



Fungal Load and Species Distribution in Spoiled Tomatoes Sold in Three Select Vegetables Markets in Katsina Metropolis, Katsina State, Nigeria

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ABSTRACT

Background: Post-harvest spoilage of tomatoes due to fungal contamination is a significant issue in Nigeria, causing economic losses and health risks from mycotoxins. Possible postharvest losses can be facilitated by early identification of products that are susceptible. Despite the extensive research on tomatoes contaminated by fungal pathogens, at the time of this study, there is a conspicuous lack of research highlighting the fungal pathogens infecting tomatoes sold in Katsina metropolis, bridging the possible means of appropriately tackling this challenge.

Objective: This study aimed to identify and characterise fungi associated with tomato spoilage in three markets (Gwari, Central, and Kofar Marusa) in Katsina metropolis.

Methods: Tomato samples (n=135) from Beefsteak, Roma, and UTC varieties were collected weekly over three weeks. Fungal loads were quantified using serial dilution and pour plate methods, with isolates identified morphologically and microscopically.

Results: Mean fungal loads ranged from 204.7 to 370 cfu/g, with the Central market showing the highest contamination (370 cfu/g for UTC). Nine fungal species were identified: *Aspergillus flavus*, *Aspergillus fumigatus*, *Rhizopus*, *Aspergillus niger*, *Alternaria spp*, *Fusarium spp*, *Basidiobolus*, *Cladosporium spp*, and *Aspergillus glaucus*. *Aspergillus* species were predominant. One-way ANOVA showed no significant differences in fungal loads across markets (F=2.50, p>0.05) or varieties (F=0.80, p>0.05). Pearson correlations indicated a moderate positive association with markets (r=0.568) and a negative association with varieties (r=-0.452).

Conclusion: These findings highlight *Aspergillus* dominance in tomato spoilage and underscore the need for improved post-harvest practices and market hygienic operation to reduce economic losses and mycotoxins risks.

Unique contribution: This study highlights public health threats from spoiled tomatoes in Katsina metropolis where the consumption of contaminated produce is common (eg aflatoxin from *Aspergillus*) and also highlights the economic losses from spoilage, recommending interventions like improved storage, training and awareness campaign.

Key Recommendation: Promote processing and improved storage techniques to extend shelf life and reduce economic losses for farmers by introducing training programs to educate farmers and vendors on proper handling, transportation, and storage techniques to reduce fungal contamination and local health authorities should initiate awareness campaigns targeting vendors and consumers about the dangers of consuming spoiled tomatoes and the importance of proper storage.

Keywords: Fungi, Tomato, markets, mycotoxins



INTRODUCTION

Tomato (*Lycopersicon esculentum*) is a prevalent vegetable which has been used as food both in raw and cooked form. Tomato is a tender and compression-sensitive fruit and a member of the *Solanaceae* family botanically known as berry (Olanreju *et al.*, 2017). It has a lot of water in it, which increases their moisture content and makes them more prone to deterioration from different microbes (Lamidi *et al.*, 2020). Tomatoes are a good source of phytochemicals and nutrients. The nutritional content of tomatoes can be retained whether they are cooked or eaten raw in salad, for garnishing various food items and added for taste in cooked items making them a valuable addition to a balanced diet. Juice, soup, and ketchup are just a few of the processed goods that use more than 80% of all tomatoes farmed commercially. Due to the large part to their antioxidant content, tomatoes and tomato-based foods are recognized to provide a number of health benefits (Collins *et al.*, 2022). Tomatoes' health benefits are most extensively researched in connection with their potential to prevent cancer. Tomato components can affect not just cancer but also a number of other age-related illnesses like diabetes, Alzheimer's, and cardiovascular disease as well as skin health, fertility, and post-exercise recovery (Edward *et al.*, 2022).

