Original Article

MYCOTIC QUALITY ASSESSMENTS OF FRUITS VENDED IN MAKURDI, BENUE STATE, NIGERIA

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ABSTRACT

Fresh fruits are susceptible to numerous postharvest pathogens including fungi. This study assessed the mycotic quality of selected fruits vended in Makurdi, Benue State, Nigeria. A total of 75 fruit samples comprising 15 samples each of banana, orange, pawpaw, mango and watermelon were collected from five selected markets: Railway, Wurukum, Wadata, High Level and Modern Market. Samples were analysed using the tissue-implantation method on Potato Dextrose Agar supplemented with chloramphenicol and incubated at 28 ± 2°C for 5 days. Fungal isolates were identified based on their macroscopic and microscopic characteristics. Pathogenicity was assessed by inoculating healthy fruits with fungal mycelial plugs and measuring the diameter of rot produced. Data were analysed using descriptive statistics, one-way analysis of variance (ANOVA), Duncan's Multiple Range Test (DMRT) and chi-square test at $P < 0.05$. A total of 129 fungal isolates belonging to five fungal groups were recovered. Aspergillus niger was the most frequently occurring isolate (35.7%), followed by Rhizopus stolonifer (27.1%), Penicillium expansum (27.1%), Fusarium spp. (6.2%) and Aspergillus flavus (3.9%). Fungal distribution differed significantly among fruit types ($\chi^2 = 35.485$, $df = 16$, $P = 0.003$), but no significant association was observed between fungal distribution and market location ($\chi^2 = 10.128$, $df = 16$, $P = 0.860$). Pathogenicity testing showed that A. niger produced the largest rot diameter (50.8 mm), followed by R. stolonifer (36.0 mm), A. flavus (35.0 mm), P. expansum (29.0 mm) and Fusarium spp. (19.0 mm). The study established that fruits vended in Makurdi harbour diverse spoilage fungi, with A. niger being the predominant and most destructive isolate under the study conditions. Improved hygiene, careful handling, appropriate storage and routine monitoring of fungal contamination are recommended to reduce postharvest losses and potential food-safety risks.

KEYWORDS: Fungal Contamination, Fruits, Postharvest Spoilage, Pathogenicity, Makurdi.

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INTRODUCTION

Fruits are the comestible part of mature ovary of flowering plants which are normally eaten raw (Ikhiwili, 2012). Fruits play an important role in human diet. They provide vitamins, minerals, dietary fibre, antioxidants and other bioactive compounds essential for health (Mailafia *et al.*, 2017; Karasawa and Mohan, 2018; Dhalaria *et al.*, 2020). However, their high moisture content, active metabolism and generally favourable conditions for microbial growth make them highly perishable commodities (Mailafia *et al.*, 2017; Mairami *et al.*, 2018). Considerable quantities of fruits and vegetables are lost between production and consumption, with postharvest losses representing an important food-security, economic and environmental challenge. These challenges are pronounced in places where appropriate storage, transportation and preservation facilities are lacking (Bancal and Ray, 2022; Food and Agriculture Organization [FAO], 2022). Reports have shown that roughly 20% of fruits and vegetables harvested for human consumption are lost to spoilage (Agriculture Institute, 2025). Fungal deterioration constitutes one of the major biological causes of postharvest losses because fungi can colonise harvested fruits, degrade host tissues and cause progressive changes in colour, texture, odour, nutritional quality and marketability (Al-Hindi *et al.*, 2011).

Fresh fruits are susceptible to numerous postharvest fungal pathogens, particularly species belonging to the genera *Aspergillus*, *Penicillium*, *Fusarium*, *Alternaria*, *Botrytis*, *Rhizopus* and *Colletotrichum* (Sanzani *et al.*, 2016; Chen *et al.*, 2023). Fungal infection may occur before harvest or during harvesting, transportation, storage and retailing. Wounds and bruises provide important entry points for infection. The prevalence and development of these fungi are influenced by fruit maturity, temperature, relative humidity, water activity, handling practices and duration of storage (Das *et al.*, 2021; Chen *et al.*, 2023). As a result, fruits displayed for prolonged periods under ambient market conditions may experience progressive fungal colonisation, particularly when damaged fruits are stored in close proximity to apparently healthy commodities.

