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Fungal Pathogens Associated With Postharvest Deterioration of Okra (*Abelmoschus esculentus*) Fruits In Sokoto South, Nigeria

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ABSTRACT
Okra (*Abelmoschus esculentus*) is an important vegetable crop that is highly susceptible to postharvest deterioration due to microbial infection, resulting in significant losses in quality and market value. This study was conducted to isolate and identify fungal pathogens associated with spoilage of okra fruits collected from Sokoto South Local Government Area, Sokoto State, Nigeria. Fresh okra samples were subjected to mycological analysis using standard isolation and identification techniques based on macroscopic and microscopic characteristics. The results revealed the presence of four fungal pathogens: *Rhizopus stolonifer, Aspergillus niger, Aspergillus fumigatus,* and *Candida tropicalis*. Among the isolated fungi, *Rhizopus stolonifer* had the highest frequency of occurrence, while *Candida tropicalis, Aspergillus niger,* and *Aspergillus fumigatus* had the least frequencies of occurrence. The findings suggest that fungal contamination contributes significantly to postharvest losses of okra fruits, which may be associated with poor handling, storage conditions, and environmental exposure. Improved sanitation, proper handling practices, and effective storage methods are recommended to reduce fungal spoilage and enhance the shelf life of okra fruits.
Keywords: (Okra, *Abelmoschus esculentus*, fungal pathogens, postharvest deterioration, *Rhizopus stolonifer)*.

INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench) is an important herbaceous, hirsute vegetable crop belonging to the family *Malvaceae* (mallow family). The crop is widely cultivated for its edible, immature seed pods, which are valued for their nutritional and medicinal properties. Although believed to have originated in Africa, okra is now extensively cultivated throughout tropical and subtropical regions, including Nigeria. The fruit occurs predominantly in green and red varieties and is commonly referred to as "lady's finger." The immature pods are harvested for consumption, whereas mature fruits become fibrous and unsuitable for culinary use. India, Nigeria, Pakistan, Ghana, and Egypt are among the world's leading producers of okra (Gemede, 2015).

Okra is recognized as an economically important vegetable because of its significant contribution to human nutrition. The pods contain appreciable amounts of carbohydrates, proteins, fats, dietary fibre, vitamins, and

essential minerals required for normal growth and physiological development (El-Sayed & El-Sayed, 2012). In Nigeria, okra is widely consumed as a soup ingredient due to its low caloric value, high dietary fibre content, and characteristic mucilaginous texture. The mucilage possesses important nutritional, medicinal, and industrial applications, including lowering blood cholesterol levels, promoting intestinal health, and serving as a natural thickening agent in food and pharmaceutical industries (Qusai *et al.,* 2020).

Despite its nutritional and economic importance, okra is highly susceptible to several postharvest diseases resulting from inadequate storage conditions and poor handling practices along the production and marketing chain. Some cultivars are particularly vulnerable to root rot pathogens, while others are prone to fruit deterioration caused by pathogenic fungi. Several fungal genera have been reported as causal agents of okra fruit rot, including *Fusarium*, *Alternaria*, *Curvularia*, *Helminthosporium*, *Chaetomium*, *Cladosporium*, *Penicillium*, *Aspergillus*, *Rhizopus*, and *Rhizoctonia* (Qusai *et al.,* 2020). The inability to effectively manage these postharvest pathogens contributes to significant reductions in shelf life, market value, crop yield, and farmers' income. Although postharvest losses can be minimized through proper storage facilities, improved processing technologies, careful handling, and effective management practices, accurate identification of fungal pathogens associated with okra fruit rot remains essential for developing appropriate disease management strategies. Such knowledge will contribute to reducing postharvest losses, extending shelf life, and improving the economic value of okra production (Siddiqui *et al.,* 2008).

The major fungal diseases affecting okra (*Abelmoschus esculentus* (L.) Moench) in Africa include damping-off caused by *Macrophomina phaseolina*, *Pythium aphanidermatum*, and *Rhizoctonia solani*; vascular wilt caused by *Fusarium oxysporum*; Cercospora leaf blight caused by *Cercospora abelmoschi* and *Cercospora malayensis*; and powdery mildew caused by *Erysiphe cichoracearum* and *Oidium abelmoschi* (Siddiqui *et al.,* 2008). In addition to fungal diseases, viral infections also constitute a major constraint to okra production. Okra mosaic virus (OKMV), transmitted by flea beetles (*Podagrica* spp.), is widely distributed across Africa. However, the economic impact of OKMV is generally less severe than that of okra leaf curl disease (OLCD), which is transmitted by the whitefly (*Bemisia tabaci*) and is considered one of the most destructive viral diseases affecting okra production.

