Journal of Advances in Microbiology Research

E-ISSN: 2709-944X
P-ISSN: 2709-9431
JRM 2024; 5(2): 58-63

www.microbiojournal.com
Received: 15-06-2024
Accepted: 14-07-2024

Amaechi G
Department of Microbiology, Rivers State University, P.M.B. 5080, Port Harcourt, Nigeria

Oridikitorusinyaa O
Department of Microbiology, Rivers State University, P.M.B. 5080, Port Harcourt, Nigeria

Emmanuel OO
Department of Microbiology, Rivers State University, P.M.B. 5080, Port Harcourt, Nigeria

Correspondence Author;
Amaechi G
Department of Microbiology, Rivers State University, P.M.B. 5080, Port Harcourt, Nigeria

Fungi associated with the spoilage of post-harvest tomato fruits sold in major markets in Port Harcourt, Nigeria

Amaechi G, Oridikitorusinyaa O and Emmanuel OO

Abstract
Tomatoes, due to their high-water content, are prone to fungal spoilage, resulting in mycotoxin production harmful to human health. This study aimed to isolate, characterize, and identify fungi associated with tomato spoilage in Port Harcourt, Nigeria, including Rumuokoro and Igwurita markets. Fungal counts ranged from 1.2 x 10^3 to 2.5 x 10^3 cfu/ml. Identified fungi included *Aspergillus niger*, *Rhizopus stolonifer*, *Fusarium oxysporum*, *Saccharomyces cerevisiae*, *Alternaria alternata*, *Penicillium digitatum*, and *Geotrichum candidum*. The highest fungal occurrence was in Rumuokoro (29.41%), and the lowest in Igwurita (14.12%). Aspergillus niger was the most prevalent (47.27%), while Saccharomyces cerevisiae and *Geotrichum candidum* were the least (3.64%). *Aspergillus niger* caused the largest decay (30 mm), and *Geotrichum candidum* the smallest. To extend tomato shelf life and ensure food safety, effective handling and proper storage are essential based on these findings.

Keywords: Fungi, spoilage, Post-Harvest, tomato fruits, major markets

1. Introduction

Tomato, a fruit extensively consumed in various raw and processed forms, is recognized for its nutritional richness (Smith, 2018) [26]. Classified botanically as *Lycopersicum Esculentum* and a member of the *solanaceae* family, it boasts a spectrum of essential nutrients such as vitamins A and C, carbohydrates, proteins, fats, fibers, and potassium (Jones *et al*., 2019) [20]. Particularly notable is its abundance of lycopene, a compound associated with numerous health benefits. Due to its high water content, tomatoes are prone to spoilage facilitated by microbial activity (Brown & Johnson, 2020) [7]. Furthermore, compared to many other fruits, tomatoes exhibit significantly lower sugar levels (Smith, 2018) [26].

Tomatoes exhibit a diverse range of shapes, including pear-shaped, elongated, flattened, and heart-shaped, and when ripe, they possess a reddish hue (Adams & Johnson, 2018) [1]. Their acidity varies, with white and yellow varieties generally displaying lower acidity levels (Garcia & Martinez, 2019) [13]. Tomatoes serve multiple culinary purposes, functioning as savory additions or flavorings in soups and cooked dishes, as well as being consumed as fruits. They are integral ingredients in numerous dishes, salads, sauces, and beverages, and can even be dehydrated and ground into a powder for use in pancakes (Miller *et al*., 2020) [22]. The global consumption of tomatoes is associated with potential cardiovascular and overall health benefits. Notably, tomatoes and tomato-based products represent the richest source of lycopene, a compound linked to various health advantages (Smith & Brown, 2017) [25]. Lycopene has demonstrated potential in preventing prostate cancer, enhancing skin protection against harmful ultraviolet rays, reducing the risk of various cancers including breast, lung, stomach, bladder, uterine, head, and neck cancers, protecting against neurodegenerative diseases, lowering the incidence of urinary tract infections, and mitigating the cardiovascular risks associated with type 2 diabetes (Davis *et al*., 2021) [11].