The significance of fungal contamination extends beyond visible deterioration. Several postharvest fungi can produce mycotoxins, which are toxic secondary metabolites capable of posing food-safety concerns (Mailafia *et al.*, 2017). *Aspergillus*, *Penicillium*, *Fusarium* and *Alternaria* species are recognised among important mycotoxin-producing fungal groups, with toxins such as aflatoxins, ochratoxin A, patulin, fumonisins and other secondary metabolites reported in food systems (Sanzani *et al.*, 2016). Studies have shown that fungal spoilage and mycotoxin contamination of fruits represent interconnected economic and food-safety problems, making the detection and characterisation of fungal contaminants important components of postharvest quality assessment (Chen *et al.*, 2023; Öztekin and Dikmetaş, 2023). Therefore, mycological examination of fruits at the point of sale can provide useful information about their microbiological quality and potential risks associated with handling and consumption.

Studies in Nigeria confirms the occurrence of different fungi in marketed fruits. Mailafia *et al.* (2017) isolated *Aspergillus niger*, *Fusarium avenaceum*, *F. solani*, *A. flavus*, *Penicillium digitatum*, *Rhizopus stolonifer* and *Saccharomyces* species from spoilt fruits sold in Gwagwalada Market, Abuja. Mairami *et al.* (2018) isolated *Aspergillus niger*, *Rhizopus nigricans*, *Mucor mucedo*, and *Fusarium*

oxysporum from spoilt fruits sold in Bwari Market, Abuja, Nigeria. Awua *et al.* (2022) isolated and identified *Aspergillus niger, Penicillium* spp., *Mucor* spp., *Bipolaris* spp. and *Cylindrocladium scoparium* from tomato fruits in Makurdi, Benue State. These findings show that commercially available fruits can harbour different fungal organisms of economic and potential public-health importance.

The situation is relevant to Makurdi, Benue State, where fungal deterioration of horticultural commodities has previously been documented. Awua *et al.* (2022) and Kator *et al.* (2018) isolated *A. niger, Penicillium* spp., *Mucor* spp., *Bipolaris* spp., *Cylindrocladium scoparium,* A*spergillus flavus, Penicillium waksmanii, Botryodiplodia theobromae, Fusarium oxysporum* and *Colletotrichum asianum* from spoiled tomatoes obtained from selected markets in Makurdi. Similarly, studies of oranges and other fruits in Makurdi have demonstrated the involvement of several fungal organisms in postharvest deterioration (Aernan *et al.*, 2015; Akinyemi and Liamngee, 2018; Selumun *et al.*, 2025; Liamngee *et al.*, 2026). However, much of the existing local research has concentrated on individual fruits that already exhibited visible spoilage, rather than providing a broader assessment of the mycotic quality of different fruits as offered for sale. As such, assessing fungal load, diversity and distribution across selected fruits and vending locations can provide a more comprehensive indication of their microbiological quality. Therefore, this study assessed the mycotic quality of selected fruits vended in Makurdi, Benue State, Nigeria. The study also recommends appropriate measures to control fungi infestation.

MATERIALS AND METHODS

Study Area

The study was conducted in Makurdi metropolis, Makurdi Local Government Area of Benue State, North-Central Nigeria. Makurdi is the capital of Benue State and is situated within the Guinea Savannah zone of Nigeria, approximately between latitudes 7°38′ and 7°47′N and longitudes 8°28′ and 8°38′E. The metropolis is bisected by the River Benue, which divides it into the North Bank and South Bank areas. Makurdi experiences a tropical wet-and-dry climate, with the rainy season generally occurring from April to October and the dry season from November to March. The area has relatively high temperatures and annual rainfall of approximately 1,200–1,500 mm, conditions that can favour the growth and proliferation of fungi on improperly handled fresh fruits (Atser *et al.*, 2025).