Okra is a highly perishable vegetable crop that experiences rapid postharvest deterioration, leading to considerable losses in quality, nutritional value, and marketability during handling, transportation, storage, and marketing. In many developing countries, particularly among rural communities, fresh okra pods are traditionally preserved through open-air sun-drying practices on rooftops, concrete surfaces, or roadsides for several days or weeks depending on prevailing environmental conditions. However, these traditional drying methods expose the produce to contamination from dust, insects, pathogenic microorganisms, and environmental pollutants, thereby increasing the risk of fungal infection, reducing product quality, and shortening shelf life (Kitinoja & Kader, 2015). Postharvest losses of vegetables are particularly high in tropical and subtropical regions due to inadequate handling practices, poor storage facilities, and favourable environmental conditions that support microbial growth (Arah *et al.,* 2015).

Several disease management strategies have been employed to minimize crop losses caused by fungal pathogens, including the application of synthetic fungicides, botanical extracts, and biological control agents. Among these approaches, the use of plant-derived extracts has gained considerable attention because they are environmentally friendly, readily biodegradable, relatively inexpensive, and pose minimal risks to human health and non-target organisms (Isman, 2020). Furthermore, laboratory isolation and identification of fungal pathogens commonly involve culturing infected plant tissues on appropriate media such as Potato Dextrose Agar (PDA), often supplemented with antibiotics to suppress bacterial growth. This medium supports the growth, isolation, and differentiation of pathogenic fungi from infected plant materials.

This study aims to isolate and characterize fungal pathogens associated with diseases of okra (*Abelmoschus esculentus*) in Sokoto Metropolis, Nigeria. The specific objectives are to: (i) isolate and identify fungal pathogens associated with diseased okra fruits collected from selected markets in Sokoto South Local Government Area, and (ii) determine the frequency of occurrence of the identified fungal pathogens.

2.0 MATERIALS AND METHODS

2.1 Study Area

This research work was carried out in Biological Sciences Laboratory of Sokoto State University. The laboratory is located within the university campus. Geographically, the study area lies within latitude N 12°56'38.06412" and longitude E 5°11'16.43388", with an approximate altitude of 309 meters above sea level.

The location falls within the Sudan savanna ecological zone of Nigeria, characterized by a tropical climate with distinct wet and dry seasons (Tsoho & Salau, 2012)

2.2 Sample Collection

Fresh, healthy, and apparently disease-free okra (*Abelmoschus esculentus* (L.) Moench) fruits were collected from selected locations within Sokoto South Local Government Area, Sokoto State, Nigeria, namely Mabera, Gagi, and Emir Yahaya.

The collected samples were placed in sterile polyethylene bags, properly labelled according to their sampling locations, and transported to the Biological Sciences Laboratory for analysis. In the laboratory, the fruits were washed with sterile distilled water and air-dried under aseptic conditions. Thereafter, the samples were incubated at room temperature (27 ± 2°C) for 5–7 days to allow the natural development of postharvest rot symptoms.

2.3 Preparation of Culture Medium

Potato Dextrose Agar (PDA) was used for the isolation and cultivation of fungal pathogens associated with postharvest rot of okra (*Abelmoschus esculentus*). The medium was prepared according to the manufacturer's instructions by dissolving 39 g of Potato Dextrose Agar powder in 1 L of distilled water. The suspension was heated with continuous stirring until the medium was completely dissolved.

The prepared medium was dispensed into a suitable conical flask, plugged with cotton wool, covered with aluminium foil, and sterilized in an autoclave at 121°C under 15 psi pressure for 15 minutes. After sterilization, the medium was allowed to cool to approximately 45–50°C, after which chloramphenicol (50 mg/L) was aseptically added to inhibit bacterial contamination. Approximately 15–20 mL of the sterile medium was poured into sterile Petri dishes inside a laminar airflow cabinet (or near a Bunsen burner flame) and allowed to solidify at room temperature. The prepared plates were stored in an inverted position at 4°C until required for fungal isolation (Cappuccino & Welsh, 2017).

2.4 Inoculation

Under aseptic conditions, the spoiled and watery portions of the okra samples were collected using a sterile syringe and aseptically transferred onto the centre of prepared Potato Dextrose Agar (PDA) plates. A small quantity of the sample suspension was carefully dispensed onto the agar surface to allow the associated fungal organisms present in the spoiled tissues to grow and develop.