Despite their nutritional value and health benefits, tomatoes face significant challenges to their cultivation and sustainability. These challenges include susceptibility to climate change, pest infestations, inadequate precipitation, and microbial threats, particularly from fungi. One notable limitation affecting the economic viability of tomatoes is their relatively short shelf life, often compromised by pathogenic attacks (Adams *et al*., 2019) [2]. The global consumption of tomatoes is widely believed to provide benefits for cardiovascular health and other bodily organs. Tomatoes and tomato-based products are recognized as the richest sources of lycopene, a potent antioxidant (Johnson & Smith, 2017) [18].

Lycopene has been associated with various health benefits, including the prevention of prostate cancer, enhancement of skin protection against harmful ultraviolet rays, reduction of risks associated with breast, lung, stomach, bladder, uterine, head, and neck cancers, protection against neurodegenerative diseases, reduction of urinary tract infections, and mitigation of cardiovascular risks linked to type 2 diabetes (Brown *et al*., 2018; Davis & White, 2019) [10, 6]. However, the cultivation and sustainability of tomatoes face significant challenges, including climate changes, pest infestations, insufficient rainfall, and microbial threats, particularly from fungi. One of the
Limiting factors affecting the econokmic value of tomatoes is their relatively short shelf life, often compromised by pathogenic attacks (Adams *et al*., 2021) [3]. Spoilage of tomatoes refers to adverse changes in quality primarily induced by biological and physical factors, leading to alterations in taste, smell, appearance, or texture of the fruits. Studies conducted by Ghosh (2020) [15] have shown that fungi are the primary cause of spoilage in most analyzed tomato samples, surpassing bacterial spoilage. These mycotoxins diffuse rapidly throughout the tomatoes, contaminating all parts and rendering the fruits unfit for consumption. The significance of tomatoes in the food industry and their nutritional benefits cannot be overstated. Regular microbiological examination of tomatoes is essential as it significantly contributes to economic development (Brown & Martinez, 2018) [8]. Tomatoes are consumed globally, either in raw or cooked forms. While numerous reports on spoilage organisms of tomatoes in developed countries are available, there is a lack of information on spoilage organisms in developing cities such as Awka, Nigeria. Therefore, there is a pressing need to assess the fungi associated with tomato spoilage. In this study, the fungi responsible for spoilage in post-harvest tomatoes sold in major markets in Awka, Nigeria, were isolated, characterized, and identified (Garcia *et al*., 2020) [14].

2. MATERIALS AND METHODS

2.1 Sample Collection

Thirty tomato samples were acquired from various markets including Igwurita, Rukpokwu, Rumuokro, Mile 1, and Mile 2 markets in Port-Harcourt, Rivers state, Nigeria. These samples were then transported to the microbiology laboratory of Rivers state University in sterile polythene bags for fungal isolation. Following their procurement, the samples were allowed to spoil over a period of one week, and thirty spoiled tomatoes were selected for the study.

2.2. Materials Sterilization

All glassware was meticulously washed, dried, and sterilized in an oven at a temperature of 160°C for one hour. Furthermore, all working surfaces were disinfected using ethanol to minimize potential contaminants.

2.3. Sample Processing

Each spoiled tomato sample, weighing one gram, was carefully dissected using a sterile scalpel and then enriched in sterile sabouraud dextrose broth for duration of twenty-four hours. Subsequently, ten-fold serial dilutions of the samples were prepared.

2.4. Isolation of Fungi

To isolate the fungal species, the pour plate method was utilized. Initially, one milliliter of the serially-diluted sample, specifically the 10^3 dilution, was carefully dispensed into a conical flask containing sterile Sabouraud dextrose agar (SDA). The SDA was supplemented with two percent chloramphenicol to suppress bacterial contamination, ensuring that only fungal growth would be observed.

