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Research Article

The fungal profiles of spoiled fruits in Dutse metropolis, Jigawa State, Nigeria

Muhammad MH*[1], Abubakar MI[1], Sulaiman MA[2]

[1]Department of Microbiology and Biotechnology, Federal University, Dutse, Jigawa, Nigeria.
[2]Department of Microbiology, Ahmadu Bello University, Zaria, Kaduna State, Nigeria.

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***Corresponding author**

Muhammad MH
E-mail: musa.hassan@fud.edu.ng

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A B S T R A C T

This study investigated the prevalence and pathogenicity of fungal species associated with spoiled fruits in Dutse Metropolis, Jigawa State, Nigeria, known for its diverse fruit markets and semi-arid climate. A total of 100 spoiled fruit samples, comprising sweet oranges (*Citrus sinensis*), bananas (*Musa sapientum*), guavas (*Psidium guajava*), watermelons (*Citrullus vulgaris*), and tomatoes (*Solanum lycopersicum*), were collected and analyzed. Fungal isolation was performed by culturing on Potato Dextrose Agar (PDA) and incubating at room temperature for 5 to 7 days, followed by observation of the fungal growth. These were identified morphologically and microscopically, and pathogenicity tests were conducted to assess their spoilage potential. *Aspergillus niger* emerged as the most frequently isolated species, representing 19.5% of total isolates and primarily affecting bananas (30%), sweet oranges (20%), watermelons (15%), and tomatoes (15%). *Mucor* spp. and *Saccharomyces* spp. followed, with frequencies of 15.9% and 14.6%, respectively. *Mucor* spp. was particularly identified in bananas (25%), guavas (10%), watermelons (10%), and tomatoes (20%). *Saccharomyces* spp. predominantly affected watermelons (35%) and sweet oranges (15%). *Fusarium* spp. (12.2%) were associated with sweet oranges (5%), bananas (15%), guavas (10%), watermelons (10%), and tomatoes (10%). *Penicillium* spp. (11.0%) were found affecting bananas (20%) and tomatoes (25%). *Aspergillus flavus* (11.0%) was identified in sweet oranges (10%) and tomatoes (20%), while *Rhizopus stolonifer* (8.5%) was found in sweet oranges (15%) and bananas (10%). Moreover, *Aspergillus fumigatus* (7.3%) was present in sweet oranges (10%) and bananas (20%). Futhermore, pathogenicity tests confirmed that all isolated fungal species were capable of causing similar spoilage symptoms in healthy fruits, indicating their potential role in post-harvest losses. These findings demonstrate the significant role of various fungal species in the spoilage of fruits in the area, with *Aspergillus niger* emerging as a primary concern for fruit quality and safety. Further studies are recommended to explore potential control measures and the impact of environmental factors on fungal prevalence.

INTRODUCTION

Fruits are essential for human nutrition, offering vital vitamins, minerals, and fiber (Bancal and Ray, 2022). However, their perishable nature poses significant challenges to storage and distribution, leading to considerable post-harvest losses(Bancal and Ray, 2022; Mengistu and Sharew, 2024) Globally, it is estimated that approximately one-third of all fruits produced are wasted, with fungal spoilage being a major contributor (Ishangulyyev *et al.*, 2019; Saleh and Al-Thani, 2019). In Nigeria, where agriculture forms the backbone of the economy, this issue is particularly pressing, as inadequate storage facilities and poor handling practices exacerbate post-harvest losses.

The tropical and subtropical climates of Nigeria, characterized by high humidity and temperatures, favor fungal growth. These environmental factors, coupled with inadequate post-harvest handling and storage practices, exacerbate the vulnerability of fruits to spoilage. Previous studies have established that different fruits have varying susceptibilities to specific fungal species, influenced by both intrinsic factors and extrinsic factors (Bano *et al*., 2023; Gbeminiyi, 2022). Intrinsic properties can be attributed to the unique biochemical compositions of different fruits, which can create environments that are either conducive or prohibitive to fungal growth. For example, citrus fruits, with their high acidity, tend to attract different fungal species than stone fruits, which may be more susceptible to other pathogens (Ram and Bhardwaj, 2004; Bukar *et al*., 2010). Moreover, the maturity stage of the fruit significantly impacts its vulnerability, as overripe fruits are often softer and have higher sugar content, making them more appealing to fungal colonization(Alegbeleye *et al*., 2022; Gbeminiyi, 2022). Extrinsic factors also play a crucial role in determining fungal susceptibility. Environmental conditions such as humidity, temperature, and light exposure can drastically affect fungal growth rates and the overall shelf life of fruits (Gbeminiyi, 2022). Handling practices, including the way fruits are picked, packaged, and transported, can introduce or spread fungal spores, further compounding spoilage rates (Mailafia *et al*., 2017).

