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Fungal Pathogens Associated with Postharvest Tomato Rot and their Distinct Decay Symptoms in Katsina, Nigeria

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ABSTRACT

Tomato fruit rot represents a significant issue in both field production and postharvest storage, leading to substantial economic losses worldwide, particularly in developing countries. This spoilage is primarily attributed to various fungal pathogens, which can either serve as primary invaders, initiating infection in healthy, undamaged tissues, or as secondary invaders, colonizing weakened or decaying fruit tissues. The objective of this study was to identify and characterize the fungal species responsible for the spoilage of postharvest tomatoes, as well as to understand the symptoms associated with each pathogen. Tomatoes exhibiting different signs of decay were collected from local markets within Katsina, Nigeria, and analyzed for fungal contamination. The study identified several fungal species, including *Rhizopus, Fusarium, Geotrichum, Aspergillus niger, Alternaria, Colletotrichum coccodes,* and *Botrytis cinerea*, among others. Each of these fungi displayed distinct patterns of decay ranging from water-soaked rot, black mold, anthracnose-like rot, to gray mold, and others. These findings confirm that fungal infection is the leading cause of tomato spoilage during storage and that each pathogen requires different management strategies. Primary invaders like *Rhizopus* and *Fusarium* are responsible for rapid fruit decay under high moisture conditions, while secondary invaders, such as *Aspergillus niger* and Botrytis, typically colonize damaged tissues. The study underscores the need for timely detection and intervention in managing these pathogens to reduce postharvest losses. Understanding the correlation between fungal species and specific decay symptoms is essential for developing targeted strategies, such as proper handling, storage conditions, and potential fungicidal treatments, to improve postharvest tomato quality and extend shelf life.

Keywords: Tomato fruit rot, Field production, Postharvest storage, fungal pathogens

INTRODUCTION

Tomato is a widely consumed fruit eaten in both raw and processed forms (Moneruzzaman *et al*., 2008). It is used in many dishes, salads, sauces and drinks and can also be dried and ground into pancakes (Onuorah & Orji, 2015). It is rich in lycopene which has many beneficial health effects. It contains large amount of water which makes it more susceptible to spoilage by the action of microorganisms (Bai *et al*., 2006). The richest source of lycopene is tomato and tomato-based products (Evangelia *et al*., 2005) They are usually displayed on benches and in baskets for prospective customers in the open market until sold, thereby exposing them to further microbial infections beside those associated with its surface and those from adjacent infected fruits (Baiyewu *et al*., 2007). It has the botanical name Lycopersicum Esculentum and belongs to the plant family solanaceae. It is rich in vitamins including vitamin A and vitamin C, carbohydrates, proteins, fats, fibres and potassium (Talvas *et al*., 2006). Microorganisms and fruits have a close, long-term relationship, Symbiotic microorganisms in fruit crops (Singh *et al*., 2020). Fungi were the source of spoilage of most of the tomato samples accessed than bacteria (Ghosh, 2009). As these microbes come in contact with tomatoes during growth, harvesting, transportation, selling at market, processing, preservation and handling, the produce are contaminated with nonpathogenic and pathogenic organisms from soil, environments, human or animal sources (Barth *et al*., 2010). The crop is grown for both fresh domestic and export market but there is increasing demand for processed tomato products (Mungai *et al*., 2000). Both the biological and physical damages during the harvest and transportation phases, coupled with large amount of water and soft endocarp makes tomatoes more susceptible to spoilage by fungi (Asan and Ekmeki, 2002: Onuoral and Orji, 2015). These post-harvest losses are more severe in developing than developed nations (Enyiukwu, 2014).

MATERIALS AND METHODS

Study Area

The study took place in the Katsina metropolis, within Katsina Local Government Area, Nigeria, situated at approximately 12.99080°N latitude and 7.60180°E longitude.