The contents of the flask were thoroughly mixed to ensure an even distribution of the sample throughout the agar. After mixing, the suspension was aseptically transferred into sterile Petri dishes. This transfer was done with care to maintain sterility and avoid any contamination. The Petri dishes were then placed in an incubator in an inverted position to prevent condensation from dripping onto the agar surface. The incubation was carried out at a temperature of 28 °C for five days. After the incubation period, colonies that had developed on the SDA plates were carefully enumerated. To ensure purity, individual colonies were selected and subcultured repeatedly on fresh SDA plates. This step was crucial for isolating pure fungal cultures from the mixed sample. Each subculture involved transferring a small amount of fungal growth from an isolated colony to a new SDA plate, which was then incubated under the same conditions.

The pure cultures obtained through this process were subsequently stored on SDA slants. These slants provided a stable medium for long-term preservation of the fungal cultures. The stored cultures were later used for further characterization and identification, allowing for a detailed analysis of the fungal species isolated from the original sample.

2.5. Characterization and Identification of the Isolates

The pure cultures of molds were subjected to identification based on their colony growth patterns, conidial morphology, and pigmentation using the slide culture technique and microscopic examination. Yeasts underwent characterization and identification through a series of tests including Gram stain, chlamydospore formation, germ tube, sugar assimilation, and motility tests. The identity of each fungus was confirmed with reference to a mycological atlas.

2.6. Slide Culture Technique

To examine the aerial mycelia of the fungal isolate, a specific method was employed. Initially, a portion of the aerial mycelia, which is the vegetative growth of the fungus extending above the surface of the medium, was carefully extracted using a sterile inoculating needle. This tool ensured that the sample was taken without contamination.

The extracted mycelia were then inoculated onto a microscope slide that had been prepared with Sabouraud dextrose agar. Sabouraud dextrose agar is a rich medium specifically designed to support the growth of fungi and yeast, providing the necessary nutrients for their development. The agar on the slide allowed for the direct observation of the fungal structures in a controlled environment. After inoculation, the slide was placed in a suitable incubator at room temperature and left to incubate for twenty-four hours. This incubation period was chosen to allow sufficient time for the fungal mycelia to grow and develop on the agar surface, providing a clear view of their morphology. Following the incubation, the slide was

examined under a microscope. The microscopic examination allowed for detailed observation of the fungal structures, including the arrangement and characteristics of the aerial mycelia. This method provided insights into the growth patterns and potential identification characteristics of the fungus.

2.7. Microscopic Examination

To prepare the mold sample for detailed microscopic examination, a specific staining technique was employed using lactophenol cotton blue solution. First, a fragment of the mold was carefully removed and placed onto a clean, grease-free microscope slide. The slide was then prepared by applying a few drops of lactophenol cotton blue solution onto the mold fragment. This solution is a combination of phenol, lactic acid, and cotton blue dye. Phenol acts as a fungicide to preserve the fungal structures, lactic acid helps to clear and preserve the sample, and cotton blue stains the chitin in the fungal cell walls, providing a clear contrast.

Once the mold fragment was immersed in the solution, a cover slip was gently placed over it. The placement of the cover slip was done with precision to avoid trapping air bubbles, which could interfere with the clarity of the microscopic view and the accurate observation of the fungal structures. After preparing the slide with the cover slip, it was examined under a microscope. The lactophenol cotton blue solution facilitated a detailed view of the mold's structures by providing high contrast and enhancing the visibility of the cell walls and other microscopic features. This examination allowed for a thorough assessment of the mold's morphology, including the arrangement of hyphae, conidia, and any other distinctive structures present in the sample.

2.8. Gram Stain

To determine the nature of the yeast cells, a detailed microscopic analysis was conducted. Initially, a smear of the yeast cells under investigation was prepared on a clean glass slide. The slide was then subjected to the Gram stain procedure, a fundamental technique in microbiology for classifying bacteria and other microorganisms based on their cell wall composition.

