



Spoilage Attributes of Fungi Associated with Tomato Spoilage

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ABSTRACT

Some fungi deteriorate the quality of tomatoes and cause economic loss to the traders. This study was carried out to investigate the spoilage attributes of fungi associated with spoilage of tomato fruits. Spoiled tomato fruits were obtained from 3 markets in Port Harcourt, Nigeria. Fungi were isolated from the spoilt area of the fruits, and they were identified through colonial and microscopic characterization. Spoilage attributes of identified fungi were determined by inoculation in healthy tomato fruits. The fungi isolated were identified as *Aspergillus niger*, *Geotrichum candidum*, *Phytophthora infestans*, *Mucor species*, *Aspergillus nidulans*, *Sclerotinia sclerotiorum*, and *Penicillium species*. *Mucor species* occurred most frequently (21.15 %) while *Geotrichum candidum* had the lowest percentage occurrence (5.77 %). *Aspergillus niger* had the highest rot diameter (52±3 mm) in healthy tomato fruits, while *Penicillium species* had the lowest rot diameter (17±3 mm) in healthy tomato fruits. It is concluded that among the fungi causing spoilage of tomatoes, *Aspergillus niger* has the highest spoilage attribute, and post-harvest sanitary control should be targeted at controlling or eliminating population of *Aspergillus species*.

Keyword: Tomatoes, Fungi, *Mucor*, Spoilage Attributes, Market, Rot Diameter.

Introduction

Tomato (*Solanum lycopersicum L*) is among the world's most important and extensively produced vegetable crops (ACMSF, 2005). The vegetable has high amounts of vitamin A and vitamin C, carbohydrates, proteins, fats, fibers, potassium, and lycopene which have numerous good health attributes (Talvas *et al.*, 2010). The richest natural source of lycopene is tomatoes (Khan *et al.*, 2021). Lycopene is reported to inhibit prostate cancer, enhance body protection mechanisms against the damaging UV rays in sunlight, reduce susceptibility to cancers of the breast, lung, stomach, bladder, and uterus, and decrease associated cardiovascular risks in type 2 diabetic patients (Shidfar *et al.*, 2010). The consumption of tomatoes has been known to improve the functions of the heart and other organs in the human body (Collins *et al.*, 2022). Tomato fruits are used in different food preparations including salads, sauces, juices, and pancakes (Effiuwewwere, 2000).

Global tomato production has steadily increased from 182 million metric tons in 2018 to 189 million metric tons in 2021, according to the Food and Agriculture Organization (FAO), with major contributors including China, the United States, and India (Szabo *et al.*, 2025). This demonstrates the crucial role tomatoes play in food security and nutrition. Post harvest losses represent a critical challenge in the tomato supply chain which suggests that 20-50% of the produce is lost between harvest and consumption depending on the region and infrastructure (Barth *et al.*, 2009). Tomato fruit is highly perishable due to its high-water content and delicate structure. This makes it susceptible to mechanical injury and microbial colonization. Tomato spoilage results in substantial economic losses for producers and marketers. The contamination of tomatoes by fungi has been considered risks to human and animal health owing to the production of mycotoxins that can cause mycotoxicoses in humans upon ingestion or inhalation of fungal spores (Baker, 2006).

The toxins are not contained in the points of infection only; due to the large amounts of fluid in tomatoes, the toxins diffuse easily within them, thereby rendering them unfit for consumption. Mycotoxins are extremely toxic substances produced by different genera of molds. The most well-known mycotoxins in foods and feeds are aflatoxins, ochratoxins, fumonisin, zearalonene, and Ochratoxin A (Noah *et al.*, 2016).

The high moisture content, soft tissue and nutrient rich composition of tomato fruits make them highly susceptible to fungal attack during harvesting, handling, transport and storage (Tamiyu *et al.*, 2021). The fungi are classified either as field pathogens or wound pathogens; field pathogens infect the fruit before harvest, but the symptoms manifest after harvest, while wound pathogens requires wounds on the surface to start infection (Barkai-Golan, 2001).