Materials:

Materials needed: Sterile equipment (e.g; petri dishes, scalpels, forceps, knife), Agar media (potato dextrose agar), distilled water, hypo, chloramphenicol, measuring cylinder, flame, autoclave, laminar flow cabinet, microscope and slides.

Sample Collection: Ten (10) tomatoes showing sign of decay were collected from different markets and farms within Katsina Local Government Area, Katsina State, Nigeria. The samples were placed in sterile polyethylene bags to prevent cross-contamination during transport to the laboratory.

CULTURE MEDIA

Potato dextro agar (P.D.A) would be used for the isolation of fungi in the spoiled tomatoes, the media has the following constituents:

Potato…………………………….……4.0g

Dextrose………………………………….20g

Agar……………………………………15g

Water………………….……………...1 liter (Tijjani *et al* 2018).

MEDIA PREPARATION AND POURING PLATES

The media was prepared by weighing 39g of P.D.A using weighing balance and suspended in 1liter of distilled water; 2ml of chloramphenicol would be added to the media. Content were sterilized using autoclaving machine at 121^0c for 15mins. It was allowed to set down for proper handling; the media was poured in to sterilized Petri dishes of 9cm in diameter.

SAMPLE COLLECTION AND PREPARATION

Fresh tomatoes were collected from markets and farms within Katsina Local Government Area, Katsina State, Nigeria were surface sterilized with 1% Nacl (sodium hypo chloride). The tomatoes part sliced along with some underlining tissue 1cm in size. The portions were placed in the plate containing the solidified sterilized P.D.A under controlled atmospheric condition in the laminar flow cabinet; it was then incubated at 28^0c for 5-7 days.

COLONY COUNT AND SUBCULTURE

Each 5-7 days after the first culture growth of colonies were monitored and the number of colonies that appeared was recorded. Each distinct colony was then sub cultured on a fresh sterilized P.D.A media.

MICROSCOPIC EXAMINATION

The pure grown isolated colonies of fungi, a steak of fungal mycelium were be placed on a clean glass slide to make the smear, one drop of potassium hydroxide was added and the cover slip was added gently to avoid air bubbles. The slide were mounted on the microscope and observed at magnification of 40 and 100. (*Tijjani et al* 2018).

IDENTIFICATION

The isolated fungi were identified by observing their cultural and conidial characteristics using wet mount preparation in potassium hydroxide (KOH). This was carried out by teasing scraping made from potato dextrose agar on a clean greese free glass slide stained with 0.5% potassium hydroxide. The slide were covered with a slip and examined under magnification x40 and x 100 (*Tijjani et al* 2018)

RESULT AND DISCUSSION

The presence of a mucky texture accompanied by a sour odor is indicative of rapid tissue degradation. Fungal genera such as *Rhizopus*, *Fusarium*, and *Geotrichum* are commonly associated with such conditions, as they thrive in moist environments and are known to cause aggressive decay. The occurrence of dark lesions combined with black fungal growth is frequently observed in post-harvest scenarios, particularly under humid storage conditions. *Alternaria* and *Aspergillus niger* are widespread saprophytic fungi that readily colonize damaged plant tissue. (Nasidi, 2021) also reported in a similar studies that Five (5) fungal pathogens were identified which include the following; Aspergillus niger, A. flavus, Rhizopus stolonifer, Penicillium sp. And Fusarium oxysporum at Geidam market Yobe state, Nigeria. Sunken, circular lesions with concentric rings are characteristic of anthracnose symptoms, typically caused by *Colletotrichum coccodes*, a primary agent of anthracnose in tomato fruits. In cases where the tissue remains firm and dry, the infection is generally slow progressing, often associated with vascular or stem-related pathogens such as *Phoma* and *Lasiodiplodia*. Soft tissue decay exhibiting gray, fuzzy mycelial growth is commonly linked to high humidity and is a hallmark of *Botrytis cinerea* infection, a ubiquitous pathogen affecting a broad spectrum of horticultural crops, particularly under cool, moist conditions. Stem-end rot, characterized by decay initiating at the point of stem attachment, suggests pathogen entry through natural openings or post-harvest injuries. *Alternaria* and *Fusarium* species are frequently implicated in such infections. Instances where the tomato fruit appears externally healthy but exhibits internal brown necrosis point to internal rot, which can be challenging to detect in early stages. *Phomopsis* and *Botryodiplodia* are often responsible for such internal infections. Rapid tissue collapse, often accompanied by visible white fungal growth, is typical of infections caused by fast-growing fungi such as *Rhizopus* and *Mucor*, particularly under post-harvest conditions. Uneven ripening, especially the persistence of green coloration near the stem (commonly referred to as green shoulder), may result from physiological disorders or pathogen-induced stress, with *Alternaria* and *Stemphylium* frequently associated under such conditions. Finally, advanced soft rot characterized by a foul odor is indicative of microbial fermentation processes. Although this symptom is often caused by bacterial pathogens such as *Erwinia*, secondary colonization by fungi such as *Fusarium* is also common.

