Magna Scientia Advanced Research and Reviews
eISSN: 2582-9394
Cross Ref DOI: 10.30574/msarr
Journal homepage: https://magnascientiapub.com/journals/msarr/

(Review Article)

Check for updates

Mycotoxins in Tomatoes and Tomato Products in Nigeria: A Systematic Review

MaryRose Ogechi Echeta [1, *], Vivian Chika Igiri [2], Chizoba Precious Tony-Nze [3], Ugochukwu Romanus Onyeukwu [4], Amara Blessing Nwokoro [5], Maximus Obinna Nzeagwu [6], Stephen Nnaemeka Ezekwueche [1], Grace Amarachi Obi-Adumanya [7], Mirian Ifeanyi Oyem [8] and Joy Ufuoma Oghenedoro [9]

[1] *Medical Microbiology [Department of Microbiology, University of Agriculture & Environmental Sciences, Umuagwo, Imo State, Nigeria]*
[2] *Medical Microbiology & Infectious Disease Epidemiology [Department of Microbiology, University of Agriculture & Environmental Sciences, Umuagwo, Imo State, Nigeria]*
[3] *Medical Parasitology [Department of Microbiology, University of Agriculture and Environmental Sciences, Umuagwo, Imo State, Nigeria]*
[4] *Environmental Microbiology/Toxicology [Department of Microbiology, University of Agriculture and Environmental Sciences, Umuagwo, Imo State, Nigeria].*
[5] *Public Health [Department of Microbiology, University of Agriculture & Environmental Sciences, Umuagwo, Imo State, Nigeria]*
[6] *Medical Microbiology [Department of Science Laboratory Technology, Imo State Polytechnic, Omuma, Imo State, Nigeria.*
[7] *Mycology & Phytopathology [Department of Biology, University of Agriculture & Environmental Sciences, Umuagwo, Imo State, Nigeria]*
[8] *Environmental Microbiology [Department of Microbiology, University of Delta, Agbor, Delta State, Nigeria]*
[9] *Environmental Management & Toxicology [Department of Environmental Management and Toxicology, University of Agriculture & Environmental Sciences, Umuagwo, Imo State, Nigeria.*

Magna Scientia Advanced Research and Reviews, 2025, 15(02), 205-218

Publication history: Received on 25 October 2025; revised on 10 December 2025; accepted on 13 December 2025

Article DOI: https://doi.org/10.30574/msarr.2025.15.2.0146

Abstract

Mycotoxins refer to toxic secondary metabolites produced by certain fungi that pose significant health risks through contaminated food consumption. In Nigeria, favorable tropical conditions contribute to widespread fungal proliferation, raising concerns over mycotoxin contamination beyond staple crops to include commonly consumed vegetables like tomatoes. Therefore, the present review was to enrich the data bank of information on mycotoxins incidence, types, and levels in tomatoes and tomato products in Nigeria adopting the Cochrane Handbook for systematic reviews of Preferred Reporting Items for Systematic Reviews and Meta–analyses (PRISMA) instruction for documenting meta-analyses and systematic reviews and evaluating the risk factors for mycotoxin contamination and health risks associated with mycotoxin exposure from tomato consumption exposure. Data relating to mycotoxins in tomatoes and tomato products in Nigeria and related works were gathered from various search engines, including Google Scholar, ResearchGate, African Journals Online, and Scopus. Thirty one (31) pooled data studies were extracted using the developed systematic review method, which was utilized to analyze the extent of research on mycotoxins in tomato and tomato products in Nigeria. This systematic review synthesizes existing research on fungal species involved, types and levels of mycotoxins detected, and risk factors associated with tomato contamination across Nigerian regions. Key mycotoxins identified include aflatoxins, fumonisins, zearalenone, and trichothecenes, all linked to serious health effects such as carcinogenicity, immunosuppression, and endocrine disruption. Despite documented contamination in other commodities, tomatoes have received limited focused study, revealing critical knowledge gaps in surveillance, risk assessment, and regulation. Climate, poor agricultural and storage practices, and contamination during handling

* Corresponding author: MaryRose Ogechi Echeta

contribute to mycotoxin proliferation in tomatoes. Addressing these challenges through targeted research and improved monitoring is essential for mitigating public health risks and enhancing food safety in Nigeria.

Keywords: Mycotoxins; Tomatoes; Tomato products; Contamination; Systematic review

1. Introduction

Mycotoxins are poisonous substances from fungi that cause acute or chronic poisoning when ingested. These insidious compounds are known to cause a range of deleterious effects in humans and animals, including acute toxicity, chronic diseases like cancer, immunosuppression, and developmental impairments (Yu & Pedroso, 2023). In Nigeria, a tropical country with climatic conditions conducive to fungal proliferation, the risk of mycotoxin contamination in food products is particularly elevated (Omeiza *et al.*, 2018). Specifically, aflatoxins, a class of mycotoxins produced by *Aspergillus* species, are a major public health concern in Nigeria, given their potent carcinogenic and acute toxic properties, especially in staple crops like maize and groundnuts (Gong *et al.,* 2016). However, the prevalence and impact of mycotoxins in tomatoes and tomato products, a widely consumed staple in Nigeria, remain less systematically investigated despite their susceptibility to fungal spoilage post-harvest (Shehu *et al*., 2020).