Sample Collection

A total of 75 fruit samples, comprising 15 samples each of banana (*Musa* spp.), orange (*Citrus sinensis*), pawpaw (*Carica papaya*), mango (*Mangifera indica*), and watermelon (*Citrullus lanatus*), were collected from fruit vendors across five selected locations in Makurdi metropolis (Railway, Wurukum, Wadata, High level and Modern Markets). Three samples of each fruit type were randomly selected from each location, placed separately in sterile labelled polyethylene bags, and transported to the Microbiology Laboratory, Department of Biological Sciences, Reverend Father Moses Orshio Adasu University Makurdi (MOAUM), for mycological analysis.

Preparation of Culture Media

Commercially dehydrated Potato Dextrose Agar (PDA) was prepared according to the manufacturer's instructions. The quantity of the medium (PDA powder) was weighed and dissolved in distilled

water. The media was heated to boil over Bunsen flame until the agar completely dissolved. The prepared medium was dispensed into suitable containers and sterilised by autoclaving at 121°C for 15 min. After sterilisation, the medium was allowed to cool to approximately 45–50°C before being aseptically poured into sterile Petri dishes and allowed to solidify (Iyaji *et al.*, 2026).

Isolation of Fungal Species from Fruits

The isolation of fungi from the fruit samples was carried out using the tissue-implantation method described by Iyaji *et al*., (2026). Each fruit was first washed with sterile distilled water to remove adhering soil and other surface debris. Using a sterile scalpel, approximately 3 mm × 3 mm tissue sections were excised from the interface between visibly infected and apparently healthy tissues. The excised portions were surface-sterilised in 1% sodium hypochlorite for 2 min and rinsed three times with sterile distilled water to remove residual disinfectant. The sterilised tissue segments were aseptically placed on solidified Potato Dextrose Agar (PDA) plates containing chloramphenicol (30 mg/L) to suppress bacterial growth. The inoculated plates were incubated at 28 ± 2°C for 5 days and examined daily for fungal growth. The fungal isolates were subcultured on PDA slants to obtain pure cultures (Iyaji *et al.*, 2026).

Identification of Fungal Isolates

The purified fungal isolates were identified based on their macroscopic and microscopic characteristics. Macroscopic identification involved examination of colony colour, texture, surface appearance, growth pattern, margin and pigmentation on PDA after incubation (Tafinta *et al.*, 2013; Iyaji *et al.*, 2026). For microscopic identification, a small portion of each fungal colony was mounted in a drop of lactophenol cotton blue (LPCB) on a clean glass slide and examined under the ×10, ×40 and ×100 objective lenses of a compound light microscope. Identification was based on characteristic structures including hyphae, septation, conidiophores, phialides, conidia, sporangia and sporangiospores. The observed characteristics were compared with standard taxonomic descriptions and identification keys for medically and agriculturally important fungi (Oyeleke and Manga, 2008; Liamngee *et al.*, 2015; Iyaji *et al.*, 2026).

Pathogenicity Test

Healthy fruits were washed with sterile distilled water and surface-sterilised with 1% sodium hypochlorite for 2 min. The fruits were then rinsed thrice with sterile distilled water and air-dried under aseptic conditions. A sterile cork borer was used to make a uniform wound of approximately 3 mm in diameter on the fruit surface. A mycelial plug (5 mm diameter) obtained from a 5-day-old pure fungal culture was aseptically placed into each wound and gently pressed to ensure contact with the fruit tissue. Control fruits were inoculated with sterile PDA plugs without fungal mycelia. The inoculated and control fruits were incubated at 28 ± 2°C and observed daily for 7 days for development of rot or other visible disease symptoms. The ability of each isolate to reproduce the characteristic symptoms observed in the original samples was used as evidence of pathogenicity. Re-isolation of the inoculated fungus from the inoculated tissues was carried out to confirm the causal association (Iyaji et al., 2026).