Table 1: Physical appearance of the Tomato (TMT) samples collected and symptoms observed

SAMPLES	SYMPTOM TYPE	MORPHOLOGICAL CLUES	FUNGAL CANDIDATES
TMT1	Water-soaked soft rot	Watery, mushy tissue with sour smell	*Rhizopus*, *Fusarium*, *Geotrichum*
TMT2	Black mold rot	Dark, soft lesions with black fungal growth	*Alternaria*, *Aspergillus niger*
TMT3	Anthracnose-like rot	Sunken, circular spots with concentric rings	Colletotrichum coccodes
TMT4	Firm dry rot	Dry, firm lesions; minimal external spread	*Phoma*, *Lasiodiplodia*
TMT5	Gray mold rot	Soft rot with gray fuzzy growth, especially in humidity	Botrytis cinerea
TMT6	Stem end rot	Dark, sunken rot at stem end; tissue softening	*Alternaria*, *Fusarium*
TMT7	Internal brown rot	Healthy exterior, brown necrosis inside	*Phomopsis*, *Botryodiplodia theobromae*
TMT8	Rapid soft rot	Collapsing tissue with white fungal growth	*Rhizopus*, *Mucor*
TMT9	Green shoulder rot	Uneven ripening, firm green patches near stem	*Alternaria*, *Stemphylium*
TMT10	Soft rot with odor	Extremely soft, collapsing tissue; foul smell	*Erwinia* (bacterial), but possibly *Fusarium*