Fungal pathogens not only cause visible rot which leads to direct quantitative losses but also pose severe threat to food safety due to the production of mycotoxins which are toxic to humans upon ingestion (Bankole and Adebajo, 2019). The mycotoxins are toxic, carcinogenic and immunosuppressive compounds that pose significant risks even at low concentrations (Wild and Gong, 2010).

Fungi can easily invade and contaminate poorly handled tomatoes through several routes such as display of tomatoes in open markets on the bare floor, in unclean baskets or buckets, or on benches (Baiyewu *et al.*, 2007). Despite the growing health concerns and economic burden, there is limited body of localized research exploring the spoilage fungi associated with tomatoes in open markets, particularly with respect to their prevalence and characteristic of spoilage. Several fungal species such as *Aspergillus*, *Fusarium* and *Penicillium* have been isolated from spoiled tomatoes and these fungi cause rot, lesions and mycelia growth rendering the fruit unmarketable (Sanyaolu, 2016, Tamiyu *et al.*, 2021).

The aim of this study was to investigate the spoilage attributes of fungi associated with spoilage of tomato fruits.

Materials and Methods

Samples collection

Spoiled tomatoes were obtained from Rumuokoro, Choba, and Mile 3 markets in Port Harcourt metropolis, Rivers state, Nigeria. A total of 54 spoiled tomato fruits were obtained. They were placed in sterile polythene bags separately and transported to the laboratory of the Department of Microbiology, Rivers State University, Nigeria for isolation of fungi.

Isolation of fungi

The spoilt areas on the tomato surfaces were disinfected with 70 % ethanol and carefully cut off using sterile knife. About 1 g of the cut off material was placed on sterile Potato dextrose agar (PDA) plates, and the plates incubated for 5 days. After incubation, the different fungal colonies that developed were isolated onto fresh PDA plates.

Colonial and microscopic characterization of the fungal isolates

The fungal isolates were subjected to colonial and microscopic characterization. Colonial characterization was carried out by observation of colonial features such as colour, reverse colour, nature of growth (fluffy or cottony growth), surface appearance (lawny, velvety, wrinkled or radial furrowed), and presence or absence of periphery. Microscopic characterization was carried out by lactophenol cotton blue staining and observation under a bright field microscope using 40× Objective lens. The observations were recorded and compared with fungal descriptions in Zafar *et al* (2017) so as to obtain a probable identity of the fungus.

Determination of spoilage attributes of identified fungi

Determination of spoilage attributes of the identified fungi was carried out as described by Chukwuka *et al* (2010) and Baiyewu *et al* (2007). Fully ripe/red healthy tomatoes were properly washed with tap water, and surface-disinfected with 70 % ethanol. Sterile cork borers were used to bore holes in the tomato fruits and the identified fungi were inoculated into the fruits separately (in triplicate).

After inoculation, sterile petroleum jelly was used to seal the holes so as to prevent external contamination. The inoculated tomato fruits were placed in sterile polythene bags (one fruit per bag). Sterile moistened cotton balls were placed in the bags to create a humid condition. The bagged fruits were incubated at ambient temperatures (26 to 33 °C) for 5 days. After incubation, the fruits were observed for spoilage and fungi re-isolated. Spoilage was assessed by measuring rot diameter and noting colour change, and re-isolated fungi were compared with the original isolates.

Results

The probable identity of the fungi isolated from the different markets is presented in Table 1a, 1b, and 1c. A total of seven species of fungi were identified: *Aspergillus nidulans*, *Aspergillus niger*, *Geotrichum candidum*, *Penicillium* species, *Mucor* species, *Phytophthora infestans*, and *Sclerotinia sclerotiorum*. *Aspergillus nidulans*, *Penicillium* species, *Mucor* species, *Phytophthora infestans*, and *Sclerotinia sclerotiorum* were identified in spoilt tomato fruits from Rumuokoro Market.

Aspergillus niger and *Geotrichum candidum* in addition to the other fungi (with exception of *Mucor* sp.) identified in spoilt tomatoes from Rumuokoro Market were identified in spoilt tomatoes from Choba Market. Of these fungi, *Aspergillus nidulans* and *Phytophthora infestans* were not isolated from spoilt tomato fruits obtained from Mile 3 Market.