Statistical Analysis

Data obtained from the study were subjected to descriptive and inferential statistical analyses using IBM SPSS Statistics version 26.0. Chi-square (χ^2) test was used to determine the association between fruit type, sampling location and occurrence of fungal isolates. Statistical significance was accepted at $P < 0.05$.

RESULTS

Table 1 shows the frequency of occurrence of fungal species isolated from fruits vended in Makurdi. *Aspergillus niger* had the highest frequency of occurrence (35.7%) and was isolated from banana, mango, watermelon, orange, and pawpaw. *Rhizopus stolonifer* and *Penicillium expansum* followed, with a frequency of 27.1% each, and were isolated from banana, mango, orange, pawpaw, and watermelon. *Fusarium* spp. had a frequency of occurrence of 6.2% and were isolated from orange and watermelon, while *Aspergillus flavus* had the least frequency of occurrence (3.9%) and was isolated from orange, pawpaw, and watermelon. A total of 129 fungal isolates were recovered from the fruits vended in Makurdi.

Table 2 shows the distribution of fungi isolated from different fruits vended in Makurdi. In banana, *Penicillium expansum* was the most predominant fungus (47.8%), while *Aspergillus niger* was predominant in mango (40.0%) and pawpaw (44.4%). In orange, *A. niger* had the highest distribution (31.3%), while *Rhizopus stolonifer* was most predominant in watermelon (40.9%). Overall, *A. niger* had the highest total occurrence (35.7%), followed by *P. expansum* and *R. stolonifer* (27.1% each), while *A. flavus* had the lowest occurrence (3.9%). Orange recorded the highest total fungal distribution (24.8%). Chi-square analysis revealed a statistically significant association between fruit type and fungal species distribution ($P = 0.003$).

The distribution of fungal isolates based on the selected locations in Makurdi is presented in Table 3. The results show that in Railway, *A. niger* and *R. stolonifer* were the most predominant fungi (32.0% each), followed by *P. expansum* (28.0%). In Wurukum, *A. niger* was the most predominant (36.4%), followed by *P. expansum* (30.3%) and *R. stolonifer* (27.3%). In Wadata, *A. niger* had the highest distribution (37.0%), followed by *P. expansum* (29.6%) and *R. stolonifer* (25.9%). In High Level, *A. niger* and *R. stolonifer* were most predominant (36.0% and 32.0%, respectively), while in Modern Market, *A. niger* was highest (36.8%), followed by *P. expansum* and *Fusarium* spp. (21.1% each). In general, *A. niger* had the highest total occurrence (35.7%), followed by *P. expansum* and *R. stolonifer* (27.1% each), while *A. flavus* had the lowest occurrence (3.9%). Wurukum recorded the highest total fungal distribution (25.6%), followed by Wadata (20.9%). Chi-square analysis revealed no statistically significant difference in fungal species distribution among the sampled locations ($P = 0.860$).

The pathogenicity of fungal isolates on fruits obtained in Makurdi, Benue State is presented in Table 4. The result show that *Aspergillus niger* produced the highest pathogenicity producing the largest diameter of rot (50.8 mm), followed by *Rhizopus stolonifer* (36.0 mm), *Aspergillus flavus* (35.0 mm), *Penicillium expansum* (29.0 mm), and *Fusarium* spp. (19.0 mm).