Tomato fruit rot, a prevalent issue in both field production and postharvest storage, is primarily caused by various fungal pathogens. These fungi can either act as primary invaders, initiating infection in healthy, undamaged tissue, or as secondary invaders, colonizing weakened or decaying fruit tissue. The identification of these fungi and their associated symptoms is critical for developing effective management strategies to mitigate losses during production, harvesting, and storage. Water-soaked soft rot is one of the most common and rapidly progressing symptoms in tomatoes, often associated with primary invaders such as *Rhizopus*, *Fusarium*, and *Geotrichum*. These fungi are known to thrive in moist, high-humidity conditions and can cause significant fruit decay within a short period. *Rhizopus* is particularly notorious for rapid softening and tissue collapse, while *Fusarium* and *Geotrichum* contribute to similar symptoms with somewhat slower rates of degradation. The presence of water-soaked lesions in tomatoes suggests a favorable environment for these fungi to proliferate, which is a key concern for postharvest fruit quality (Mundt *et al*., 2002). As primary invaders, these fungi attack healthy fruit tissue, making them difficult to manage once they initiate infection. In contrast, black mold rot, caused by fungi such as *Alternaria* and *Aspergillus niger*, is typically associated with damaged or senescent tissue and represents a classic case of secondary invasion. Both fungi are saprobes, meaning they primarily feed on decomposing organic matter (Agrios, 2005). *Alternaria* and *Aspergillus niger* colonize tissues that have already been compromised by physical injury or initial microbial attack. While these fungi may not infect fresh, healthy tissue directly, their growth accelerates once the fruit's integrity is compromised. The formation of black mold on the surface of tomatoes is a common sign of their presence, which is a significant issue for fruit storage and handling, particularly in high-humidity conditions (Bresinsky *et al*., 2014). The development of anthracnose-like rot, typically seen as sunken lesions with concentric rings, is linked to primary infection by *Colletotrichum coccodes*. As a well-documented causative agent of anthracnose, *Colletotrichum coccodes* infects healthy, undamaged tissue, often under stressed environmental conditions. The firm dry rot observed in some tomato samples is primarily caused by primary invaders such as *Phoma* and *Lasiodiplodia*. These pathogens are capable of infiltrating internal tissues, often initiating decay within the fruit's vascular system. *Lasiodiplodia theobromae*, in particular, is known for its ability to invade stem tissues, leading to a gradual, internal rot that is not immediately visible on the fruit's exterior. While these fungi are slower to cause visible decay compared to *Rhizopus* or *Fusarium*, their capacity to invade deeper tissues makes them a concern for long-term storage (Lonsdale *et al*., 2005). The gray mold rot caused by *Botrytis cinerea* is another example of a secondary invader, typically affecting overripe or damaged tissue. *Botrytis* is known for its ability to proliferate in moist, cool environments and is a significant postharvest pathogen in tomatoes. It thrives on senescent tissue or tissues compromised by initial injury or other pathogens. As a secondary invader, *Botrytis* generally does not infect healthy tissue directly but contributes to the rapid deterioration of fruit once initial decay has set in (Elad *et al*., 2004). The fuzzy gray mold that *Botrytis* produces is a clear indicator of its presence, and its spread is often enhanced by inadequate postharvest storage conditions. In cases of stem end rot, fungi such as *Alternaria* and *Fusarium* invade through natural openings or mechanical damage at the stem attachment site. These fungi are secondary invaders, which take advantage of existing tissue damage to colonize the fruit and cause further necrosis. Stem end rot is particularly problematic in postharvest situations, where mechanical damage during handling or harvesting provides entry points for fungal pathogens. The stem-end infection pathway is a common route for fungi to enter tomatoes postharvest, leading to significant losses in fruit quality and shelf life (Farr & Rossman, 2014). The internal brown rot, often difficult to detect in the early stages due to its internal nature, is primarily caused by primary invaders like *Phomopsis* and *Botryodiplodia*. These pathogens enter the fruit through vascular tissues or wounds and cause extensive internal decay, which is often not visible until the infection has progressed. Such deep-tissue infections can lead to severe quality degradation, especially when tomatoes are stored for extended periods. Both *Phomopsis* and *Botryodiplodia* are capable of causing latent infections, making early detection crucial in managing these diseases during storage (Ellis & Pfeifer, 2005). Rapid soft rot caused by *Rhizopus* and *Mucor* represents another instance of primary infection. These fungi are among the most aggressive pathogens, capable of causing rapid tissue breakdown and the formation of a mushy, collapsed fruit. Both *Rhizopus* and *Mucor* are fast-growing fungi that thrive in moist conditions, and they are frequently encountered in tomatoes that have been improperly handled postharvest or stored in high-humidity environments. The presence of rapid tissue collapse is a hallmark of these pathogens' virulence. In the case of green shoulder rot, a phenomenon characterized by uneven ripening, fungi such as *Alternaria* and *Stemphylium* are often secondary invaders, taking advantage of fruit that is stressed due to poor ripening conditions. This condition is frequently associated with environmental stressors and is exacerbated by fungal colonization, leading to further degradation of the fruit's quality. These fungi are opportunistic pathogens that contribute to the deterioration of fruit when the natural ripening process is disrupted (Baldwin *et al*., 2005). Finally, soft rot with odor, typically caused by *Erwinia* and secondary colonization by *Fusarium*, is a critical issue in postharvest tomato management. *Erwinia*, a bacterial pathogen, is the primary cause of soft rot, causing rapid tissue breakdown and a foul odor due to its fermentation activity. *Fusarium* often acts as a secondary invader, colonizing tissues already infected by *Erwinia*. The combined action of both pathogens results in severe tissue disintegration, making it one of the most challenging types of postharvest decay to manage.