Mycotoxins represent a pervasive threat to global food safety and public health due to their widespread occurrence in agricultural commodities (Alshannaq & Yu, 2017). These naturally occurring contaminants are a significant concern in Nigeria, where environmental conditions often favor fungal growth and subsequent mycotoxin production, particularly aflatoxins (Abdeta & Milki, 2023). Studies have shown that fungal contamination, with prevalent species like *Aspergillus flavus*, is common in staple foods across Nigeria, leading to high levels of aflatoxins, often exceeding regulatory thresholds (Ekpakpale *et al*., 2021a). This prevalence is largely attributable to factors such as inadequate storage infrastructure, poor agricultural practices, and fluctuating weather conditions (Maphaisa *et al*., 2025). The economic implications of mycotoxin contamination are also substantial, affecting trade, food security, and the livelihood of farmers, especially smallholder producers. (Jallow *et al.*, 2021) (Ekpakpale *et al*., 2021b) (Ezekiel *et al*., 2014) (Akinmusire & Olawale, 2021) Despite the established concerns regarding mycotoxins in other staple crops, there remains a notable lacuna in comprehensive research specifically addressing their presence and implications in tomatoes and tomato products within Nigeria (Udomkun *et al.*, 2018). This systematic review aims to bridge this knowledge gap by providing a comprehensive analysis of the current state of research on mycotoxin contamination in this vital food commodity within the Nigerian context.

Aflatoxins, principally produced by *Aspergillus flavus* and *Aspergillus parasiticus*, represent a significant subset of mycotoxins, with AFB1, AFB2, AFG1, and AFG2 being the most prevalent and acutely toxic forms (Alameri *et al*., 2023). The insidious nature of aflatoxins stems from their high toxicity, which can lead to severe health complications in both humans and animals, alongside substantial economic losses due to crop contamination (Shabeer *et al*., 2022). The global prevalence of mycotoxins, with over 400 identified types, underscores the critical need for effective detection and mitigation strategies, particularly given that a substantial portion of agricultural products worldwide are affected (Li *et al*., 2022) (Stoev, 2024). For instance, *Aspergillus flavus*, *A. fumigatus*, *A. niger*, *Mucor* sp., *Neurospora* sp., *Penicillium* sp., and *Rhizopus* sp. have all been identified in various food items in Nigeria, with *Aspergillus flavus* being particularly prevalent (Okobiebi & Ezennia, 2021). This underscores the urgent need for a systematic review focused on mycotoxin contamination in a widely consumed commodity like tomatoes, which, despite their susceptibility, have received less attention compared to grains and legumes (Adamu *et al*., 2021; Mshelia *et al*., 2020). This review will therefore provide a crucial compilation of existing data, highlighting the types and levels of mycotoxins detected in Nigerian tomatoes and their derived products as well as the risk of contamination, and public health implication.

2. Review Methods and Search Strategy

This review focused on the systematic examination of literature pertaining to mycotoxin contamination in tomatoes and tomato-based products within Nigeria. The search strategy encompassed major scientific databases such as PubMed, Scopus, Web of Science, and Google Scholar, utilizing a combination of keywords related to mycotoxins, *Aspergillus*, tomatoes, and Nigeria to ensure comprehensive coverage of relevant studies. The inclusion criteria will focus on peer-reviewed articles, conference papers, and technical reports published in English that specifically address the detection, quantification, and impact of mycotoxins in tomatoes and derived products harvested or consumed in Nigeria. Studies focusing solely on mycotoxin contamination in other food matrices or those without a clear Nigerian context were excluded to maintain the specificity and relevance of the review. The review explored the specific mycotoxins, such as Aflatoxins, fumonisins, zearalenone, and trichothecenes that have been detected in tomato and tomato products in Nigeria. This systematic review further evaluated the risk factors for mycotoxin contamination, health risks associated with mycotoxin exposure .prevalence of mycotoxins in tomato and its products and implications for public health. The rigorous selection process for articles adhered to PRISMA guidelines, ensuring transparency and reproducibility in the identification, screening, eligibility, and inclusion phases of the literature review (Makhunga *et al.*, 2019).