Table 1: Frequency of Occurrence of Fungal Species Isolated from Fruits Vended in Makurdi

Fungal isolates	Fruits infected	Frequency (%)
Aspergillus niger	Banana, mango, watermelon, orange and pawpaw	46 (35.7)
Rhizopus stolonifer	Banana, mango, orange, pawpaw and watermelon	35 (27.1)
Penicillium expansum	Banana, mango, orange, pawpaw and watermelon	35 (27.1)
Fusarium spp.	Orange and watermelon	8 (6.2)
Aspergillus flavus	Orange, pawpaw and watermelon	5 (3.9)
Total		**129 (100.0)**

Table 2: Distribution of Fungal Isolates Recovered from Different Fruits Vended in Makurdi

Fruit	Fungi Distribution					
	***A. niger* (%)**	***A. flavus* (%)**	***P. expansum* (%)**	***R. stolonifer* (%)**	***Fusarium spp* (%)**	**Total (%)**
Banana	9 (39.1)	0 (0.0)	11 (47.8)	3 (13.0)	0 (0.0)	23 (17.8)
Mango	10 (40.0)	0 (0.0)	5 (20.0)	10 (40.0)	0 (0.0)	25 (19.4)
Orange	10 (31.3)	1 (3.1)	6 (18.8)	8 (25.0)	7 (21.9)	32 (24.8)
Pawpaw	12 (44.4)	3 (11.1)	7 (25.9)	5 (18.5)	0 (0.0)	27 (20.9)
Watermelon	5 (22.7)	1 (4.5)	6 (27.3)	9 (40.9)	1 (4.5)	22 (17.1)
Total	**46 (35.7)**	**5 (3.9)**	**35 (27.1)**	**35 (27.1)**	**8 (6.2)**	**129 (100.0)**

$\chi^2 = 35.485$, df = 16, p = 0.003

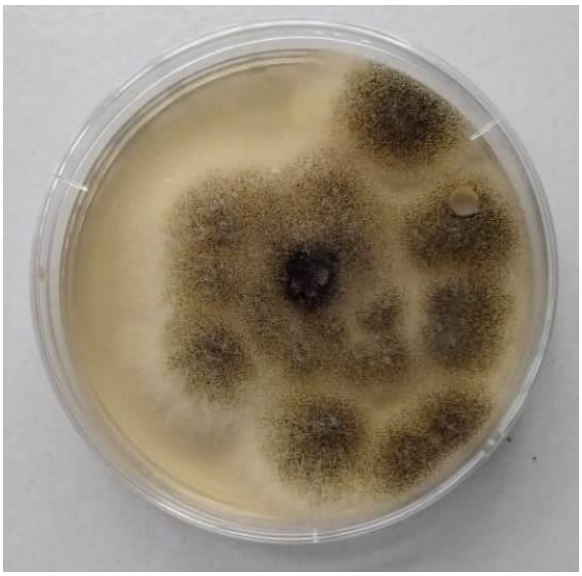
Table 3: Distribution of Fungal Isolates based on Location

Location	Fungi Distribution					
	***A. niger* (%)**	***A. flavus* (%)**	***P. expansum* (%)**	***R. stolonifer* (%)**	***Fusarium spp* (%)**	**Total (%)**
Railway	8 (32.0)	1 (4.0)	7 (28.0)	8 (32.0)	1 (4.0)	25 (19.4)
Wurukum	12 (36.4)	1 (3.0)	10 (30.3)	9 (27.3)	1 (3.0)	33 (225.6)
Wadata	10 (37.0)	1 (3.7)	8 (29.6)	7 (25.9)	1 (3.7)	27 (20.9)
High Level	9 (36.0)	1 (4.0)	6 (24.0)	8 (32.0)	1 (4.0)	25 (19.4)
Modern Market	7 (36.8)	1 (5.3)	4 (21.1)	3 (15.8)	4 (21.1)	19 (14.7)
Total	**46 (35.7)**	**5 (3.9)**	**35 (27.1)**	**35 (27.1)**	**8 (6.2)**	**129 (100.0)**

