicillium sp*

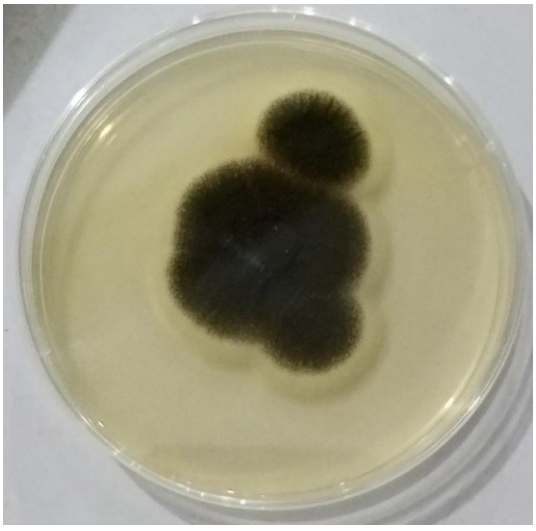

*Plate 2a. Macroscopic view of Aspergillus niger*

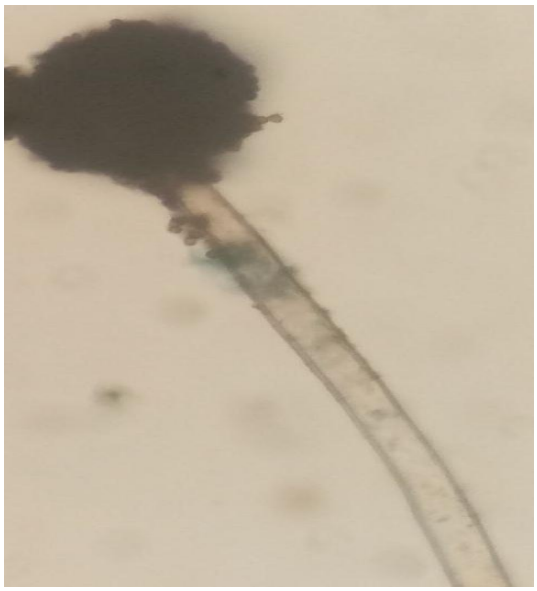

*Plate 2b. Microscopic view of Aspergillus niger*

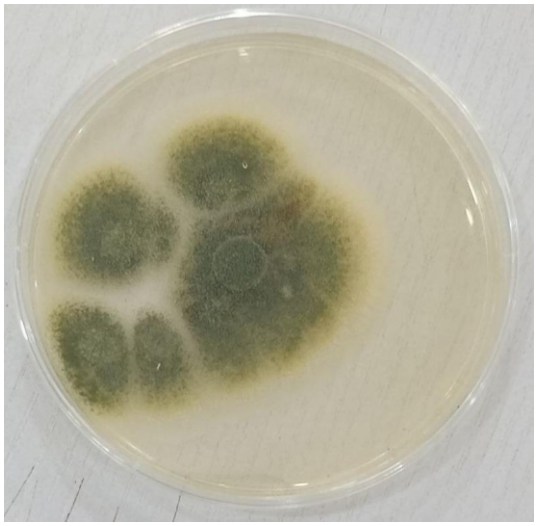

*Plate 3a. Macroscopic view of Aspergillus flavus*

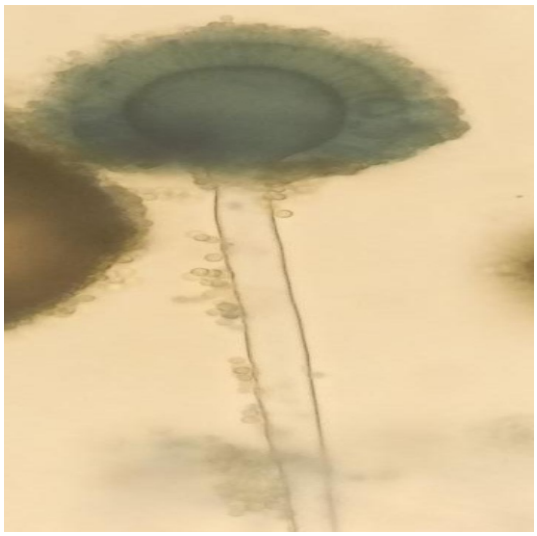

*Plate 3b. Microscopic view of Aspergillus flavus*

*Mean Fungi Occurrence in Sorghum Grains Collected from Selected Storehouses in Makurdi LGA*