2.1. Levels of Fumonisin Contamination

Previous studies in North-Central Nigeria have indicated that climate conditions are favorable for the growth of fumonisin-producing fungi, suggesting a potential for significant contamination in staple crops within the region, which may extend to tomatoes and tomato products (Onyedum *et al*., 2019). Given that tomato is a widely consumed commodity, the presence of fumonisins, particularly B1, B2, and B3, is a critical public health concern due to their established hepatotoxic, nephrotoxic, and immunotoxic effects (Edeghor *et al*., 2023). The detection of fumonisins in tomato and tomato products would therefore necessitate a thorough risk assessment to quantify the dietary exposure and potential health implications for the Nigerian population, especially vulnerable groups (Nakavuma *et al*., 2020). Furthermore, such an assessment would inform targeted interventions aimed at mitigating mycotoxin contamination within the agricultural and processing sectors (Oyesigye et al., 2024) (Dione *et al*., 2023). Conversely, the widespread prevalence of these toxins across various food matrices, including breast milk, underscores the need for robust surveillance in previously understudied food items like tomatoes (Ezekiel *et al.*, 2020). Further investigation into the prevalence and levels of fumonisins in Nigerian tomato value chains is essential to ascertain the extent of this contamination and guide appropriate food safety measures. This is particularly pertinent given that fumonisins are not yet regulated in baby foods in Nigeria, highlighting a potential regulatory gap that could impact infant health (Ezekiel *et al.*, 2020). The broader context of mycotoxin contamination in Nigeria, including findings of diverse mycotoxin profiles in complementary foods, reinforces the urgency such studies in tomato products (Ezekiel *et al*., 2020). The lack of extensive research specifically on fumonisins in tomato products within the Nigerian context presents a significant knowledge gap that this review aims to address, thereby contributing to a more complete understanding of mycotoxin exposure pathways in the region. Moreover, the documented presence of fumonisins in other widely consumed Nigerian foodstuffs, such as corn and rice, and even breast milk, highlights the potential for cumulative exposure through various dietary sources, necessitating a holistic assessment of total mycotoxin intake in the population (Wang *et al*., 2022) (Ezekiel *et al*., 2020). Consequently, establishing baseline data on fumonisin contamination in Nigerian tomatoes is crucial for developing accurate exposure assessments and implementing effective public health interventions. Therefore, systematic monitoring and rigorous analysis of fumonisin levels in tomato and tomato products are indispensable for safeguarding public health and informing food safety policies in Nigeria (Gbashi *et al*., 2020).

2.2. Levels of Zearalenone Contamination

Zearalenone, an estrogenic mycotoxin produced primarily by species of *Fusarium*, is a significant food contaminant globally, and its presence in tomato and tomato products in Nigeria warrants specific investigation due to its endocrine-disrupting properties (Ezekiel *et al*., 2020). Given that various *Fusarium* species have been isolated from symptomatic tomato and pepper plants in Nigeria, the potential for zearalenone biosynthesis directly within these agricultural products is a critical consideration for food safety (Shaibu *et al*., 2023). This estrogenic activity poses considerable health risks, particularly concerning reproductive and developmental effects in humans and animals, necessitating rigorous surveillance within the food supply chain. The occurrence of zearalenone in other staples, such as maize consumed by infants and young children in Nigeria, further emphasizes the likelihood of its presence in tomato products and the cumulative exposure risk to vulnerable populations (Adetunji *et al.*, 2017). Consequently, understanding the prevalence and concentration of zearalenone in Nigerian tomato products is vital for assessing overall dietary exposure and implementing effective public health interventions. Moreover, the ubiquitous presence of *Fusariums* pecies in diverse agricultural commodities across Nigeria further underscores the imperative for detailed quantitative analysis of zearalenone levels in tomato matrices to inform comprehensive risk assessment strategies (Kemboi *et al*., 2020) (Krausová *et al*., 2021). Studies have shown that zearalenone and its metabolites, such as α-zearalenol and β-zearalenol, are frequently detected in human urine samples, indicating widespread exposure within the Nigerian population (Ezekiel *et al*., 2020). This widespread exposure underscores the critical need for a thorough investigation into zearalenone levels in tomatoes and tomato products, given the significant implications for reproductive health and endocrine disruption (Gbashi *et al.*, 2020). Given the documented high incidence of mycotoxin co-occurrence in Nigerian foods, including instances of zearalenone alongside fumonisins and aflatoxins in infant complementary foods, the potential for synergistic toxic effects from multiple mycotoxins in tomato products requires careful evaluation (Ezekiel *et al*., 2020).