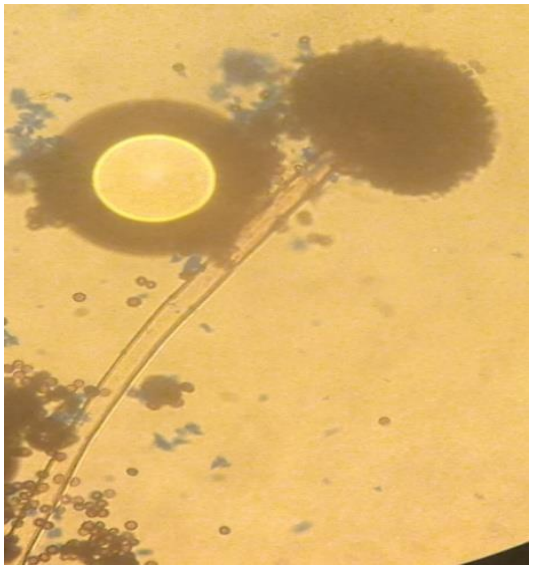
$\chi^2 = 10.128$, df = 16, p = 0.860

Table 4: Pathogenicity of Fungal Isolates on the Fruits Obtained in Makurdi, Benue State

Fungal Isolates	Diameter of rot (mm)
Aspergillus niger	50.8
Rhizopus stolonifer	36
Penicillium expansum	29
Fusarium spp.	19
Aspergillus flavus	35



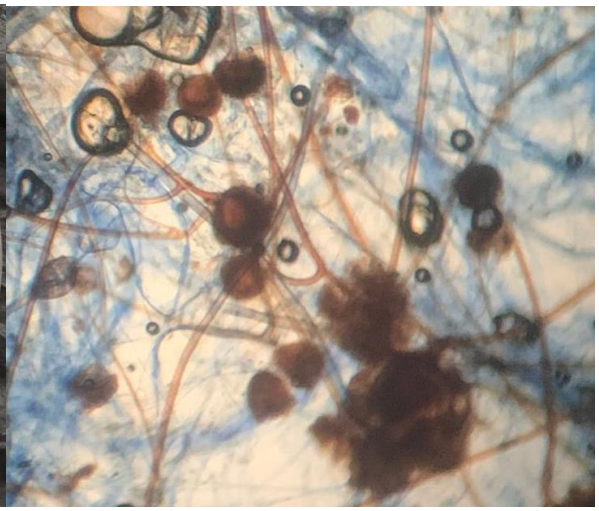
Macroscopic view of *A. niger*



Microscopic view of *A. niger*



Macroscopic view of *R. stolonifera*



Microscopic view of *R. stolonifera*



Plate 1a *A. flavus* on PDA

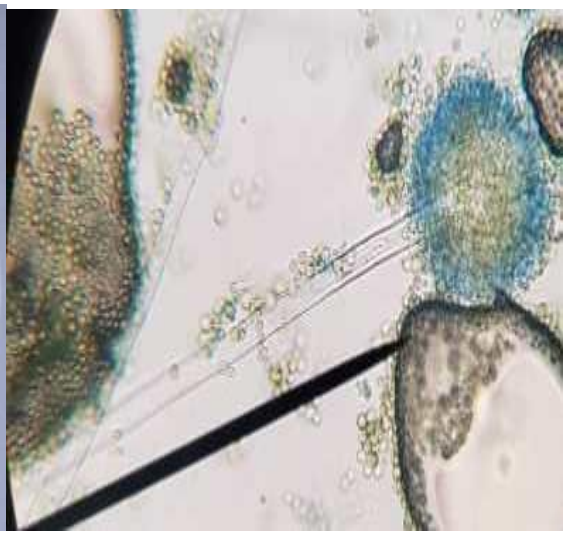
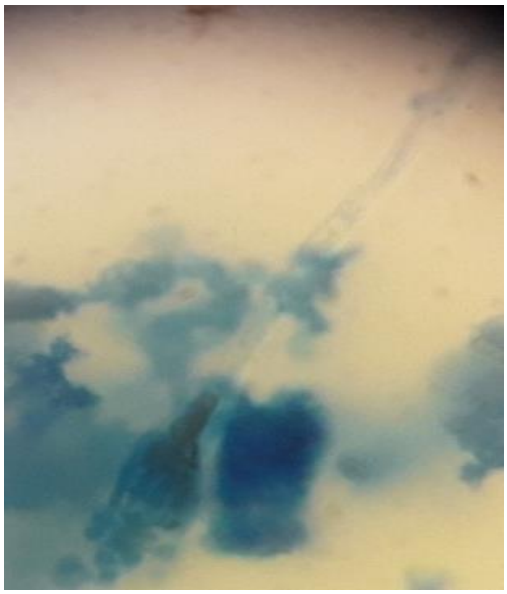