The frequency of fungal occurrence across the markets is presented in Table 2. The most prevalent fungus was *Mucor* species (21.15 %), while the least prevalent fungus was *Geotrichum candidum* (5.77 %).

The spoilage attributes of the identified fungi is presented in Table 3a, 3b, and 3c. For fungi from Rumuokoro market, *Aspergillus nidulans* caused the largest rot area (46±2 mm), while *Penicillium* species caused the least rot area (17±3 mm). For fungi from Choba market, *Aspergillus niger* caused the largest rot area (51±3 mm), while *Penicillium* species caused the least rot area (18±2 mm). For fungi from Mile 3 market, *Aspergillus niger* caused the largest rot area (52±3 mm), while *Penicillium* species caused the least rot area (18±2 mm). Spoilage attributes included change in colour, rotten tissue, wrinkled tissue, and sometimes water filled rotten tissue.

Table 1a: Colonial and microscopic characteristics of fungal isolates from Rumuokoro Market

Isolate codes	Colonial characteristic	Microscopic morphology	Probable fungi
RO1, RO5, RO6	White colony which appears fluffy on the surface and white on the reverse side	Aseptate branching hyphae with terminal sporangia	<i>Phytophthora infestans</i>
RO2, RO3, RO15, RO17, RO18	White cottony growth that turns grey and white to greyish colour on the reverse side	Hyphae were non-septate and branched. Long sporangiophores with non-septate terminal spore sporangia	<i>Mucor</i> sp.
RO4, RO11, RO12, RO16	White colony with yellow spotting on top and white colour on the reverse	Philides in bunch, septate hyphae columnar conidia head	<i>Aspergillus nidulans</i>
RO7, RO9, RO10, RO14	Green velvety colony with radial furrowed surface surrounded by white periphery; reverse cream colour	Conidia in chains from the top of the philides with a septate hyphae	<i>Penicillium</i> sp.
RO8, RO13	White to greyish colour which appear fluffy and clear white on the reverse side	Septate branching hyphae, No visible conidia, No spores	<i>Sclerotinia sclerotiorum</i>

Table 1b: Colonial and microscopic characteristics of fungal isolates from Choba Market

Isolate codes	Colonial characteristic	Microscopic morphology	Probable fungi
CHO1, CHO8	White colony with yellow spotting on top and white colour on the reverse	Philides in bunch, septate hyphae columnar conidia head	<i>Aspergillus nidulans</i>
CHO2, CHO3, CHO10, CHO11, CHO13, CHO16	White colony which appear fluffy on the surface and white on the reverse side	Aseptate branching hyphae with terminal sporangia	<i>Phytophthora infestans</i>
CHO4, CHO6	White to cream colour which appear fluffy and clear white on the reverse side	Hyphae are hyaline, septate branched and break up into chains of hyaline, one celled	<i>Geotrichum candidum</i>
CHO5, CHO17, CHO18	Green velvety colony with radial furrowed surface surrounded by white periphery; reverse cream colour	Conidia in chains from the top of the philides with a septate hyphae	<i>Penicillium</i> sp.
CHO7, CHO14	Blackish colony with blackish spores rapidly spreading and cream colour on the reverse side	Septate branching hyphae with conidiophores that are non septate	<i>Aspergillus niger</i>
CHO12, CHO15	White to greyish colour which appear fluffy and clear white on the reverse side	Septate branching hyphae, No visible conidia, No spores	<i>Sclerotinia sclerotorium</i>

Table 1c: Colonial and microscopic characteristics of fungal isolates from Mile 3 Market

Isolate code	Colonial characteristic	Microscopic morphology	Probable fungi
M3.1	White to cream colour which appear fluffy and clear white on the reverse side	Hyphae are hyaline, septate branched and break up into chains of hyaline, one celled	<i>Geotrichum candidum</i>
M3.2, M3.4, M3.7, M3.8, M3.9, M3.14	White cottony growth that turns grey and white to greyish colour on the reverse side	Hyphae were non-septate and branched. Long sporangiophores with non-septate terminal spore sporangia	<i>Mucor</i> sp.
M3.5, M3.16, M3.18	Blackish colony with blackish spores rapidly spreading and cream colour on the reverse side	Septate branching hyphae with conidiophores that are non-septate	<i>Aspergillus niger</i>
M3.6, M3.12, M3.13, M.17	White to greyish colour which appear fluffy and clear white on the reverse side	Septate branching hyphae, No visible conidia, No spores	<i>Sclerotinia sclerotorium</i>
M3.10, M3.11, M3.15	Green velvety colony with radial furrowed surface surrounded by white periphery; reverse cream colour	Conidia in chains from the top of the philides with a septate hyphae	<i>Penicillium</i> sp.