The mean fungi occurrence in *Sorghum* grains collected from selected storehouses in Makurdi Local Government Area, Benue State is presented in Table 1. The findings revealed that the storehouse in Northbank recorded the highest mean fungi occurrence (2.33), followed by the storehouse in Wurukum and the one in Yaikyo market both with 2.00. There was no significant difference in the mean fungi occurrence in *Sorghum* grains collected from the storehouses.

***Table 1: Mean Fungi Occurrence in Sorghum Grains Collected from Selected Storehouses in Makurdi LGA***

| Location | Mean Fungi Occurrence |
|---|---|
| Store in Wurukum | 2.00 |
| Store inYaikyo market | 2.00 |
| Store in Northbank | 2.33 |
| **FLSD (0.05)** | **NS** |

***Key:*** *FLSD: Fisher's Least Significant Difference; NS: Not Significant*

## Percentage Seed Germination and Vigour of *Sorghum* Grains Collected from Selected Storehouses in Makurdi LGA

The percentage germination and vigour of *Sorghum* grains collected from selected storehouses in Makurdi LGA is presented in Table 2. The results show that the store house in Yaikyo market and the store house in Northbank recorded the highest germination each with (73.30%) followed by the store house in Northbank (70.00%). There was significantly higher vigour in grains obtained from the store house inYaikyo market (820.0) compared with the storehouse in Wurukum which showed 743.8 and the store house in Northbank which showed 526.7.

***Table 2: Germination and Vigour of Sorghum Grains Collected from Selected Storehouses in Makurdi LGA***

| Location | Germination (%) | Vigour |
|---|---|---|
| Storehouse in Wurukum | 70.00 | 743.8 |
| Storehouse inYaikyo market | 73.30 | 820.0 |
| Storehouse in Northbank | 73.30 | 526.7 |
| **FLSD (0.05)** | **NS** | **97.98** |

***Key:*** *FLSD: Fisher's Least Significant Difference; NS: Not Significant*

## Occurrence of Specific Fungi on *Sorghum* Grains Collected from Selected Stores in Makurdi LGA

The occurrence of specific fungi on *Sorghum* grains collected from selected storehouses in Makurdi LGA is presented in Table 3. The results showed that in *Sorghum* grains from the store house in Wurukum, *Aspergillus flavus*, was the most predominant (50.0%), followed by *Penicillium* sp (33.3%) and *Aspergillus niger* (16.7%). In the grains from the storehouse in Yaikyo market, *Penicillium* sp had the highest occurrence (50.0%) followed by *Aspergillus niger* at 33.3% and *Aspergillus flavus* with 16.7%. In the grains from the storehouse in Northbank, *Aspergillus flavus* was also the most occurring fungus (57.1%), followed by *Penicillium* sp (28.6%) and *Aspergillus niger* (14.3%). Overall, *Aspergillus flavus* had the highest total occurrence (50.0%), followed by *Penicillium* sp (36.8%) and *Aspergillus niger* (21.1%). Grains from the storehouse in Northbank recorded the highest total fungal occurrence (36.8%), while grains from the storehouse in Wurukum and Yaikyo market had equal occurrence each with (31.6%). Chi-square analysis revealed that the that there was no significant relationship in fungi occurrence with respect to location.