Plate 1b. *A. flavus* under microscope



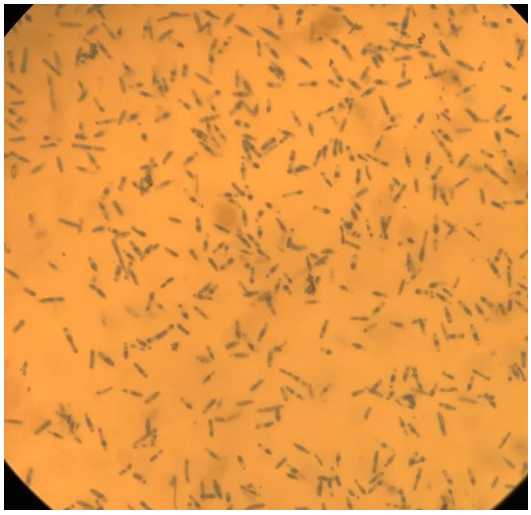
Macroscopic view of *Penicillium* sp



Microscopic view of *Penicillium* sp



Macroscopic view of *Fusarium* sp.



Microscopic view of *Fusarium* sp.

DISCUSSION

The result of the study established that fruits vended in selected markets in Makurdi were contaminated with a variety of fungi associated with post-harvest deterioration. A total of 129 fungal isolates were recovered, comprising *Aspergillus niger*, *Rhizopus stolonifer*, *Penicillium expansum*, *Fusarium* spp. and *Aspergillus flavus*. *A. niger* was the most frequently occurring fungus overall (35.7%), followed by *R. stolonifer* and *P. expansum* (27.1% each), while *A. flavus* had the lowest occurrence (3.9%). The recovery of these fungi from several fruit types demonstrates that fungal contamination is not restricted to a particular fruit but may occur across different fruits exposed to similar handling, transportation, marketing and storage conditions.

The predominance of *A. niger* agrees with several previous studies conducted on individual fruits. Ugwuanyi *et al.* (2019) recovered *A. niger*, *A. flavus* and *Fusarium* spp. from spoiled orange and pawpaw fruits, while Samuel *et al.* (2018) reported *A. niger* as the most frequently occurring fungus among spoiled pineapple, watermelon,

orange, pawpaw and tomato sold in Gwagwalada Market, Abuja. Abubakar *et al.* (2023) reported *A. niger* as the most frequent fungal isolate from spoiled orange fruits, accounting for 47.6% of isolates. The predominance of *A. niger* in the present study is also consistent with Ishwa *et al.* (2024), who found *A. niger* to be the more virulent of the fungi associated with mango rot in markets within Makurdi. It also agrees with Mukhtar *et al.* (2019) who reported *A. niger* as the predominant fungi associated with the spoilage of fruits in Utako market, Abuja, Nigeria. This finding is also in conformity with that of Mailafia *et al.* (2017) who found *A. niger* as the predominant fungal isolate from spoiled fruits vended in Gwagwalada market, Abuja, Nigeria. Mairami *et al.* (2018) also reported *A. niger*as the most dominant spoilage causing organism on fruits vended in Bwari Market while *Fusarium oxysporum* was the least abundant fungi. These similarities suggest that *A. niger* is widely distributed in fruit-marketing environments and can readily colonise different fruits when favourable conditions exist.