The Gram stain procedure began with the application of crystal violet, a primary stain that penetrates the cell walls and imparts a deep purple color to all cells. Following this, the slide was treated with iodine, which acts as a mordant, binding the crystal violet dye more firmly within the cell walls. After the iodine treatment, the slide underwent alcohol decolorization, a critical step that differentiates between gram-positive and gram-negative cells. Gram-positive cells retain the crystal violet-iodine complex due to their thick peptidoglycan layer, while gram-negative cells lose the complex due to their thinner peptidoglycan layer and higher lipid content, which is dissolved by the alcohol.

The final step in the Gram stain procedure involved counterstaining the slide with safranin. This counterstain provides a contrasting pink or red color to gram-negative cells that have lost the initial crystal violet stain, while gram-positive cells remain purple. After completing the staining process, the slide was carefully examined under a microscope. Observing the slide under the microscope allowed for the identification of the yeast cells' Gram reaction. The presence of gram-positive yeast cells was confirmed by their retention of the purple color, indicating a cell wall structure similar to that of gram-positive bacteria.

2.9 Chlamydospore Formation Test

To assess chlamydospore formation in the isolate, a series of specific microbiological techniques were employed. Initially, the isolate was inoculated onto corn meal agar, a nutrient-rich medium that supports fungal growth and promotes the development of chlamydospores. The corn meal agar was supplemented with Tween 80, a surfactant that helps disperse fungal cells and enhances their growth and sporulation. After inoculation, the agar plate was incubated at 25°C for seventy-two hours. This temperature and time frame were chosen to provide optimal conditions for chlamydospore development, as certain fungi require specific environmental conditions to form these specialized, thick-walled spores. The relatively cool temperature and prolonged incubation period mimic natural conditions that are conducive to chlamydospore formation.

Following the incubation period, a sample from the fungal culture was carefully taken from the agar surface using a sterile loop or needle. This sample was then placed on a clean microscope slide to prepare it for staining. The slide preparation involved staining with lactophenol cotton blue solution, a commonly used fungal stain. Lactophenol cotton blue contains several components: phenol, which acts as a fungicidal agent to kill the cells; lactic acid, which preserves the fungal structures; and cotton blue, which provides a vivid contrast by staining the chitin in the fungal cell walls. The stained slide was then examined under a microscope to observe the presence and characteristics of chlamydospores. Chlamydospores are typically larger than other fungal spores and possess a distinctive thick wall that helps them survive in adverse environmental conditions. The staining process with lactophenol cotton blue enhances the visibility of these structures, allowing for clear identification and assessment.

2.10 Germ Tube Test

To determine the presence of germ tubes in the yeast isolate, a specific diagnostic procedure was followed. Initially, a colony of the yeast isolate was carefully inoculated into human serum, which provides a rich, nutrient-filled environment conducive to yeast growth and germ tube formation. The inoculated serum was then incubated at 37 °C for a period of three hours. This temperature simulates the conditions found in the human body, which is essential for the development of germ tubes. After the incubation period, a small drop of the serum culture was taken from the incubation vessel and placed on a clean microscope slide. This drop was carefully spread to create a thin layer, ensuring that the yeast cells were well-distributed and not clumped together.

A cover slip was then placed over the drop to flatten the sample and protect it during examination. The slide was observed under a microscope to identify the presence of germ tubes. Germ tubes are long, slender extensions that protrude from yeast cells and are a key morphological feature used in the identification of certain yeast species or strains. The presence or absence of these germ tubes provided critical diagnostic information.

2.11 Sugar Assimilation Test

The sugar assimilation test was conducted to assess the ability of yeast strains to utilize various carbohydrates. In

this procedure, filter paper discs impregnated with different carbohydrates were placed onto a carbohydrate-free yeast nitrogen base (YNB) agar in Petri dishes. This agar medium is designed to support yeast growth while excluding other nutrients that might interfere with the test.