*Table 3: Occurrence of Specific Fungi on Sorghum Grains Collected from Selected Stores in Makurdi LGA*

| | Fungi Occurrence (%) | | | |
|---|---|---|---|---|
| **Location** | ***A. flavus*** | ***Penicillium* sp** | ***A. niger*** | **Total (%)** |
| Storehouse in Wurukum | 3 (50.0) | 2 (33.3) | 1 (16.7) | 6 (31.6) |
| Store in Yaikyo market | 1 (16.7) | 3 (50.0) | 2 (33.3) | 6 (31.6) |
| Store in Northbank | 4 (57.1) | 2 (28.6) | 1 (14.3) | 7 (36.8) |
| **Total** | **8 (50.00)** | **7 (36.8)** | **4 (21.1)** | **19 (100.0)** |

$\chi^2 = 2.45$; $df = 4$; $P = 0.65$

## Aflatoxin Level in *Sorghum* Grains Collected from Selected Storehouses in Makurdi LGA

The aflatoxin level in *Sorghum* grains collected from selected storehouses in Makurdi LGA is shown in Table 4. There was significantly higher aflatoxin level in *Sorghum* grains obtained from the storehouse in Northbank (6.85) µg/kg compared with that obtained from the storehose in Yaikyo market (1.34) µg/kg, while the *Sorghum* grains obtained from the store house in Wurukum had no detectable aflatoxin (0.00) µg/kg.

*Table 4: Aflatoxin Level in Sorghum Grains Collected from Selected Storehouses in Makurdi LGA*

| Location | Aflatoxin Level (µg/kg) |
|---|---|
| Storehouse in Wurukum | 0.00 |
| Storehouse in Yaikyo market | 1.34 |
| Storehouse in Northbank | 6.85 |
| **FLSD (0.05)** | **0.45** |

***Key:*** *FLSD: Fisher's Least Significant Difference; NS: Not Significant*

## Threshold permissible limit by European Union (4µg/kg); Threshold limit by Standard Organization of Nigeria (20µg/kg)

## Discussion

*Sorghum* grains are susceptible to diseases caused by some plant pathogenic fungi, thereby limiting the successful production of the crop [17]. The findings from this research identified three fungi in *Sorghum* grains from selected store houses in Makurdi, Benue State of Nigeria. These fungi are *Aspergillus niger*, *Penicillium* sp and *Aspergillus flavus*. This result agrees with the findings of [17] who isolated similar fungi on *Sorghum* seeds in Owerri metropolis, Imo State in Nigeria. The genus *Aspergillus* is a common mold in tropical and sub-tropical countries and causes aflatoxin-contamination in poorly stored commodities such as *Sorghum*, cereal and cotton seeds [17]. The present study revealed that *Aspergillus flavus*. showed the highest frequency of occurrence. The predominance of *Aspergillus flavus* may be linked to its ability to colonize *Sorghum* grains both pre- and postharvest, causing anthracnose and other seed and seedling infections that compromise seed viability [18]. Its higher occurrence compared with *Aspergillus niger* and *Penicillium* sp. could also be attributed to favorable storage conditions such as higher moisture content, suboptimal ventilation, or poor sanitary practices, which promote fungal growth [19]. Seed-borne fungi are known to significantly affect germination, seedling vigour, and overall crop establishment. *Aspergillus flavus*., in particular, can lead to seed rot, necrosis, and reduced seedling emergence, thereby impacting crop productivity [20]. Similarly, *Aspergillus niger* and *Penicillium* species are common storage fungi that can produce mycotoxins, reduce seed quality, and limit germination if present in high densities [21].

The variation in fungal occurrence observed in this study may also be influenced by environmental factors. Differences in temperature, relative humidity, and handling practices across storage locations can determine which fungi dominate seed populations [22]. The study revealed that *Sorghum* grains obtained from the storehouse in Northbank showed the highest fungal incidence compared with grains sourced from the storehouse in Yaikyo market and the storehouse in Wurukum. This variation in fungal occurrence in the different store houses can be attributed to differences in storage conditions, handling practices, and duration of storage. Poor ventilation, higher relative humidity, inadequate cleaning of storage facilities, and prolonged storage periods create favourable conditions for the growth and proliferation of seed-borne fungi such as *Aspergillus flavus*, *Penicillium* sp. and *Aspergillus niger* [21]; [19]. The lower fungal occurrence in *Sorghum* grains from the storehouse in Yaikyo market and the storehouse in Wurukum may suggest better storage management practices, including proper drying of grains before storage, maintenance of hygienic storage conditions, and possibly shorter storage durations. These observations highlight the critical role of good postharvest management in reducing fungal contamination and preserving grain quality in *Sorghum*.