Fungal spoilage of fruits causes economic losses and health risks from potential mycotoxin production (Saleh and Al-Thani, 2019). Mycotoxins are toxic metabolites produced by certain fungi that contaminate food and pose serious health risks (Pandey *et al*., 2023). Spoilage microbes can be introduced into crops through seeds, during the growing process, at harvest, and during postharvest handling, storage, or distribution (Tafinta *et al*., 2014). Common fungal genera associated with fruit spoilage include *Aspergillus*, *Penicillium*, and *Mucor* (Mailafia *et al*., 2017; Oviasogie *et al*., 2015; Baiyewu *et al*., 2007). *Aspergillus niger* and *Aspergillus flavus* are often isolated from various fruits (Baiyewu *et al*., 2007).

This study aims to investigate the fungal species associated with spoiled fruits in Dutse Metropolis, focusing on five commonly consumed fruit types: sweet oranges, bananas, guavas, watermelons, and tomatoes. By analyzing the occurrence and prevalence of these fungi, this research seeks to provide essential information about the characteristics of the fruit spoilage in the area.

MATERIALS AND METHODS

Study Area

This study was conducted in Dutse, Jigawa State, Nigeria. The area was chosen for its diverse fruit markets and varying climatic conditions. Jigawa State has a semi-arid climate, characterized by extended dry periods and a brief rainy season.

Sample Collection

Five different types of fruits were collected from local markets in Dutse, with each type consisting of 20 samples: sweet orange (*Citrus sinensis*), banana (*Musa sapien*tum), guava (*Psidium guajava*), watermelon (*Citrullus vulgaris*), and tomato (*Solanum lycopersicum*), all showing signs of spoilage. A total of 100 spoiled fruit samples were collected over a period of three months (August to November 2023). Each fruit was individually placed in a sterile plastic bag to prevent cross-contamination during transport to the laboratory, and they were taken to the Microbiology Laboratory at Federal University Dutse for fungal analysis.

Fungal isolation

Each spoiled fruit sample was surface-sterilized with 70% ethanol-soaked cotton wool for 1 minute, then rinsed with sterile distilled water to remove contaminants. The fruit samples were then cut into small pieces (approximately 2 mm in diameter) and placed on Potato Dextrose Agar (PDA) plates. The agar plates were incubated at 28±3°C for 5 to 7 days, and the growth of fungal colonies was monitored daily. The fungal colonies that developed were regularly subcultured to obtain and maintain a pure culture of the fungal isolates. Non-infected fruits were also examined as a control.

Fungal Identification

Fungi were identified based on their morphological characteristics, including colony growth pattern, conidial morphology, and colony color. Identification was achieved by transferring a small portion of fungal mycelium to a glass slide and adding a drop of lactophenol cotton blue (LPCB). The mycelium was spread evenly on the slide with the sterile needle, and a cover slip was gently placed on top to avoid air bubbles. The slide was then placed on the microscope and viewed using the 10x and 40x objective lenses. The morphological characteristics of the fungi isolated from the spoiled fruits were determined and identified in accordance with the methods described by Alsohaili and Bani-Hasan (2018) and Watanabe (2002).

Decay Test of Isolated Fungi

Pathogenicity tests were conducted to determine which fungal strains isolated from infected samples could replicate the same spoilage symptoms in healthy fruits. Healthy fruits were surface sterilized with 70% ethanol, washed with water, and allowed to dry. A 2 mm diameter wound was made on the surface of the healthy fruits, which were then inoculated with the isolated fungal mycelia at the wounded site and incubated at room temperature. Control samples were inoculated with sterile distilled water. Signs of spoilage, such as softening, discoloration, and mold growth, were monitored. Sterilized forceps were used to transfer samples from diseased areas onto fresh PDA plates, which were incubated at 28 ± 2°C for 5-7 days. The fungal growth that developed was documented.