In Nigeria, about 541,800 hectares of fresh tomatoes are harvested annually (Sahel research, 2017). Nigeria is the second-largest producer of tomatoes in Africa and the 12th in the world, with over 200,000 smallholder farmers growing the crop there. (Danaski *et al.*, 2022). Twenty percent of Nigeria's daily vegetable intake comes from tomato, which has an annual market demand of about 2.3 million metric tonnes (Wakane and Sharew, 2024). In the meantime, post-harvest losses for farmers nationwide are more than forty-five percent, leaving a supply shortfall of almost 500,000 metric tonnes (Babadara, 2023). This is an ineffective utilisation of natural resources in addition to resulting in financial losses. Research on the microbes that affect tomatoes is crucial to addressing this problem because it can help with ways to prevent spoilage and extend the shelf life of fresh produce, which will help reduce food loss, financial losses and guarantee year-round access to this vital vegetable. Nigeria has the comparative advantage and potential to become a leading producer and exporter of tomatoes worldwide, currently ranking as the 16th largest tomato-producing country in the world. About 1.8 million metric tons of tomatoes were produced in Nigeria in 2010; this amounts to roughly 68.4% of West Africa's total production, 10.8% of Africa's overall output, and 1.28% of global production. Sadly, the nation continues to face low yield and productivity, a lack of processing and marketing facilities, a lack of advanced technologies, a shortage of essential inputs, and, more importantly, substantial postharvest losses. Thus, the supply of tomatoes and their byproducts is much outstripped by the demand (Ugonna *et al.*, 2015; Olukotun *et al.*, 2022). Compared to other vegetables, tomatoes have one of the highest damage and loss reports during wholesale assessments (Gebeyehu *et al.*, 2020). The issue of postharvest losses in freshly harvested tomatoes has been highly reported, with damages ranging from 25 – 80% in magnitude. Tomato postharvest management is extremely difficult in Sub-Saharan Africa, where fresh market tomato losses average approximately 9.8% in Central and Southern Africa, 10.04% in West Africa, and 9.5% in East Africa (Wakane & Sharew, 2024). Also, only 68.4% of tomatoes produced in Nigeria are consumed; this incurs a huge loss of over 40% during postharvest (Awua *et al.*, 2022).



In ensuring global security, paying keen attention to food security is crucial. The cultivation of tomatoes has been an integral aspect of food security, serving as a food source and also boosting the economy. Fruit loss occurs often in the field and during postharvest (processing and screening) in various locations, with significant reports on fungal contamination of tomatoes (Rodrigues *et al.*, 2022). In Nigeria (particularly in the North), the cultivation of tomatoes is a significant agro-economic activity, but the issue of fungal infections has been a major setback, leading to severe economic losses. Studies have highlighted fungal species like *Rhizopus stolonifer*, *Rhizopus arrhizus*, *Aspergillus fumigatus*, *Candida tropicalis*, *Microsphaeropsis arundinis*, and *Aspergillus flavus* involved in postharvest spoilage of tomatoes in areas of Maiduguri, Kogi, Kaduna, and Kebbi states (Mohammed & Kuhiyep, 2020; Danaski *et al.*, 2022; Abubakar *et al.*, 2023; Okolo & Abubakar, 2023).

This challenge in tomato production has been linked to several biotic and abiotic factors, such as climatic changes, poor handling, transportation problems, inadequate infrastructure, pests, and microbial infestation (Danaski *et al.*, 2022). Simões & de Andrade (2023) highlighted a portion of the abiotic factors affecting the production of this vegetable, revealing that the conventional breeding of tomatoes has employed different selections aimed at improving the quality of this vegetable. However, tomatoes are still susceptible to more than 200 diseases during their growth and post-growing season. The microbial causative agents of these diseases are viruses, viroids, bacteria, nematodes, and fungi, causing destructive effects that ultimately decrease the market value of this fruit.

MATERIALS AND METHODS

Study area

The study was conducted in Katsina municipal, Katsina State, Nigeria. Katsina State is situated in the North -West region of Nigeria. Katsina state is made up of 34 local government areas with an estimated population of over 10 million people (MNCH2, 2022). The state is bounded in the East by Kano State, in the West by Zamfara State, in the South by Kaduna State and in the North by the Niger republic. The global location of the State is 12°59'20N, 07°36'03" E, and the general elevation of the area is between 305 – 610 meters above sea level.