The occurrence of *R. stolonifer* and *P. expansum* is also noteworthy. *R. stolonifer* has previously been reported among the major fungi associated with banana, mango, pawpaw, orange and watermelon spoilage. Mairami (2024) identified *R. stolonifer* and *A. niger* as the most prominent fungi associated with banana spoilage in Kwali Market, while Ngongu *et al.* (2018) isolated *R. stolonifer* together with *A. niger*, *Penicillium chrysogenum*, *Fusarium oxysporum* and *Bipolaris harlodes* from decaying orange fruits. The relatively high occurrence of *P. expansum* in the present study is particularly reflected in banana, where it accounted for 47.8% of isolates. This finding differs from Sani and Kasim (2019), who reported *C. musae*, *A. niger* and *Fusarium* sp. as the most frequently occurring fungi in deteriorating bananas in Sokoto. Such differences may be related to fruit variety, maturity, geographical location, environmental conditions, handling practices and differences in isolation procedures.

The significant association between fruit type and fungal species distribution (P = 0.003) shows that the fungal profile changed according to the fruit examined. *P. expansum* predominated in banana, *A. niger* in mango, pawpaw and orange, while *R. stolonifer* was predominant in watermelon. This variation may be explained by differences in fruit composition, moisture content, peel characteristics, acidity and susceptibility to tissue injury. Ogbogu *et al.* (2014) demonstrated that fungal development in pawpaw was influenced by environmental factors such as temperature, moisture and pH. Padmaja *et al.* (2018) observed changes in the proximate composition of banana during deterioration, including increased moisture and reduced carbohydrate content. These findings show that the suitability of a fruit for colonisation may differ according to its physicochemical characteristics and stage of deterioration.

The absence of a significant association between market location and fungal species distribution (P = 0.860) suggests that the major fungal species were relatively widespread across the sampled markets. Although descriptive differences were observed, with Wurukum recording the highest overall fungal distribution (25.6%) and Wadata the next highest (20.9%). This finding may reflect similarities in fruit sourcing, transportation routes, storage conditions and handling practices across the markets. It differs from Ishwa *et al.* (2024), who reported significant differences in fungal occurrence across markets for mango fruits in Makurdi. The finding suggested that market-specific conditions may influence

some fruit-fungus relationships even within the same geographical area.

The pathogenicity results provide further evidence of the importance of the isolated fungi. *A. niger* produced the largest mean rot diameter (50.8 mm), followed by *R. stolonifer* (36.0 mm), *A. flavus* (35.0 mm), *P. expansum* (29.0 mm) and *Fusarium* spp. (19.0 mm). The high pathogenicity of *A. niger* agrees with Ishwa *et al*. (2024) who reported *A. niger* as the most virulent fungus associated with the spoilage of mango fruits in Makurdi. It is also consistent with findings of Abdul-Rahaman *et al*. (2023), who reported greater incidence and decay severity associated with *A. niger* in orange fruits. However, the result differs from Awoite *et al*. (2013), Mairami *et al.* (2018), Mukhtar *et al.* (2019) and Ogbogu *et al.* (2014), where *R. stolonifer* was reported as the most pathogenic organism associated with the spoilage of fruits. This difference demonstrates that fungal pathogenicity can vary according to the host fruit and experimental conditions.

Conclusion

The study established the presence of important spoilage fungi in fruits vended in selected markets in Makurdi, Benue State. *Aspergillus niger*, *Rhizopus stolonifer*, *Penicillium expansum*, *Fusarium* spp. and *Aspergillus flavus*, were responsible for the spoilage of fruits. *A. niger* had the highest overall frequency of occurrence (35.7%), while *A. flavus* had the lowest (3.9%). The distribution of fungi differed significantly according to fruit type (P = 0.003), with *P. expansum* predominant in banana, *A. niger* in mango and pawpaw, and *R. stolonifer* in watermelon. However, fungal distribution did not differ significantly among the sampled markets (P = 0.860). Pathogenicity testing showed that *A. niger* produced the largest rot diameter (50.8 mm), identifying it as the most destructive isolate under the conditions of the study.

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