The study revealed that *Sorghum* grains obtained from the storehouse in Northbank had the highest incidence of fungi, whereas grains from the storehouse in Yaikyo market and the storehouse in Wurukum showed lower fungal contamination. Correspondingly, *Sorghum* grains from the storehouse in Yaikyo market and the storehouse in Wurukum also recorded higher germination rates compared with those from the store in Northbank. This inverse relationship between fungal incidence and seed germination aligns with well-established observations that seed-borne fungi negatively affect seed viability and seedling vigour [18]; [20]. High fungal loads, as observed in *Sorghum* grains from the storehouse in Northbank, can reduce germination by causing seed rot, embryo damage, or depletion of seed reserves, leading to poor seedling establishment [22]. In contrast, *Sorghum* grains from the storehouse in Yaikyo market and the storehouse in Wurukum, which had lower fungal contamination, maintained higher germination rates likely due to better storage conditions, proper drying, and improved handling practices that limit fungal growth [21].

The study revealed variation in aflatoxin levels among *Sorghum* grain samples from different storehouses in Makurdi LGA. *Sorghum* grains from the storehouse in Northbank recorded the highest aflatoxin concentration (6.85 µg/kg), followed by the storehouse in Yaikyo market (1.34 µg/kg), while *Sorghum* grains from the storehouse in Wurukum had undetectable levels (0.00 µg/kg). Aflatoxins are secondary metabolites produced primarily by *Aspergillus* species, especially *A. flavus* and *A. parasiticus*, which can colonise cereals under favourable environmental conditions such as high moisture content, elevated temperature, and poor storage hygiene [23]. The increased aflatoxin level in the storehouse in Northbank may be linked to the higher fungal occurrence observed in the *Sorghum* grains from this source, coupled with suboptimal storage conditions such as inadequate drying, high humidity, or prolonged storage. These conditions provide an ideal environment for the proliferation of aflatoxin-producing fungi [21]. In contrast, the absence of detectable aflatoxin in the *Sorghum* grains from the storehouse in Wurukum suggests that the *Sorghum* grains were stored under relatively clean and dry conditions, which inhibited fungal growth and toxin production.

## Conclusion

The study revealed that *Aspergillus flavus*, *Aspergillus niger* and *Penicillium* sp were the fungi isolated from *Sorghum* grains collected from storehouses in Makurdi Local Government Area, Benue State, with *Aspergillus flavus* showing the highest frequency of occurrence. *Sorghum* grains from the store house in Northbank recorded the highest fungal incidence, while grains from the storehouse in Yaikyo market had the highest germination and seedling vigour. Aflatoxin B1 was detected in all *Sorghum* samples obtained from the storehouse in Yaikyo market and the storehouse in Northbank, while no aflatoxin was detected in *Sorghum* samples from the storehouse in Wurukum. The levels of aflatoxin in the *Sorghum* grains from the storehouse in Yaikyo market and the storehouse in Northbank were below the permissible limit by the Standard Organisation of Nigeria but the level of aflatoxin in *Sorghum* from the storehouse in Northbank exceeded the permissible limit by European Union.

## Recommendations

Based on the findings from the study, the following recommendations are made;

i. Farmers within and outside Makurdi Local government area of Benue State should source high-quality *Sorghum* grains from stores in Wurukum for planting and consumption.

ii. Government and other related agencies should engage in routine testing of stored seeds for aflatoxin levels to ensure safety and quality.

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