Table 2: Frequency of fungal occurrence across the markets

Fungi	Markets			Total occurrence (%)
	Rumuokoro	Choba	Mile 3	
<i>Aspergillus nidulans</i>	4	2	0	11.54
<i>Aspergillus niger</i>	0	2	3	9.62
<i>Penicillium</i> sp.	4	3	3	19.23
<i>Mucor</i> sp.	5	0	6	21.15
<i>Phytophthora infestans</i>	3	6	0	17.31
<i>Sclerotinia sclerotorium</i>	2	2	4	15.38
<i>Geotrichum candidum</i>	0	2	1	5.77
Total isolates	18	17	17	52 (100%)

Table 3a: Rot diameter and fungal spoilage attributes of fungi isolated from tomatoes in Rumuokoro Market

Fungi	Rot diameter (mm)	Spoilage attributes
<i>Aspergillus nidulans</i>	46±2	Water filled whitish yellow almost completely rotten area
<i>Penicillium</i> sp.	17±3	Dark green slightly wrinkled area having a hard other part
<i>Mucor</i> sp.	23±2	White hairy wrinkled, partially rotten area
<i>Phytophthora infestans</i>	18±2	Greyish white slightly wrinkled area
<i>Sclerotinia sclerotorium</i>	38±2	White wrinkled partially rotten area

Table 3b: Rot diameter and fungal spoilage attributes of fungi isolated from tomatoes from Choba Market

Fungi	Rot diameter (mm)	Spoilage attributes
<i>Aspergillus nidulans</i>	48±2	Water filled whitish yellow almost completely rotten area
<i>Aspergillus niger</i>	51±3	Water filled black completely rotten area
<i>Penicillium</i> sp.	18±2	Dark green slightly wrinkled and hard surface area
<i>Phytophthora infestans</i>	19±2	Greyish white slightly wrinkled area
<i>Sclerotinia sclerotorium</i>	38±2	White wrinkled partially rotten area
<i>Geotrichum candidum</i>	32±3	Thick white wrinkled area

Table 3c: Rot diameter and fungal spoilage attributes of fungi isolated from tomatoes from Mile 3 Market

Fungi	Rot diameter (mm)	Spoilage attributes
<i>Aspergillus niger</i>	52±3	Water filled black completely rotten area
<i>Penicillium</i> sp.	18±2	Dark green slightly wrinkled and hard surface area
<i>Mucor</i> sp.	28±3	White hairy wrinkled, partially rotten area
<i>Sclerotinia sclerotorium</i>	38±2	White wrinkled partially rotten area
<i>Geotrichum candidum</i>	32±2	Thick white wrinkled area

Discussion

Spoilage is primarily mediated by fungi pathogens through physical injuries, physical deterioration of fruits due to long storage, packing and distribution at various channels and selling outlets (Akinyele and Akinkunmi, 2012). In this study, the fungal isolates from spoiled tomatoes were *Aspergillus niger*, *Geotrichum candidum*, *Phytophthora infestans*, *Mucor* species, *Aspergillus nidulans*, *Sclerotinia sclerotiorum*, and *Penicillium* species. The finding in this study is in agreement with the work of Mbajuka et al., (2014) who reported *Aspergillus niger*, *Penicillium* species and *Aspergillus nidulans* also as frequent fungal pathogen associated with the spoilage of tomato. The findings in this study also align consistently with the work of Batt et al. (2018) on retail tomatoes confirmed *Aspergillus niger* as a primary isolate, with a significant portion of strains harbouring the genetic potential for OTA production, though expression in tomatoes requires specific conditions. Sanyaolu (2016) reported that *Aspergillus niger*, *Mucor* species, *Penicillium* species, *Geotrichum* species and *Phytophthora* species have been implicated in the spoilage or deterioration of tomato fruits. The presence of *Mucor* species, while common in soil-borne spoilage, elevates the health risk profile of the spoilt batch. This corroborates the work of Prakash and Chakrabarti (2019) that highlighted the environmental ubiquity of mucoralean spores and their emerging threat as opportunists. The detection of *Sclerotinia sclerotiorum* and *Phytophthora infestans* aligns with their established roles as field pathogens and their isolation from fruit indicates a likely pre-harvest infection (Fry et al., 2015). *Penicillium*, *Aspergillus*, *Geotrichum*, and *Phytophthora* have been isolated from tomatoes in a study by Etebu et al (2013). They were described as biotic constraints partaking in post-harvest spoilage of tomatoes.