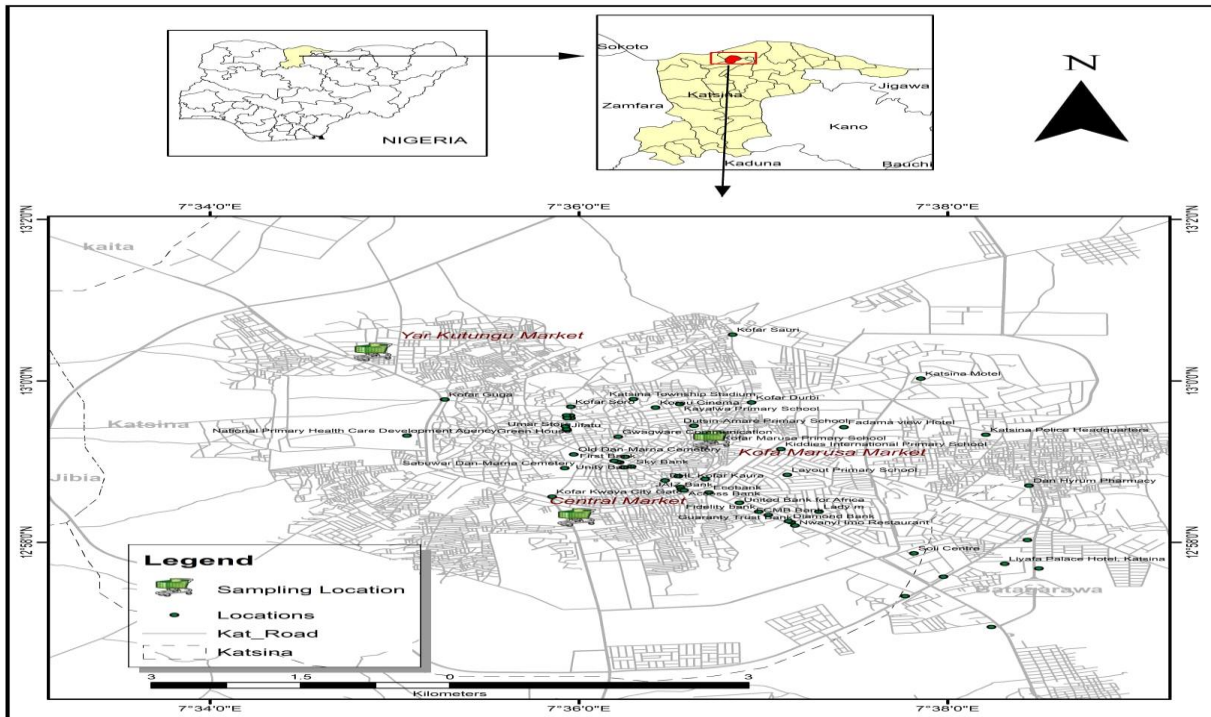


Figure 1: Map of Katsina state showing the study area. (Source: Department of Geography, Federal University of Dutsin ma (2025))

Sample Collection

Three (3) markets were selected in Katsina municipal for this study namely; Kasuwar gwari, Kofar marusa market and Katsina central market. A total of 135 tomatoes were collected. The tomatoes were randomly collected per week (15 samples from each market and 5 samples from different point) from the three selected markets for three weeks and were placed immediately in a polytene bag and transported to Department of Microbiology, Al-Qalam University Katsina for mycological analysis.

Mycological Analysis

For the enumeration of Fungi, the serial dilution method as described by Willey et al., (2011) was employed. 1ml from the homogenate solution (10^{-1} dilution) was transferred in to 9 ml of the diluents (0.1% peptone water), this gave the dilution of 10^{-2} . This procedure was repeated up to the fifth dilution which gave the dilution of 10^{-5} .

The dilution bottles were agitated to respond settled materials. 1ml of each dilution was pipetted into separate corresponding petri dishes in duplicates. About 15ml of Potato dextrose agar cooled to 45°C was be poured in to each plate. The sample and the agar medium were mixed by rotating the plate on a flat surface and allow solidifying. The petri dishes were inverted and incubated at 35°C for 3-5 days. Plates containing colonies were selected and counted. The number obtained was multiplied by the dilution factor which gave the number of fungal colony forming unit of the sample, (CFU/g).



Isolation and Identification of Fungi

The colonies on each plate were counted and recorded, after which distinct fungal colony were sub-cultured onto fresh potato dextrose agar medium to obtain pure culture base on morphological characteristics.

For the purpose of identifying fungal isolates, cotton blue and lacto-phenol stain, Sangeetha and Devarajan's (2012) method was utilized. A mounting needle was used to apply a drop of the stain to a clean slide while dipping a little piece of the fungal cultures mycelium into a drop of lacto-phenol. With the help of the needle, the mycelium was evenly distributed throughout the surface of glass slide. To remove air bubbles, a cover slip was applied sparingly and carefully. The slide was mounted after which x10 and x40 objective lenses were used to examine it according to Cheesbrough's (2006) identification guide.

Statistical Analysis

All experiments were conducted in triplicate and the results were expressed as mean \pm standard deviation of the measurements. Excel (Microsoft Co, Redmond, WA, USA) was used to calculate the standard deviation. The data obtained was subjected to one-way ANOVA and 95% confidence interval, also the relationship between the variables was determined with Pearson correlation using Statistical Package for Social Sciences for significant differences (SPSS Version 23.0).