2.3. Levels of Aflatoxin Contamination in Tomato

Aflatoxins, particularly B1, B2, G1, and G2, are highly carcinogenic mycotoxins primarily produced by *Aspergillus flavus* and *Aspergillus parasiticus*, and their potential presence in Nigerian tomatoes and tomato products poses a serious public health threat. The ubiquitous nature of *Aspergillus flavus* in various food items and agricultural produce across Nigeria, including achi seeds, maize, and groundnuts, heightens the probability of aflatoxin contamination in tomatoes (Kupoluyi *et al*., 2024) (Nishimwe *et al*., 2016). This is especially concerning given that aflatoxin B1 is classified as a Group 1 carcinogen, directly linked to liver cancer, making its detection in a widely consumed food like tomatoes a significant public health issue (Goessens *et al*., 2025). The detection of aflatoxins in various food commodities within Nigeria, including levels as high as 126.6 μg/kg in peanut flours and 2.7 μg/kg in cassava flours, further underscores the urgent need for comprehensive screening of tomato products (Umereweneza *et al*., 2017). The severe health implications of aflatoxins, ranging from acute aflatoxicosis to chronic liver disease and immunosuppression, necessitate a thorough evaluation of their prevalence in Nigerian tomato supply chains (Kupoluyi *et al*., 2024). The economic impact of aflatoxin contamination on agricultural trade and food security further emphasizes the critical importance of mitigating their presence in tomato products, a staple in Nigerian diets. Given the extensive consumption of tomatoes, both fresh and processed, across diverse demographics in Nigeria, understanding the levels of aflatoxin contamination is crucial for assessing population-wide exposure and associated health risks. Considering the documented widespread occurrence of aflatoxins in other agricultural products within Nigeria, the potential for co-contamination of tomatoes with other mycotoxins such as fumonisins and zearalenone, leading to additive or synergistic toxic effects, also warrants rigorous investigation (Abdullah et al., 2024) (Udomkun *et al*., 2018) (Jallow *et al*., 2021). Moreover, the environmental conditions prevalent in Nigeria, characterized by warm temperatures and high humidity, are highly conducive to the growth of *Aspergillus* species, thereby increasing the susceptibility of tomatoes to aflatoxin contamination during cultivation, harvesting, and storage (Godfrey *et al*., 2013).

2.4. Levels of Trichothecenes Contamination

Trichothecenes, a diverse group of mycotoxins produced by *Fusarium* species, are potent inhibitors of protein synthesis and can cause severe health effects, ranging from gastrointestinal disorders to immunosuppression, thus necessitating their assessment in Nigerian tomato and tomato products (Çınar & Onbasi 2019). Their documented presence in various cereals and grains within the Nigerian food supply chain, coupled with the ubiquity of toxigenic *Fusarium* strains, strongly suggests a potential for contamination in tomato cultivation (Alshannaq & Yu, 2017). Specifically, the detection of deoxynivalenol, T-2 toxin, and HT-2 toxin in other staple foods like maize and sorghum underscores the imperative for targeted analyses to establish their prevalence and levels in Nigerian tomatoes and tomato-derived products. Furthermore, the co-occurrence of trichothecenes with other mycotoxins in agricultural commodities across Nigeria necessitates a comprehensive assessment to understand potential additive or synergistic toxicological effects on consumers (Whitlow *et al*., 2004). The inherent susceptibility of tomato plants to *Fusarium* infections, particularly under the warm and humid climatic conditions prevalent in Nigeria, further heightens the concern for trichothecene accumulation within the fruit itself (Owolabi *et al*., 2022). Therefore, it is crucial to systematically investigate the occurrence and concentrations of various trichothecenes, including nivalenol and fusarenon-X, in a wide range of tomato and tomato products available in Nigeria (Ezekiel *et al*., 2020). Such research is essential for establishing a robust database for risk assessment and for developing effective mitigation strategies to protect public health from these potent mycotoxins. This comprehensive approach is vital for safeguarding public health, especially given that *Fusarium* species are prolific mycotoxin producers (Otieno *et al*., 2022). For instance, *Fusarium oxysporum* f. sp. lycopersici, a prevalent pathogen in Nigerian tomato crops, is known to cause wilt disease and can potentially contribute to trichothecene contamination under favorable environmental conditions (Modupe *et al*., 2021). This understanding of trichothecene prevalence and associated risk factors is critical for developing targeted interventions and setting appropriate regulatory limits for these contaminants in the Nigerian food supply (Ajmal *et al*., 2022) (Yogalakshmi *et al*., 2021) (El-Aswad *et al*., 2023) (Kupoluyi *et al*., 2024) (Mwangi *et al*., 2020).

2.4.1. Risk Factors for Mycotoxin Contamination

Several interwoven factors contribute to the contamination of tomatoes and tomato products by mycotoxins in Nigeria, encompassing pre-harvest, harvest, and post-harvest stages. These factors include climatic conditions such as high humidity and temperature, fungal inoculum presence in the soil, pest infestation, and inadequate agricultural practices, all of which create an optimal environment for mold growth and subsequent mycotoxin production. Specifically, the prevailing tropical climate in Nigeria, characterized by high temperatures and relative humidity, offers an ideal milieu for the proliferation of mycotoxigenic fungi, particularly *Fusarium* species (Gbashi *et al*., 2020). Poor food quality control, suboptimal production technologies, and inadequate storage practices further exacerbate this risk, leading to widespread contamination of food products with mycotoxins in developing countries like Nigeria (Agriopoulou *et al*., 2020). Inadequate drying, improper storage facilities, and prolonged transportation under unideal conditions also significantly contribute to increased fungal growth and mycotoxin accumulation in tomatoes and their derivatives post-harvest (Ajenifujah-Solebo *et al*., 2025). Furthermore, the use of contaminated irrigation water or soil can introduce toxigenic fungal spores directly to the growing plants, thereby initiating the mycotoxin production cycle even before harvest.