The frequency occurrence of the fungi (Table 2) showed that *Mucor* species was the most prevalent (21.15 %), followed by *Penicillium* species (19.23 %). *Mucor* species was found in tomatoes obtained from Mile 3 and Rumuokoro markets but absent in Choba market. *Mucor* species is commonly found in rotten fruits and as saprophytes. The occurrence of *Mucor* species could be attributed to mechanical injuries and poor handling practices. Uneven distribution of the isolated fungi highlights differences in storage conditions, hygiene practices, and environmental

factors that might influence fungal proliferation in different market locations. The high occurrence of *Mucor* and *Penicillium* species is consistent with findings by Onuorah and Ezeibekwe (2016), who reported that these fungi are common postharvest pathogens in tomatoes, particularly under humid conditions. Therefore, the distribution of fungal isolates in the fruits from the three market indicate high contamination of tomatoes and this could be as a result of poor sanitation, overcrowding, poor storage and unhygienic practices by the fruits handlers.

The extent of decays and spoilage attributes showed that *Aspergillus niger* and *A. nidulans* produced the highest rot in fully ripe/red healthy tomato fruits. Both fungi also showed the most severe symptoms of spoiling with infected areas turning black or whitish yellow, becoming entirely rotten, and soaked in water. These finding agree with prior observation by Okeke (2019) who reported *Aspergillus niger* as prominent rotting fungus in tomatoes stored under humid circumstances, with rotting diameters exceeding 90 mm. *Aspergillus* species produce a wide range of extracellular enzymes that efficiently break down the complex structural component of plant cell walls (De Vries and Visser, 2001). They are thermotolerant and therefore thrive and cause rot at temperatures that would inhibit other fungi, especially during storage (Ribeiro et al., 2021). On the other hand, among the isolated fungi, *Penicillium* species caused the least damage with the infected area turned green and only showed small wrinkles. This comparatively minimal spoiling corresponds with the findings of Adeleke and Ogunbanwo (2020) who identified *Penicillium* as a slow glowing yet persistent pathogen in post-harvest fruits. It appears post-harvest controls should be targeted mainly at minimizing or eliminating population of *Aspergillus* species since they are the fungal species with the highest spoilage attribute among fungi that causes spoilage of tomato fruits.

Conclusion

Tomatoes are highly susceptible to spoilage by fungi primary due to their high moisture content and thin skin. Consumption of spoiled tomatoes can introduce various toxins with potential carcinogenic, nephrotoxic and immunosuppressive to individuals with weakened immunity. In the case of cross contamination, Spoilt produce can disseminate fungal spores or toxins to nearby food items or to handlers.

The fungi in this study caused spoilage patterns in healthy tomato fruits which was characterized by change in colour and textures, and production of water filled tissue. *Aspergillus niger* and *Aspergillus nidulans* exhibited the most aggressive spoilage with large colony diameters leading to complete fruit rot and water soaking. *Penicillium* sp. and *Mucor* sp. caused moderate spoilage characterized by wrinkling and partial rot, while *Phytophthora infestans*, *Geotrichum candidum* and *Sclerotinia sclerotiorum* showed milder effects. The presence of these fungi particularly the highly destructive *Aspergillus* species, pose a serious threat to fruit quality and storage life. Control measures should focus on minimizing mechanical injury, improved sanitation during distribution, and controlled temperature storage. Also post-harvest sanitary control should be targeted at controlling or eliminating population of *Aspergillus* species.

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