Statistical Analysis

All statistical analyses were conducted using GraphPad Prism (version 10). The frequency of each fungal species was calculated and expressed as both percentages and prevalence.

RESULTS

The study identified a range of fungal species associated with spoiled fruits in Dutse Metropolis, Jigawa State, Nigeria. The occurrence frequencies of the identified species and their respective spoiled fruits are presented in Table 1. The most isolated fungal species was *Aspergillus niger*, detected in 19.5% of the sampled fruits, primarily affecting sweet oranges, bananas, watermelons, and tomatoes. This was followed by *Mucor spp*. at 15.9%, and *Saccharomyces spp.*, which accounted for 14.6% of the spoilage. Furthermore, other species included *Fusarium spp.* (12.2%), *Penicillium spp.* (11.0%), and *Aspergillus flavus* (11.0%), all of which spoiled a variety of fruits. *Rhizopus stolonifer* and *Aspergillus fumigatus* were also identified, occurring at frequencies of 8.5% and 7.3%, respectively.

Table 1: Occurrence rate of fungal species

Identified fungal species	Spoiled fruits	Occurrence frequency (%)
Aspergillus niger	Sweet orange, Banana,Watermelon, Tomato	16(19.5)
Mucor spp	Banana, Guava, Watermelon,Tomato	13(15.9)
Saccharomyces spp	Sweet orange, Watermelon,Tomato	12(14.6)
Fusarium spp	Sweet orange, Banana, Guava,Watermelon, Tomato	10(12.2)
Penicillium spp	Banana, Tomato	9(11.0)
Aspergillus flavus	Sweet orange, Banana,Tomato	9(11.0
Rhizopus stolonifer	Sweet orange, Tomato, Banana	7(8.5)
Aspergillusfumigatus	Sweet orange, Banana	6 (7.3)

The prevalence and distribution of fungal species linked to spoiled fruits are summarized in Table 2. The analysis was based on a sample of 100 fruits across five types, with each type represented by 20 samples: sweet orange, banana, guava, watermelon, and tomato. The findings indicate that *Aspergillus niger* was the most frequently isolated species from bananas (30%) and sweet oranges (20%). *Mucor* spp. was particularly prevalent in bananas (25%) and tomatoes (20%). *Saccharomyces* spp. was predominantly found in watermelons (35%). Other species, such as *Penicillium* spp. and *Aspergillus flavus*, were also present, with *Penicillium* spp. affecting tomatoes (25%) and *Aspergillus flavus* detected in both sweet oranges (10%) and tomatoes (20%). *Rhizopus stolonifer* was detected at lower frequencies, mainly in sweet oranges (15%) and bananas (10%). Similarly, *Aspergillus fumigatus* was present in sweet oranges (10%) and bananas (20%).

Table 2: Prevalence and distribution of fungi linked to spoiled fruits.

Fungal species	Type of fruit (n = 20, %)				
	Sweet orange	Banana	Guava	Watermelon	Tomato
Aspergillus niger	4 (20)	6 (30)	0 (0)	3(15)	3(15)
Mucor spp	0 (0)	5 (25)	2(10)	2 (10)	4 (20)
Saccharomyces spp	3 (15)	0 (0)	0 (0)	7 (35)	2 (10)
Fusarium spp	1 (5)	3 (15)	2 (10)	2 (10)	2 (10)
Penicillium spp	0 (0)	4 (20)	0 (0)	0 (0)	5 (25)
Aspergillus flavus	2 (10)	3 (15)	0 (0)	0 (0)	4 (20)
Rhizopus stolonifer	3(15)	2(10)	0 (0)	0 (0)	2 (10)
Aspergillus fumigatus	2 (10)	4 (20)	0 (0)	0 (0)	0 (0)

The pathogenicity tests conducted after inoculation for 5-7 days on fresh fruits confirmed the ability of various fungal species to cause spoilage. The results are summarized in Table 3. All tested fungal species, including *Aspergillus niger*, *Mucor spp.*, *Saccharomyces spp.*, *Fusarium spp.*, *Penicillium spp.*, *Aspergillus flavus*, *Rhizopus stolonifer*, and *Aspergillus fumigatus*, exhibited positive pathogenicity, indicating their potential to contribute to fruit spoilage.