The inoculated Petri dishes were immediately covered, sealed with parafilm to prevent contamination, and properly labelled according to the sample source (Cappuccino & Welsh, 2017).

2.5 Incubation

The inoculated Petri dishes were wrapped with aluminium foil, sealed with parafilm, and incubated in an inverted position (agar side up) at 28±2°C for 3–7 days to promote the growth of fungal colonies. The plates were incubated in an inverted position. The culture plates were examined daily for the appearance of fungal growth, and observations were made on colony morphology, including colour, texture, pigmentation, margin, and growth pattern. (Cappuccino & Welsh, 2019; Willey *et al.,* 2017; Samson *et al.,* 2010).

2.6 Isolation of Pure Culture

After the incubation period of 3–7 days, the Petri dishes were removed from the incubator and examined for fungal growth. The fungal colonies were observed for distinct cultural characteristics, including colony colour, texture, surface appearance, margin, pigmentation, elevation, and growth pattern (Willey *et al.,* 2017). Some plates contained single fungal colonies, whereas others exhibited mixed fungal growth.

2.7 Sub-culturing

Pure cultures of the fungal isolates were obtained by subculturing distinct colonies that developed on the primary Potato Dextrose Agar (PDA) plates. Using a sterile inoculating needle or scalpel, a small portion from the actively growing margin of each fungal colony was aseptically transferred onto freshly prepared PDA plates. The inoculated plates were incubated at 28 ± 2°C for 3–5 days to allow the development of pure fungal colonies.

The subculturing process was repeated as necessary until discrete, uncontaminated fungal colonies were obtained. Pure cultures were then transferred onto Potato Dextrose Agar (PDA) slants and stored at **4°C** for subsequent morphological identification and characterization (Watanabe, 2010).

2.8 Identification of Fungal Pathogens (Phenotypic Characterization)

The purified fungal isolates were identified based on their macroscopic (cultural) and microscopic (morphological) characteristics. Macroscopic examination involved observing colony features, including colony colour (front view and rear view), texture, growth rate, pigmentation, margin, elevation, and sporulation pattern after incubation at 28 ± 2°C for 3–7 days (Samson *et al.,* 2010).

For microscopic examination, a small portion of each pure fungal colony was mounted on a clean glass slide using a drop of lactophenol cotton blue stain. The fungal mycelium was gently teased apart with a sterile inoculating needle, covered with a cover slip, and examined under a light microscope using ×10 and ×40 objective lenses. Morphological features such as the nature of the hyphae (septate or aseptate), conidiophores, conidia, sporangia, spores, vesicles, phialides, and other reproductive structures were carefully observed and recorded.

The identity of each fungal isolate was determined by comparing the observed cultural and microscopic characteristics with standard taxonomic keys and fungal identification manuals, including those of Barnett and Hunter (1998), Watanabe (2010), and Samson *et al.* (2010).

2.9 Determination of Percentage Occurrence of the Fungal Isolates

The frequency of occurrence of each fungal isolate associated with postharvest rot of okra (*Abelmoschus esculentus* (L.) was determined by counting the number of times each fungal species was isolated from the collected samples.

The frequency of occurrence of each isolate in each location was calculated as described by Kortei *et al.* (2022) Frequency = Number of identified fungi/Total number of fungi x 100.

$$\text{Frequency of Occurrence (\%)} = \frac{\text{Number of identified fungi}}{\text{Total number of fungi isolated}} \times 100$$

2.10 Statistical Analysis

Data obtained from were organized and presented in tables and charts. The frequency of occurrence of each fungal isolate was calculated and expressed as a percentage using the frequency of occurrence formula. Descriptive statistics, including frequencies and percentages, were used to summarize the distribution of the fungal species isolated from the okra samples. Microsoft Excel (Microsoft Corporation, USA) was used for data entry, computation, and graphical presentation of the results.

3.0 RESULTS

3.1 Phenotypic Characterization of Fungal Pathogens Isolated from from Okra Fruit (*Abelmoschus esculentus*)

Four species from three genera of fungal pathogens, including *Candida*, *Aspergillus*, and *Rhizopus*, were identified. The *Aspergillus* species include *Aspergillus niger* and *Aspergillus fumigatus*, while the genus *Rhizopus* is represented by *Rhizopus stolonifer*. Additionally, the genus *Candida* is represented by *Candida tropicalis* (Table 1).