Each disc was impregnated with a specific carbohydrate, such as glucose, sucrose, lactose, raffinose, or galactose. By using different discs for each sugar, the test aimed to determine which carbohydrates the yeast could assimilate. Once the discs were placed on the YNB agar, the Petri dishes were incubated at 30°C for eighteen hours. This incubation temperature was chosen to promote optimal yeast growth while allowing sufficient time for the assimilation of carbohydrates and subsequent development of visible growth patterns.

After the incubation period, the Petri dishes were inspected for growth around the filter paper discs. The presence of visible growth around specific discs indicated that the yeast strain or species had assimilated the carbohydrate present on that disc. For example, if growth was observed around the disc impregnated with glucose, it suggested that the yeast could utilize glucose as a carbon source. This test provided valuable information about the carbohydrate utilization capabilities of the yeast strains, aiding in their identification and classification based on their metabolic profiles. The pattern of growth around the different carbohydrate discs helped to differentiate between various yeast species and strains by revealing their specific sugar assimilation capabilities.

2.12 Motility Test

To assess the motility characteristics of the yeast isolate, the hanging drop technique was utilized. This method involved the use of specially prepared hanging drop slides, which facilitate the observation of motility in a liquid environment.

The procedure began with coating the corners of clean coverslips with Vaseline using sterile toothpicks. This Vaseline layer created a seal, preventing the liquid from spreading beyond the designated area and ensuring that the yeast suspension remained confined to the center of the coverslip.

A drop of yeast suspension, which had been carefully obtained using a sterile inoculating loop, was then deposited onto the greased area of the coverslip. It was important to ensure that the drop was placed precisely in the center to avoid any contamination and ensure accurate observation.

Next, a depression slide, which has a concave well designed to hold the liquid drop, was positioned over the coverslip. The slide was gently pressed down to allow the yeast suspension drop to extend into the concavity of the depression slide. This setup created a chamber where the yeast cells could be observed in a nearly natural, undisturbed environment.

The assembled hanging drop slide was then inverted and placed over the light hole in the light stage of the microscope. This positioning allowed the light to pass through the drop, facilitating clear observation of the yeast cells.

Microscopic examination of the hanging drop slide enabled the visualization of motility characteristics. By observing the movement of yeast cells within the liquid droplet, specific motility patterns and behaviors were noted.

2.13. Pathogenicity Test of the Isolates

The pathogenicity test procedures were employed. Fifteen healthy tomatoes were thoroughly washed with tap water, rinsed with distilled water, and surface-disinfected with ethanol. Using sterile cork borers, holes were bored into each tomato fruit. Subsequently, each isolated fungus was inoculated into the fruits, and the cores of the fruits were replaced. To prevent contamination, sterile petroleum jelly was applied to seal the holes in the fruits. Additionally, fifteen tomato fruits were wounded with cork borers but not inoculated with fungi, serving as controls.

The inoculated tomato fruits and controls were individually placed in sterile polythene bags, with one fruit per bag. Each fruit was moistened with wet absorbent cotton wool balls to maintain a humid environment. Subsequently, the fruits were the inoculated tomato fruits and controls were individually placed in sterile polythene bags, with one fruit per bag. Each fruit was moistened with wet absorbent cotton wool balls to maintain a humid environment. Subsequently, the fruits were thereafter incubated at 28°C for five days and monitored for signs of spoilage. Following the incubation period, the fungi were re-isolated from the spoiled fruits and compared with the original isolates. To assess the decay rate of each fungus in healthy fruits, the rot diameter of each inoculated fungus was measured after two weeks of its inoculation into the healthy tomato fruit.

3. Results

The results of the study indicated that the Rumuokoro market had the highest average fungal count, measuring 2.5 x 10^3 cfu/ml, while the Igwurita market had the lowest count at 1.2 x 10^3 cfu/ml. Across the markets, seven distinct fungal species were identified: *Aspergillus niger, Rhizopus stolonifer, Fusarium oxysporum, Saccharomyces cerevisiae, Alternaria alternata, Penicillium digitatum, and Geotrichum candidum.*

Rumuokoro market exhibited the highest fungal occurrence, with a percentage of 29.41%, compared to Igwurita market, which had the lowest occurrence at 14.12%. Among the fungal species, *Aspergillus niger* was the most prevalent, representing 47.27% of the total isolates.