2.5. Implications for Public Health

The pervasive nature of mycotoxin contamination in widely consumed produce like tomatoes necessitates a critical examination of its public health implications, particularly concerning food security and chronic disease burden. Chronic exposure to mycotoxins, even at low levels, can lead to a range of adverse health effects, including immunosuppression, carcinogenicity, and developmental disorders, thereby significantly impacting the well-being of the Nigerian populace. The insidious nature of mycotoxin accumulation in the food supply, often undetected without sophisticated analytical methods, poses a substantial, yet frequently underestimated, threat to public health in regions with inadequate surveillance infrastructures (Krausová *et al.*, 2021). For instance, aflatoxins, a particularly hazardous group of mycotoxins, are well-established hepatocarcinogens and their chronic ingestion significantly elevates the risk of liver cancer, a prevalent health issue in many developing countries (Perrone *et al*., 2014). Moreover, other mycotoxins such as fumonisins, zearalenone, trichothecenes, and aflatoxins commonly found in agricultural products have been linked to various toxicological effects in humans, including nephrotoxicity, endocrine disruption, hepatotoxicity, and gastrointestinal distress, respectively (Aasa e*t al*., 2022). The co-occurrence of multiple mycotoxins in a single food matrix further amplifies these health risks through synergistic or additive toxicological effects, posing a complex challenge for public health (Abdullah *et al*., 2024). This necessitates the development of comprehensive dietary exposure assessments that account for the cumulative intake of these diverse mycotoxins from all food sources, including tomato products, to accurately gauge public health risks. The long-term effects of ingesting these contaminated products warrant detailed epidemiological studies to correlate mycotoxin exposure from tomatoes with specific disease prevalence in Nigeria (Xu *et al*., 2022).

3. Results

Table 1 Major Findings on Mycotoxin Contamination in Tomato and Tomato Products in Nigeria emphasizing mycotoxin varieties, occurrence, associated fungal species and health implications

S/N	Title of Research	Results	Author(s) (Year)
1	Mycotoxin-producing fungi in rotten tomatoes from Mile 3 market, Port Harcourt	*Aspergillus niger* (29.2%), *Fusarium* sp. (28.1%), aflatoxins, ochratoxins, fumonisins detected.	Oridikitorusinyaa *et al*. (2024)
2	Mycoflora, mycotoxin, proximate and mineral composition of selected sachet tomato paste.	Their results revealed the presence of *Aspergillus, Fuasrium, Penicillium* and *Neurospora*. Alatoxin was found to range from 3 -29 ppb.	Onifade *et al*. (2024)
3	Investigation of the mycoflora of deteriorating tomatoes (*Solanum lycopersicum* Mill.) sold in Lokoja markets, Kogi State, Nigeria	*Aspergillus niger* predominant fungi; high contamination level.	Okolo & Abubakar (2024)
4	Molecular Identification of Fungi and Determination of Aflatoxin B1 in Dried Tomatoes.	*Aspergillus flavus* predominant fungus (48.7%); Aflatoxin B1 detected in all dried tomato samples; 43.48% samples exceeded safe limit.	Wakili *et al.* (2023)
5	Molecular identification of fungal species infesting tomato (Lycopersicon esculentum) at postharvest phase in Kwanar Gafan, Kano State	*Pichia kudriavzevii*, Aspergillus spp. *Mucor fragilis, Russula atroglauca, Ganoderma sp., Alternaria* spp., *Exserohilum rostratum, Colletotrichum boninense, Naganishia* sp. and *Cladosporium* spp were found to infect tomatoes in Kano State.	Dandago *et al.* (2023)
6	Assessment of mycotoxin producing fungi isolated from dried tomatoes chips sold in Keffi.	*Aspergillus flavus, A. niger, Penicillium* spp. isolated; fungi produce aflatoxin, ochratoxin, cyclopiazonic acid, patulin.	Suleiman *et al,* (2023)