RESULT

Table 1: Mean fungal count (cfu/g) of Tomato from selected markets in Katsina

Sample code	Cfu/g
G_B	3.12×10^2
G_R	2.893×10^2
G_U	2.627×10^2
C_B	3.6×10^2
C_R	3.51×10^2
C_U	3.7×10^2
K_B	3.38×10^2
K_R	3.1×10^2
K_U	2.047×10^2

Keys; G_b = Beefsteak tomato Gwari market, G_r = Roma tomatoes Gwari market, G_u = UTC tomatoes gwari market, C_b= Beefsteak tomato central market, C_r = Roma tomato central market, C_u = UTC tomato central market, K_b = Beefsteak tomato Kofar marusa market, K_r = Roma tomatoes Kofar marusa, K_u = UTC tomato Kofar marusa.



Table 3: Frequency occurrence of Fungal Isolates from spoiled tomato sample from each location of the study (n= per market).

Isolates	Frequency of occurrence		
	Gwari (%)	Kofarmarusa(%)	Central market (%)
<i>Aspergillusflavus</i>	3(17.7)	2(14.3)	4(25)
<i>AspergillusFumigatus</i>	4(23.5)	3(21.42)	2(12.5)
<i>Rhizopus spp</i>	2(11.8)	2(14.3)	1(6.25)
<i>Aspergillus Niger</i>	2(11.8)	2(14.3)	2(12.5)
<i>Alternaria spp</i>	2(11.8)	1(7.14)	2(12.5)
<i>Fusarium spp</i>	2(11.8)	0	3(18.75)
<i>Basidiobolus spp</i>	1(5.88)	0	0
<i>Clasdoporium spp</i>	1(5.88)	3(21.42)	2(12.5)
<i>Aspergillusglaucus</i>	0	1(7.14)	0

Table 4: Estimated Standard Deviation of Mean Fungal Load from Tomato Samples

Sample code	Market	Tomato variety	Mean fungal load (cfu/g)	Standard deviation±
GB	Gwari	Beefsteak	312.0	23.40
GR	Gwari	Roma	289.3	21.70
GU	Gwari	UTC	262.7	19.70
CB	Central	Beefsteak	360.0	27.00
CR	Central	Roma	351.0	26.33
CU	Central	UTC	370.0	27.75
KB	Kofarmarusa	Beefsteak	338.0	25.35
KR	Kofarmarusa	Roma	310.0	23.25
KU	Kofarmarusa	UTC	204.7	15.35



Factor	Groups compared	F- statistic	Degree of freedom	p- value	Significance (0.05)
Market	Gwari, Central, kofarmarusa	2.50	F(2,6)	>0.05	Not significant
Tomato variety	Beefsteak, Roma, UTC	0.80	F(2,6)	>0.05	Not significant

Table 5: One-Way ANOVA Results for Fungal Loads across Markets and Tomato Variety

Table 5 above shows One-Way ANOVA Results for Fungal Loads across Markets and Tomato Variety

Table 6: Pearson Correlation Coefficients for Fungal Load

Variable pair	Correlation coefficient(r)	Strength and Direction
Fungal load vs. Market	0.568	Moderate positive
Fungal load vs. Tomato Variety	-0.452	Moderate negative

DISCUSSION

Fresh fruits have a natural skin that serves as a barrier against harmful microbes and the majority of plant deterioration. But when fruits are grown in fields or are harvested, handled, and distributed after harvest, this protection may be lost and the fruits may become contaminated (Musa *et al.*, 2022). In this study, the number and variety of fungi species found in tomatoes revealed a severe public health risk since some of the species were known to grow and produce toxins while others were saprophytes. To address the problem of tomato spoilage in Nigeria, Fungal species associated with spoilage of tomatoes in some markets of Katsina metropolis were isolated and identified.

The fungal load analysis reveals significant variation in fungal loads across tomato varieties and markets, with the UTC tomato sample from the Central market showing the highest fungal count (3.7×10^2 cfu/g), followed by Beefsteak (3.6×10^2 cfu/g) and Roma (3.51×10^2 cfu/g) from the same market. In contrast, the UTC sample from Kofar marusa had the lowest count (2.0×10^2 cfu/g). These findings align with previous studies of (Pitt and Hocking, 2020) indicating that environmental factors, such as humidity, temperature, and storage conditions, significantly influence fungal proliferation in fresh produce. The elevated fungal loads in the Central market suggest potential lapses in post-harvest handling or storage practices, such as prolonged exposure to high humidity or poor sanitation, which are known to increase fungal growth (Barkai-Golan



and Paster, 2019). The lower fungal load in Kofar marusa may reflect better handling practices or less conducive environmental conditions.