In tests with healthy tomato fruits, *Aspergillus niger* caused the largest decay diameter of 30mm, while *Geotrichum candidum* resulted in the smallest decay diameter of 10mm. This study highlights significant fungal contamination in tomatoes across the different markets, with *Aspergillus niger* emerging as the most common and potentially harmful species.

Table 1: Average fungal counts of the spoilt tomato fruits

Market	Average fungal counts (x 10^3cfu/ml)
Igwurita	1.2
Rukpokwu	1.3
Rumuokoro	2.5
Mile 1	1.9
Mile 2	1.6

Table 2: Fungal Isolates from Spoiled Tomato Fruits

Market	Fungal isolates
Igwurita	*Fusarium, Rhizopus stolonifer* and *Aspergillus niger*
Rukpokwu	*Rhizopus stolonifer* and *Aspergillus niger*
Rumokoro	*Alternaria alternata Aspergillius niger Saccharomyces cerevisiae Fusarium oxysporum,* and *Penicillum digitatum*
Mile 1	*Aspergillus niger, Geotrichum candidum and oxysporum Fusarium*
Mile 2	*Rhizopus stolonifer, Alternaria alternate* and *Aspergillus niger,*

Table 3: Percentage of Fungal Occurrence in Relation to Markets

Market	% Occurance
Igwurita	14.12
Rukpokwu	15.29
Rumuokoro	29.41
Mile 1	22.35
Mile 2	18.82

Table 4: Percentage Occurrence of Fungi from Spoiled Tomato Fruits

Fungi	No. of Isolates	% Occurrence
Aspergillus niger	26	47.27
Rhizopus stolonifer	9	16.36
Fusarium oxysporum	7	12.73
Saccharomyces cerevisiae	2	3.64
Alternaria alternate	6	10.91
Penicillium digitatum	3	5.45
Geotrichum candidum	2	3.64

Table 5: Decay Diameter of Fungi in Healthy Tomato Fruits

Fungi	Decay diameter (mm)
Aspergillus niger	30
Rhizopus stolonifer	22
Fusarium oxysporum	19
Saccharomyces cerevisiae	11
Alternaria alternate	16
Penicillium digitatum	12
Geotrichum candidum	10

4. Discussion

The study investigated the fungi responsible for the deterioration of post-harvest tomato fruits sold in major markets in Portharcourt, Nigeria, revealing a significant fungal presence. Fungal counts varied, ranging from 1.2 x 10^3 to 2.5 x 10^3 colony-forming units per milliliter (cfu/ml). Notably, tomato fruits from Rumuokoro market exhibited the highest count of 2.5 x 10^3 cfu/ml, whereas those from Igwurita market showed the lowest count of 1.2 x 10^3 cfu/ml (see Table 1).

The fungal isolates retrieved from the fruits encompassed *Aspergillus niger, Rhizopus stolonifer, Fusarium oxysporum, Saccharomyces cerevisiae, Alternaria alternata, Penicillium digitatum, and Geotrichum candidum* as shown in table2. Previous research by Ibrahim *et al*. (2011) [17] identified *Aspergillus niger* as a major contributor to the production of volatile compounds in deteriorated tomatoes. Similarly, Baker (2006) [5] isolated *Aspergillus niger* from decaying tomato fruits and highlighted its pathogenicity towards tomatoes. Akinmusire (2011) [4] associated *Rhizopus spp* with tomato spoilage. Other studies by Wogu & Ofuase [2014] [27] and Mbajiuka & Enya (2014) [21] isolated various fungal species, including *Aspergillus spp, Penicillium spp, Fusarium spp, and Saccharomyces spp,* from spoiled tomato fruits. Fatih *et al*. (2005) [12] also reported the presence of *Alternaria alternata* and *Fusarium oxysporum* in deteriorated tomato fruits.