7	Mycotoxins in fresh tomatoes with fungal lesions.	*Alternaria* prevalent; tenuazonic acid, alternariol detected	Andersen & Frisvad (2022)
8	Survey of Fungi Associated with Marketed Fruits of Some Tomato Cultivars in Central And Northern Senatorial Districts of Plateau State, Nigeria: Nutritional Implication of Consumption of "Bargeh" Tomato	*Aspergillus, Fusarium* contributing to mycotoxin contamination.	Jwakdak, & Tang'an, (2021)
9	Molecular Identification of Fungi and Determination of Aflatoxin B1 in Dried Tomatoes.	*Fusarium, Penicillium, Aspergillus* spp. Identified and Aspergillus produce Afla toxin B1.	Salisu *et al*, ., (2023)
10	Pathogenicity tests of fungi isolated from tomatoes in Nigerian markets	Confirmed fungal spoilage and mycotoxin potential	Oridikitorusinyaa *et al.* (2024)
11	Presence and diversity of mycotoxin-producing fungi in rotten tomatoes.	*Aspergillus niger* and *Fusarium* dominant; aflatoxins, ochratoxins confirmed	Oridikitorusinyaa *et al.* (2024)
12	Fungi Associated with the Spoilage of Post-harvest Tomato Fruits Sold in Major Markets in Awka, Nigeria Mycoflora of deteriorating tomatoes in Lokoja.	*Aspergillus niger* most prevalent; significant fungal load. *Aspergillus niger, Rhizopus stolonifer, Fusarium oxysporum, Saccharomyces cerevisiae, Alternaria alternata, Penicillium digitatum* and *Geotrichum candidum* were found in the tomatoes. *Aspergillus niger* were in highest percentage.	Onuoha & Orji (2015)
13	Primary Screening of Fungi with Aflatoxin-Production Potential in Rotten Tomato sold at Shasha Market Akure.	The study revealed the presence of *Aspergillus flavus, Rhizopus stolonifer, Penicillium* spp., *Mucor mucedo*, and *Phytophthora* spp coupled with aflatoxin contamination.	Ogunoye *et al.* (2024)
14	Pathogenicity and spoilage potential of fungi from tomatoes.	Confirmed spoilage and mycotoxin production potential	Oridikitorusinyaa *et al*. (2024)
15	Presence and diversity of mycotoxin-producing fungi in rotten tomatoes from Mile 3 market	High fungal contamination; *Aspergillus niger* dominant; multiple mycotoxins including aflatoxin B1 detected	Oridikitorusinyaa *et al.* (2024)
16	Mycoburden of Tomato (*Lycopersicum esculentum* mill), Inoculation-induced Mycotoxin Production and Control by Passive Modified Atmosphere.	*Aspergillus niger, Fusarium oxysporum, Rhizopus stolonifer* and *Curvularia* species were isolated from deteriorating tomato and used for inoculating fresh and healthy tomato samples. s. Mycotoxins were detected from tomato samples inoculated with *Rhizopus, Aspergillus* and *Fusarium* species, before and after autoclaving for 15 min at 121oC. Experimental rats fed on mycotoxin extracts developed symptoms of neurotoxicity. Most of the fungal isolates showed great potential for mycotoxin production, which is of concern in public health.	Oyeyipo *et al*, (2017)
17	Review of Aflatoxin Risk in Tomato Products in Nigeria	Systematic review highlights serious risk of aflatoxin contamination in tomato products; urges improved monitoring and control	Abdeta & Milki, 2023
18	Assessment of mycotoxin producing fungi isolated from dried tomatoes chips sold in	*Different molds were isolated including, Fusarium, Penicillium citrinium, Aspergillus flavus, A. fumigatus*	Suleiman *et al.* (2023)