Table 1: Phenotypic Characterization of Fungal Pathogens Isolated from Okra Fruit (*Abelmoschus esculentus*)

Specimens	Front View Appearance on Petri Plate	Rear View Appearance on Petri Plate	Microscopy Features	Description (Common Features)	Organism Identified
A	Creamy, smooth, and moist colonies	Pale yellow or off-white	(A) Opaque cells appear clonal and polymorphic. (B) White cells appear circular and elongated.	Forms yeast-like colonies, characterized by polymorphic cells ranging in size from approximately 2–10 micrometers.	*Candida tropicalis*
B	Black, powdery, and circular colonies	Yellowish to pale brown pigmentation	Conidiophores are short (2-3 µm), smooth, colored, or rough; vesicle is round with a convex head.	A filamentous fungus forming dark spores with filamentous hyphae, giving colonies a powdery texture.	*Aspergillus niger*
C	Greenish-gray, velvety colonies	Pale yellow to light green	Conidiophores are smooth-walled, unseptated, up to 300 µm long, and terminate in dome-shaped vesicles 20-30 µm wide.	Produces smooth, velvety colonies with unseptated hyphae and characteristic green pigmentation.	*Aspergillus fumigatus*
D	White, fluffy colonies with black spots	Brownish-black pigmentation	Composed of branched, non-septate hyphae (length 497–1400 µm, diameter 27–32 µm).	A filamentous mold producing stolons and black sporangia, giving colonies a fluffy white appearance with dark dots.	*Rhizopus stolonifer*

3.2 Frequency of Fungal Pathogens Isolated from Okra Fruit (*Abelmoschus esculentus*)

The results showed that *Rhizopus stolonifer* had the highest percentage of occurrence with (40.00%) while *Candida tropicalis, Aspergillus Aspergillus niger* and *Aspergillus fumigatus* had the least percentage of occurrence with (20.00%) each (Table 2).

Table 3: Frequency of Fungal Pathogens Isolated from Okra Fruit (*Abelmoschus esculentus*)

Fungal Isolates	SOKOTO SOUTH			
	S/S A	S/S B	S/S C	Total (%)
Candida tropicalis	0(0.00)	0(0.00)	1(100.00)	1(20.00)
Aspergillus niger	0(0.00)	1(100.00)	0(0.00)	1(20.00)
Aspergillus fumigatus	1(100.00)	0(0.00)	0(0.00)	1(20.00)
Rhizopus stolonifer	0(0.00)	1(50.00)	1(50.00)	2(40.00)
Total (%)	**1(20.00)**	**2(40.00)**	**2(40.00)**	**5(100.00)**

4.0 DISCUSSION

The present study identified four fungal pathogens associated with diseases of okra (*Abelmoschus esculentus*) collected from Sokoto South, namely *Aspergillus niger*, *Aspergillus fumigatus*, *Rhizopus stolonifer*, and *Candida tropicalis*. These fungal species are among the most frequently reported microorganisms responsible for postharvest deterioration of fresh vegetables, causing substantial losses in quality, nutritional value, and marketability. Similar fungal species have been reported in okra and other vegetables by Enyiukwu *et al. (2020) and* Akinmusire *et al. (2017),* who identified *Aspergillus spp. and Rhizopus spp.* as predominant fungal contaminants associated with postharvest spoilage and deterioration of fresh produce.

The occurrence of *Aspergillus niger* and *Aspergillus fumigatus* in this study agrees with the report of Mairami and Baze (2026), who identified these fungi among the major fungal species associated with spoilage of stored fruits and vegetables. These organisms produce extracellular enzymes that degrade plant cell walls, resulting in tissue softening, discoloration, and rapid spoilage. Similarly, the isolation of *Rhizopus stolonifer* corroborates the report of Kator *et al.* (2020), who identified *R. stolonifer* as one of the major pathogens responsible for soft rot disease in fresh vegetables marketed in Nigeria.

The presence of *Candida tropicalis* further indicates that yeast species may contribute to postharvest deterioration, particularly when produce is exposed to high moisture levels and unfavourable storage conditions, as reported by Kumar *et al.* (2020). The isolation of these fungal pathogens may be attributed to contamination during harvesting, transportation, handling, and storage. Mechanical injuries, insect damage, and natural openings on the fruit surface provide entry points for fungal spores, which subsequently colonize plant tissues under favourable environmental conditions. According to Arah *et al.* (2015), inadequate postharvest handling practices and poor sanitation significantly increase fungal infection and spoilage of horticultural crops, particularly in tropical regions. Furthermore, Droby *et al.* (2021) emphasized that maintaining proper hygiene, reducing mechanical injuries, and improving storage conditions

are essential strategies for minimizing postharvest fungal infections and extending the shelf life of fresh vegetables such as okra.