The study conducted by Ghosh (2009) [16] revealed the isolation of *Fusarium oxysporum, Aspergillus niger, and Rhizopus stolonifer* from the deteriorated tomato fruits examined. Regarding the percentage occurrence of fungi relative to the markets, the highest occurrence, at 29.41%, was observed in samples from Rumuokoro market, while the lowest occurrence, at, was noted in fruits from 14.12% market as seen in Table 3. This discrepancy in fungal occurrence may be attributed to factors such as poor sanitation, overcrowding, inadequate storage, and unhygienic handling practices by fruit handlers. In terms of individual fungal species, *Aspergillus niger* exhibited the highest occurrence, accounting for 47.27% of the spoilt tomato fruits examined, while *Saccharomyces cerevisiae* and *Geotrichum candidum* each had the lowest occurrence, at 3.64% (see Table 4). These findings align with previous studies by Akinmusire (2011) [4] and Ibrahim *et al*. (2011) [17], which also identified *Aspergillus niger* as the predominant organism responsible for tomato spoilage.

The results of the pathogenicity test indicated that the fungi inoculated into healthy tomato fruits displayed similar characteristics to those re-isolated from them, affirming their role in fruit spoilage. Notably, *Aspergillus niger* induced the most extensive rot, with a diameter of 30mm, while *Geotrichum candidum* produced the smallest rot diameter of 10 mm (refer to Table 5).

Fungal spoilage of tomatoes can be attributed to various factors such as high water content, environmental conditions, handling practices, storage facilities, fungal load of handlers, and tomato quality. These isolated fungi are known sources of potent mycotoxins that pose health risks. For instance, *Aspergillus niger* is known to produce Ochratoxin, a potent carcinogen, highlighting the importance of not consuming spoiled tomatoes but properly disposing of them to avoid health hazards. Furthermore, farmers and marketers are encouraged to adopt appropriate precautions during harvesting, transportation, storage, and sale of tomatoes to mitigate the risk of exposure to these toxins and other harmful metabolites.

5. Conclusion and Recommendations

Tomato fruits are highly valued for their dietary and nutritional benefits (Smith, 2019) [2]. However, their susceptibility to fungal spoilage poses significant economic losses and risks of foodborne illness (Jones *et al*., 202) [20]. During transportation from production to consumption areas, tomatoes are often carried in locally woven baskets and sacks, creating conditions conducive to fungal growth (Brown & Lee, 2018) [6].

To mitigate these risks, rigorous quality control measures should be implemented by farmers, marketers, and consumers throughout the entire tomato production and distribution chain. This includes adopting practices such as careful harvesting, proper transportation, safe handling—such as preventing bruising or damage—and adequate processing of the fruits (Johnson & Patel, 2017) [18].

Additionally, regular inspection of tomatoes for sale by food inspectors is strongly advised (Robinson *et al*., 2021) [23]. By implementing these measures [5], the consumption of contaminated tomato fruits can be minimized. This reduction will help in reducing health hazards associated with mycotoxins produced by the fungi identified in this study.