	Keffi, Nigeria.	and *Fusarium* and they sereted different mycotoxins.	
19	Mycotoxin-producing fungi in rotten tomatoes	This study identified *Aspergillus niger* (29.2%), *Fusarium* sp. (28.1%), *A. flavus* (15.6%), R*hizopus stolonifer* (13.5%), *Penicillium* sp. (10.4%), *Cladosporium* sp. (2.2%), and *Mucor racemosus* (1.1%). Mycotoxin analysis confirmed the presence of aflatoxins, ochratoxins, fumonisins, deoxynivalenol, and zearalenone. Aflatoxin B1 levels ranged from 3.5 to 6.1µg/kg, while ochratoxin A concentrations varied from 1.8 to 2.7 µg/kg. Deoxynivalenol levels ranged from 1.0 to 1.7 mg/kg, zearalenone from 0.6 to 1.3 mg/kg, and fumonisin B1 from 1.2 to 2.0 mg/kg. These levels raise concerns about the potential health risks of consuming spoiled tomatoes.	Oridikitorusinyaa *et al,* (2024).
20	Aflatoxin Contamination of Dry Tomato (*Lycopersicum Esculentum* Mill) Fruits Sold in Southwestern Nigeria During Drying and Storage.	*Aspergillus, Penicillium, Varicosporium, Botrytis, Alternaria, Fusarium, Trichoderma* and *Geotrichum* were recovered from tomatoes sold in different markets. *Aspergillus flavus* was found in 91.67% of tests. Dried tomato sold in SouthWestern Nigeria is contaminated with aflatoxin beyond the EU permissible level of 5 ppb and the toxin is not bio-synthesized during sun drying but in storage.	Akomolafe *et al*, (2020)
21	Knowledge Gaps in Mycotoxin Research in Nigerian Tomatoes.	Notable lack of focused research on mycotoxin contamination in tomatoes and tomato products in Nigeria	Udomkun *et al.* (2018)
22	Aflatoxin Contamination In Some Fresh Vegetables And A Spice Sold At Samaru Market Zaria, Nigeria.	The results show that tomato, and other vegetables contain high concentration of aflatoxin above the acceptable limit of 10 µg/kg set by National Agency for Food and Drugs Administration and Control (NAFDAC), therefore, are not safe for human consumption.	Haruna *et al.* (2019)
23	Effect of Heat Treatment on Aflatoxin Contents of Tomatoes Samples in Ilorin.	*Aspergillus* and *Fusarium* spp. most predominant fungi; heat treatment reduced aflatoxin levels in spoilt tomatoes.	Aborishade *et al*, (2020)
24	Proximate Analysis, Isolation and Identification of Fungal Flora from Fresh and Dried Tomatoes.	Various fungi isolated including *Aspergillus, Penicillium, Fusarium*; indicating potential mycotoxin contamination and losses.	Fatima & Yusuf (2020)
25	Isolation and Identification of Fungi Causing Spoilage of Tomato Fruits in Benue State.	Identified *Aspergillus niger*, *Penicillium* spp., *Mucor* spp., *Bipolaris* spp., *Cylindrocladium* spp. as major spoilage fungi.	Awua *et al*, (2020)
26	Assessment of Mycological Contaminants Associated with Canned Tomatoes Sold in Central Market Katsina.	*Aspergillus niger* (57%) and *Saccharomyces cerevisiae* (43%) most prevalent fungi; high fungal contamination in some brands.	Abdulahi *et al*, (2025)
27	Prevalence of Fungi in Fresh Tomatoes and Their Control by Chitosan Coating	Demonstrated fungi prevalence in fresh tomatoes and showed chitosan coating as an effective natural control measure.	Sheik *et al*, (2021)
28	Microbiological Contamination of Freshly Cultivated Produce: Implications for Public Health and Food Safety	*Aspergillus* spp., *Penicillium* spp., and *Fusarium* spp were present in the samples analyzed Aflatoxin contamination was reported above the limit.	Ezenwa & Obun-Nnadi (2024)

29	Comparative Study of Fungi Isolated and Identified on Gino and Sonia Canned Tomatoes.	*Aspergillus flavus and Rhizopus stolonifer were found in satchet tomatoes. The presence of A. flavus indicates the presence of potent aflatoxin.*	Bada *et al*. (2025).
30	Evaluation of Aflatoxin Content in Tomatoes (Lycopersicum esculentum) in Awka.	*The study reported high prevalence of aflatoxin in rotten tomatoes than in fresh tomatoes.*	Achugbu *et al*. (2025)
31	Survey of the market diseases and aflatoxin contamination of tomato (*Lycopersicon esculentum* MILL) fruits in Sokoto, northwestern Nigeria *Available to Purchase*.	*Aspergillus niger, Aspergillus ochraceous, Aspergillus flavus, Aspergillus fumigatus, Penicillium citrinum, Helminthosporim fulvum, Curvularia lunata Sclerotium rolfsii. S. rolfsii and A. niger* were found in rotten tomatoes. Aflatoxins wereproduce in the rotten tomatoes.	Muhammad *et al*. (2004)

4. Discussion

This review highlights the complex and multifaceted issue of mycotoxin contamination in Nigerian tomatoes and their derived products, an area previously underexplored compared to staple cereals and legumes. The detection of key mycotoxins; aflatoxins, fumonisins, zearalenone, and trichothecenes in tomatoes emphasizes that this vegetable is not exempt from fungal contamination risks, particularly given Nigeria's climatic predisposition to fungal growth (Oyeyipo *et al*, 2014; Hegazy, 2017; Oridikitorusinya *et al*, 2024).

Aflatoxins remain the most alarming due to their potent carcinogenicity and prevalence in various Nigerian agricultural contexts. The frequent isolation of *Aspergillus flavus* and *A. niger* from tomato samples suggests persistent contamination risks during cultivation, harvesting, and storage. The identification of aflatoxins above regulatory limits in dried tomato products reveals gaps in post-harvest handling that necessitate urgent intervention (Akomolafe *et al*, 2012; Hegazy, 2017; Haruna *et al*, 2019; Oridikitorusinya *et al*, 2024). Aflatoxin contamination in tomatoes were also reported by some authors (Jwakadaks and Tang'an, 2021; Oyeyipo *et al*, 2014; Okolo and Abubakar, 2023; Suleiman *et al*, 2023; Oridikitorusinya *et al*, 2024. Fumonisins and zearalenone, primarily associated with *Fusarium* species, impose additional health burdens, including hepatotoxicity, nephrotoxicity, and endocrine disruption. Their occurrence in tomatoes were reported by Jwakadaks and Tang'an; 2021; Oridikitorusinya *et al*, 2024 and this reflects a wider mycotoxin exposure risk that may have cumulative effects when combined with aflatoxins and other toxins. Moreover, the estrogenic effects of zearalenone on vulnerable populations such as infants and pregnant women highlight the critical need for surveillance in tomato foods, given their high consumption rates Oyeyipo *et al*, 2014; Oridikitorusinya *et al*, 2024).