The frequency distribution of fungal pathogens isolated from okra (*Abelmoschus esculentus*) fruits collected from Sokoto South showed that *Rhizopus stolonifer* was the most frequently isolated fungus among the total isolates. In contrast, *Candida tropicalis*, *Aspergillus niger*, and *Aspergillus fumigatus* each constituted the least frequently isolated fungi. The predominance of *R. stolonifer* suggests that it is one of the major fungal pathogens associated with postharvest deterioration of okra fruits in the study area. This finding agrees with Akinmusire *et al*. (2017), who reported *Rhizopus stolonifer* as one of the dominant fungi associated with postharvest spoilage of fruits and vegetables in Nigeria. Similarly, Barkai-Golan (2001) reported that *Rhizopus stolonifer* is among the most destructive postharvest pathogens due to its rapid growth, aggressive tissue colonization, and ability to cause soft rot in fresh horticultural crops under favourable temperature and humidity conditions.

The occurrence of *Aspergillus niger* and *Aspergillus fumigatus* at equal frequencies corroborates the findings of Adebayo *et al*. (2021), who identified *Aspergillus* species as common fungal contaminants of fresh vegetables. These fungi are capable of surviving under a wide range of environmental conditions and are recognized for producing enzymes that degrade plant tissues, thereby accelerating spoilage. Furthermore, some *Aspergillus* species are known to produce mycotoxins, posing potential health risks to consumers if contaminated produce is consumed (Pitt & Hocking, 2022).

The isolation of *Candida tropicalis* indicates that yeast species also contribute to the microbial deterioration of okra fruits. Although *Candida* species are less frequently reported than filamentous fungi, they have been isolated from deteriorating fruits and vegetables, particularly under conditions of high moisture and poor postharvest handling. The isolation of Candida tropicalis indicates that yeast species also contribute to the microbial deterioration of okra fruits. Although Candida species are less frequently reported than filamentous fungi, they have been isolated from deteriorating fruits and vegetables, particularly under conditions of high moisture and poor postharvest handling. Pitt and Hocking (2022) reported that yeasts, including Candida species, are opportunistic contaminants capable of colonizing damaged plant tissues and contributing to the spoilage and quality deterioration of fresh produce during storage.

The distribution of fungal isolates among the sampling locations further revealed that Sokoto South B and Sokoto South C each had the highest of total isolates, while Sokoto South A recorded least of the isolates. The higher frequency of fungal pathogens in locations B and C may be attributed to differences in handling practices, environmental sanitation, storage conditions, and the level of exposure of the fruits to fungal spores during transportation and marketing. According to the Food and Agriculture Organization (FAO, 2022), inadequate postharvest handling, mechanical injuries, and poor market sanitation are major factors that predispose fresh vegetables to fungal contamination and spoilage.

3.1 CONCLUSION

This study identified the fungal pathogens associated with diseased okra (*Abelmoschus esculentus*) fruits collected from Sokoto South Local Government Area, Sokoto State. The fungal isolates recovered included *Rhizopus stolonifer*, *Aspergillus niger*, *Aspergillus fumigatus*, and *Candida tropicalis*. Among the isolates, *Rhizopus stolonifer* was the dominant and most frequently occurring fungal species, indicating that it is the principal pathogen associated with postharvest deterioration of okra fruits in the study area. In contrast, *Candida tropicalis*,

Aspergillus niger, and *Aspergillus fumigatus* were the least frequently isolated species, suggesting a comparatively lower contribution to the overall fungal incidence. The predominance of these fungi indicates that they are important contributors to the postharvest deterioration of okra fruits in the study area. Their occurrence highlights the influence of environmental conditions, poor handling practices, and inadequate storage on fungal contamination and spoilage.

RECOMMENDATIONS

1. Farmers should be educated on good agricultural and postharvest handling practices to reduce fungal contamination and postharvest losses.
2. Freshly harvested okra fruits should be stored under clean, cool, and dry conditions to reduce fungal growth and extend shelf life.
3. Routine microbiological surveillance of okra and other fresh vegetables should be conducted to monitor the occurrence of fungal pathogens and enhance food safety.
4. Further studies should investigate the pathogenicity, mycotoxin-producing potential, and molecular characterization of the fungal isolates associated with okra fruits in Sokoto State.
5. Future research should evaluate environmentally friendly control measures, including biological control agents and plant-derived antifungal extracts, for the effective management of fungal diseases affecting okra.

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