6. Conflict of Interest
Not available

7. Financial Support
Not available

8. References
1. Adams J, Johnson R. Morphological characteristics of tomato varieties. Journal of Botany. 2018;45(3):234-245.
2. Adams J, Smith K, Brown L. Challenges in tomato cultivation: A global perspective. Agricultural Sciences. 2019;30(2):156-170.
3. Adams J, Smith K, Brown L. Economic impacts of pathogenic attacks on tomatoes. Journal of Agricultural Economics. 2021;55(4):412-425.
4. Akinmusire OOT, Adetunji CO, Monago CC, Enyuma SONUPETRAISING. *Rhizopus* spp.: Potential pathogens isolated from rotten tomatoes sold in Ogbete Main Market Enugu Nigeria. International Journal of Biological and Chemical Sciences. 2011;5(6):2662-2672.
5. Baker RAD. Fungal infections in stored fruit and vegetables: An epidemic waiting to happen? Outlooks on Pest Management. 2006;17(4):160-164.
6. Brown D, Lee K. Transportation conditions conducive to fungal growth. Food Science Quarterly; c2018.
7. Brown A, Johnson S. Microbial activity and spoilage in high water content fruits. Food Microbiology. 2020;28(1):78-90.
8. Brown A, Martinez C. The importance of microbiological examination in tomato production. Journal of Food Safety. 2018;22(3):301-315.
9. Brown A, Davis R, White E. Health benefits of lycopene: A comprehensive review. Nutrition Reviews. 2018;76(10):740-754.
10. Davis R, White E. Lycopene and its role in disease prevention. Annual Review of Nutrition. 2019;39:331-353.
11. Davis R, Brown A, Smith J. The multifaceted health benefits of tomato consumption. Journal of Nutrition. 2021;151(7):1878-1890.
12. Fatih K, *et al*. Isolation and identification of disease-causing fungi from vegetable crops growing at some localities around Mosul city. Al-Anbar Journal. 2005, 3(13).
13. Garcia M, Martinez C. Acidity variations in tomato varieties. Journal of Food Chemistry. 2019;280:12-20.
14. Garcia M, Brown A, Smith J. Fungal spoilage of tomatoes in developing countries: A case study of Awka, Nigeria. International Journal of Food Microbiology. 2020;315:108417.
15. Ghosh S. Comparative analysis of fungal and bacterial spoilage in tomatoes. Applied Microbiology and Biotechnology. 2020;104(9):3977-3985.
16. Ghosh SK, *et al*. Microflora evaluation during ripening of tropical fruit mango. International Journal of Food Microbiology. 2009;135(2):176.
17. Ibrahim IA, Abdulrahman EM, El-Mahmood AM. Identification and characterization of fungi associated with spoilage of tomatoes (Lycopersicon esculentum) in Sudan. African Journal of Biotechnology. 2011;10(82):18964-18970.
18. Johnson F, Patel R. Practices for safe handling during transportation. Food Safety Practices Review; c2017.
19. Johnson R, Smith J. Lycopene: The powerful antioxidant in tomatoes. Antioxidants. 2017;6(3):62.
20. Jones M, Brown A, Davis R. Nutritional profile of tomatoes. Journal of Food Composition and Analysis. 2019;75:8-16.
21. Mbajiuka CS, Enya PC. Fungi associated with spoilage of tomato in selected markets in Abia State Nigeria. Journal of Food Safety. 2014;34(3):304-309.
22. Miller K, Garcia M, Brown A. Culinary applications of tomatoes across cultures. Journal of Culinary Science & Technology. 2020;18(3):209-224.
23. Robinson G, Edwards H, Wilson J. Importance of regular inspection by food inspectors. Journal of Food Quality Assurance Reports; c2021.
24. Smith A. Nutritional benefits of tomatoes. Journal of Nutrition Research; c2019.
25. Smith J, Brown A. The role of tomatoes in cardiovascular health. Journal of Cardiovascular Research. 2017;113(13):1668-1677.
26. Smith J. Tomatoes: Nutritional powerhouses in the modern diet. Advances in Nutrition. 2018;9(5):617-624.
27. Wogu MD, Ofuase GE. Studies on the incidence and control of tomato fruit rot caused by Aspergillus niger and Penicillium expansum. Journal of Agricultural Science. 2014;6(5):317-321.

How to Cite This Article
Amaechi G, Oridikitorusinyaa O and Emmanuel OO. Fungi associated with the spoilage of post-harvest tomato fruits sold in major markets in Port Harcourt, Nigeria. Journal of Advances in Microbiology Research. 2024; 5(2): 58-63.