Table 3: Pathogenicity Test Results of Fungal Species on Fresh Fruits After 7 Days of Inoculation

Identified fungal species	*A. niger*	*Mucorspp*	*Saccharomyces spp*	*Fusarium spp*	*Penicillium spp*	*A. flavus*	*R. stolonifer*	*A. fumigatus*
Pathogenicity status	+	+	+	+	+	+	+	+
Contribution to Fruit Spoilage	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Key: + = Isolates exhibit growth characteristics similar to those of the original diseased samples.

DISCUSSION

The preservation of fruits is critical for food security, economic stability, and public health. In Nigeria, fruit spoilage poses significant challenges due to the country's tropical climate, which fosters fungal growth. In the present study, the results indicate that a range of fungal species was isolated from spoiled fruits, with *Aspergillus niger* emerging as the most prevalent, detected in 19.5% of sampled fruits. This species is well-documented as a dominant spoilage agent in various fruits (Mailafia *et al*., 2017). This finding aligns with previous studies that report *A. niger* as a dominant spoilage organism in various fruit types (Mailafia *et al*., 2017; Zakaria and Li, 2015). Its high incidence in sweet oranges, bananas, watermelons, and tomatoes suggests a wide ecological niche, allowing it to thrive in different fruit substrates. Moreover, the high incidence of *A. niger* is concerning, as it is known to produce aflatoxins, which pose serious health risks(Kumar *et al*., 2016). Following *A. niger*, *Mucor spp.* and *Saccharomyces spp.* were identified at frequencies of 15.9% and 14.6%, respectively. *Mucor* species are commonly associated with soft rot and can cause significant economic losses(Saito *et al*., 2016). Meanwhile, *Saccharomyces spp.*, typically known for its role in

fermentation, has also been implicated in fruit spoilage (Mailafia *et al*., 2017), suggesting a dual role in both food preservation and spoilage processes. Other fungal species such as *Fusarium spp.*, *Penicillium spp.*, and *Aspergillus flavus* were also present, each accounting for 12.2% and 11.0% of spoilage. These findings support earlier research indicating the prevalence of these genera in various post-harvest situations (Ahmed *et al*., 2020; Bukar *et al*., 2010). Similarly, *A. flavus* is another potential aflatoxin producer, raising further concerns regarding food safety. The presence of *Rhizopus stolonifer* and *Aspergillus fumigatus* at lower frequencies (8.5% and 7.3%, respectively) further highlights the diversity of spoilage organisms that can affect fruits. *Rhizopus* is well-known for causing rapid decay in soft fruits, while *A. fumigatus* can pose respiratory risks, particularly in immunocompromised individuals (Arastehfar *et al*., 2021; Liu *et al*., 2024).

The study found that bananas and sweet oranges were significantly affected by *Aspergillus niger*, with prevalence rates of 30% and 20%, respectively. These findings align with previous studies showing *Aspergillus* species commonly spoil these fruits during storage (Mailafia *et al*., 2017). Furthermore, *Mucor spp*. showed high prevalence in bananas (25%) and tomatoes (20%) (Saito *et al*., 2016). *Saccharomyces spp.* exhibited the highest spoilage rate in watermelons (35%). While typically associated with fermentation, certain strains of *Saccharomyces* can also contribute to fruit spoilage (Mailafia *et al*., 2017). The presence of *Penicillium spp.* and *Aspergillus flavus* in tomatoes further complicates the spoilage process, given their known capacity to produce mycotoxins (Pfliegler *et al*., 2019).

The pathogenicity tests confirmed the spoilage potential of the identified fungal species, with all tested fungi exhibiting positive results after 7 days of inoculation. This confirms the findings of previous studies, which have shown that these fungi can compromise the integrity and quality of fruit. The significant pathogenicity of *Aspergillus niger* and *Mucor spp*. emphasizes the necessity for effective management strategies in fruit handling and storage (Mailafia *et al*., 2017; Saito *et al*., 2016).

The diversity of fungal species identified in this study suggests that post-harvest handling practices must be reevaluated to prevent spoilage. Proper sanitation practices and the use of fungicides can help reduce fungal contamination. Furthermore, educating farmers and vendors about optimal storage conditions could significantly reduce the incidence of fungal spoilage.

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