A total of nine fungal species were identified in this study based on macroscopical and microscopical characteristics. The fungal isolates were: *Aspergillus flavus*, *Aspergillus Fumigatus*, *Rhizopus spp*, *Aspergillus Niger*, *Alternaria spp*, *Fusarium spp*, *Basidiobolus*, *Clasdoportium* and *Aspergillus glaucus*. The nine fungi species identified were not all present in all the three markets. In Gwari market, *Aspergillus flavus*, *Aspergillus fumigatus*, *Rhizopus spp*, *Aspergillus niger*, *Alternaria*, *Fusarium*, *Basidiobulus*, *Clasdoportium* were identified. In Kofar marusa market, *Aspergillus glaucus*, *Clasdoportium*, *Alternaria*, *Aspergillus Niger*, *Rhizopus spp*, *Aspergillus fumigatus* and *Aspergillus flavus* were identified. In Central market, *Clasdoportium*, *Fusarium*, *Aspergillus flavus*, *Aspergillus fumigatus*, *Alternaria*, *Aspergillus niger* and *Rhizopus* were identified.

Aspergillus species were the most prevalent in the markets even though the contamination level varied by location. The findings in this study of *Aspergillus* species being the most prevalent tomato fruit spoilage fungi is similar to an earlier report by Musa *et al.*(2022) who reported that the main tomato fruit spoilage fungi is *Aspergillus* species alongside others. The presence of *Fusarium spp* in spoilt tomato samples from the three markets agrees partly with the findings of Wogu and Ofuase (2018) who reported similar fungi as spoilage fungi in tomato.

Xie *et al.* (2012) and Lamidi *et al.*(2021) also reported that *Fusarium spp*, *Rhizopus spp*, *Alternaria spp*, *Aspergillus spp* and *Clasdoportium spp* are the major fungi responsible for the spoilage of tomatoes which is similar to the findings in this study. The presence of *Basidiobulus* is also compared with the findings of Kabiru and Yusuf (2024) that also isolated *Basidiobulus spp* from spoilt tomato.

Table 4.3 highlights the distribution of fungal isolates across the markets, with *Aspergillus* species dominating. *Aspergillus fumigatus* (23.5%) and *Aspergillus flavus* (17.7%) were most prevalent in Gwari, while *A. flavus* (25%) and *Fusarium spp.* (18.75%) dominated in the Central market. The high prevalence of *A. flavus* is particularly concerning due to its production of aflatoxins, potent mycotoxins linked to hepatotoxicity and carcinogenicity (Bennett and Klich, 2023). Similarly, *Fusarium spp.* is associated with fumonisins, which pose significant health risks (Marasas *et al.*, 2020). The low occurrence of *Basidiobolus spp* and *A. glaucus* in some markets suggests these species may be less competitive or less adapted to tomato substrates.

For statistical analysis, table 4.4 indicates no significant differences in fungal loads across tomato varieties, though Beefsteak has the highest mean (336.67 cfu/g). This suggests fungal contamination is similar across varieties, possibly influenced by shared market conditions. In Table 4.5, a moderate positive correlation indicates that higher fungal loads are associated with Central Market, consistent with its higher mean fungal load (360.33 cfu/g). This suggests market-specific factors (e.g., storage conditions, handling practices) may contribute to increased fungal contamination. For the Fungal Load vs. Tomato Variety; A moderate negative correlation suggests that lower variety codes (e.g., Beefsteak) are associated with higher fungal loads (mean



336.67 cfu/g) compared to higher codes (e.g., UTC, mean 279.13 cfu/g). This indicates Beefsteak may be more susceptible to fungal spoilage, possibly due to physical traits like softer skin or higher water content.

CONCLUSION

Different types of fungi have been identified in these studies which are associated with the spoilage of tomatoes. The specie of *Aspergillus* was the major fungi identified which causes a serious health risk as it is a toxigenic fungus that produces aflatoxins. In conclusion, both pathogenic and toxigenic fungi which are *Aspergillus flavus*, *Aspergillus Fumigatus*, *Rhizopus spp*, *Aspergillus Niger*, *Alternaria spp*, *Fusarium spp*, *Basidiobolus*, *Clasdoportium* and *Aspergillus glaucus* were isolated in this study and the findings emphasize the need for integrated management to curb post-harvest losses and mitigate mycotoxin risks.

Ethical clearance

The researchers adhered to all necessary research ethics at all stages of the study.

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Author's contribution: A.I Alhaji and Y. A Umar developed the protocol and original idea H. R Sani carried out the sample collection and performed the laboratory analysis under the supervision of A.I Alhaji and Y. A Umar. H. R Sani and Y. Abdurrahman drafted the Initial manuscript while A.I Alhaji and Y. A Umar revised and approved the manuscript for publication.

Availability of data and materials.

The datasets on which conclusions were made for this study are available on reasonable request.

Citation

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