Table 2: Primary and Secondary invaders of fungi affecting tomato

SYMPTOM TYPE	FUNGAL CANDIDATES	Primary or Secondary Invader	Clarification
Water-soaked soft rot	*Rhizopus*, *Fusarium*, *Geotrichum*	Primary	These fungi are primary invaders that actively infect fresh, undamaged tissue, especially under moist conditions.
Black mold rot	*Alternaria*, *Aspergillus niger*	Secondary	*Aspergillus niger* and *Alternaria* are often secondary invaders, colonizing previously injured or senescent tissue.
Anthracnose-like rot	Colletotrichum coccodes	Primary	*Colletotrichum coccodes* is a primary invader, causing initial infection in healthy tissue, particularly under stress.
Firm dry rot	*Phoma*, *Lasiodiplodia*	Primary	These fungi are typically primary invaders that penetrate healthy tissue, particularly in stems or vascular regions.
Gray mold rot	Botrytis cinerea	Secondary	*Botrytis cinerea* is often a secondary invader, infecting previously damaged or overripe tissue, thriving in humidity.
Stem end rot	*Alternaria*, *Fusarium*	Secondary	Both fungi are secondary invaders, infecting through wounds or natural openings at the stem, often after harvest.
Internal brown rot	*Phomopsis*, *Botryodiplodia*	Primary	Both *Phomopsis* and *Botryodiplodia* are primary invaders that infect through

SYMPTOM TYPE	FUNGAL CANDIDATES	Primary or Secondary Invader	Clarification
			wounds or vascular tissue, causing internal rot.
Rapid soft rot	*Rhizopus*, *Mucor*	Primary	*Rhizopus* and *Mucor* are primary invaders, rapidly colonizing fresh tissue, especially under high moisture conditions.
Green shoulder rot	*Alternaria*, *Stemphylium*	Secondary	*Alternaria* and *Stemphylium* often act as secondary invaders, exploiting stressed or poorly ripened tissue, sometimes influenced by environmental factors.
Soft rot with odor	*Fusarium* (secondary), *Erwinia* (primary, bacterial)	*Erwinia* – Primary, *Fusarium* – Secondary	*Erwinia* is a primary invader responsible for soft rot, often caused by bacterial infection. *Fusarium* can be a secondary invader, colonizing decayed tissue later

CONCLUSION

This study investigates the fungal pathogens responsible for postharvest tomato spoilage, distinguishing between primary invaders (*Rhizopus*, *Fusarium*, *Colletotrichum coccodes*) that attack healthy fruits under humid conditions, and secondary invaders (*Aspergillus niger*, *Alternaria*, *Botrytis cinerea*) that colonize damaged or previously infected tomatoes. Each fungus exhibits distinct decay patterns, necessitating targeted management approaches. To reduce spoilage, the study recommends improved storage, careful handling, and appropriate fungicide use. It also emphasizes the need for further research into fungal behavior and resistant tomato varieties to enhance shelf life and reduce food waste, especially in resource-limited regions.

RECOMMENDATION

I. **Invest in Resistant Varieties:**

- Support ongoing research to develop tomato cultivars resistant to major fungal pathogens such as *Fusarium*, *Alternaria*, and *Rhizopus*.
- Promote the use of genetically resistant varieties to minimize reliance on chemical fungicides.

II. **Study Alternative Control Methods:**

- Prioritize research into biological control agents and environmentally sustainable approaches for managing fungal infections.
- Explore the potential of beneficial microorganisms like *Trichoderma* spp. for suppressing pathogenic fungi.

CONFLICT OF INTEREST

The author declare no conflict of interest

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