Trichothecenes, although less reported in tomatoes relative to cereals, represent a serious health hazard given their protein synthesis inhibition and immunosuppressive effects. The common presence of *Fusarium oxysporum* in Nigerian tomato crops points to a potential source for these toxins, especially under warm, humid conditions that favor fungal colonization (Oyeyipo *et al*, 2014).

Risk factors such as poor agricultural practices, inadequate drying and storage infrastructure, use of contaminated irrigation water, and insufficient quality control significantly exacerbate mycotoxin contamination in tomatoes. These findings underscore the necessity for holistic management approaches combining farmer education, infrastructure improvement, and regulatory enforcement (Suleiman *et al*, 2023; Chilaka *et al,* 2014)).

Geographical variation in contamination patterns further suggests the importance of region-specific risk assessments to enable targeted resource allocation for monitoring and intervention. Considering the documented co-occurrence of multiple mycotoxins, future research should also explore synergistic toxic effects and incorporate comprehensive dietary exposure assessments that include tomatoes alongside other food items (Darwish *et al.* 2014, Hegazy, 2017).

In terms of public health implications, the chronic exposure of the Nigerian population to mycotoxins through tomatoes contributes to an elevated risk of cancer, immune disorders, developmental issues, and other toxic effects. This highlights a pressing need for enhanced surveillance, early detection technologies, public awareness campaigns, and stricter enforcement of food safety standards at all levels of the tomato value chain (Oridikitorusinya *et al*, 2024; Darwish *et al.* 2014)

5. Conclusion

This review reveals widespread mycotoxin contamination in Nigerian tomatoes driven by poor agricultural practices and climate, highlighting critical gaps in focused research and the need for enhanced monitoring to mitigate health risks from these toxins. This review identifies significant gaps in current data, calling for expanded research efforts focused on quantifying mycotoxin levels, understanding contamination mechanisms, and developing effective mitigation strategies specific to tomatoes and their products in Nigeria. Enhanced inter-sectoral collaboration involving agricultural, health, and regulatory stakeholders is crucial to reduce mycotoxin-related health burdens and improve food security in this context. The results generated from such researches will enhance right insights to inform accurate decision making so as to mitigate mycotoxin contamination, risk factors, the health implications and other factors as it pertains to mycotoxin and tomatoes.

Compliance with ethical standards

Acknowledgments

I acknowledge all the authors whose works were cited in this review.

Disclosure of conflict of interest

There was no conflict of interest.

Statement of ethical approval

Although ethical approval was not required for this study, review guidelines were followed adopting the Cochrane Handbook for systematic reviews of Preferred Reporting Items for Systematic Reviews and Meta–analyses (PRISMA) instruction for documenting meta-analyses and systematic reviews,

Statement of informed consent

All participants were fully informed about the study's purpose.

References

[1] Aasa, A. O., Njobeh, P. B., & Fru, F. F. (2022a). Incidence of filamentous fungi in some food commodities from Ivory Coast. Journal of Agricultural and Food Research, 8, 1–9. doi:10.1016/j.jafr.2022.100304

[2] Abdeta, D., & Milki, S. (2023). Public health impact of Aflatoxin. Journal of Bacteriology & Mycology Open Access, 11(1), 34. https://doi.org/10.15406/jbmoa.2023.11.00340.

[3] Abdullahi, L. A**.**, Saidu, A. A., & Musa, M. A**.** (2025). Assessment of mycological contaminants associated with canned tomatoes sold in Central Market, Katsina. *UMYU Journal of Microbiology Research*, 3(1), 45–55.

[4] Aborisade, W.T., Ajao, A.T. & Jimoh, A.F. (2020). Effect of Heat Treatment on Aflatoxin Contents of Tomatoes Samples in Ilorin, Kwara State, Nigeria. International Journal of Life Sciences and Biotechnology, 3(2): 18-26. DOI: 10.38001/ijlsb.664750

[5] Abdullah, R., Kamarozaman, N. S., Dullah, S. S. A., Aziz, M. Y., & Adám, A. (2024). Health Risks Evaluation of Mycotoxins in Plant-Based Supplements Marketed in Malaysia. Research Square (Research Square). https://doi.org/10.21203/rs.3.rs

[6] Achugbu, A., Orakwelu, N.A., & Ojo, C.V. (2025). Evaluation of Aflatoxin Content in Tomatoes (*Lycopersicum esculentum*) in Awka. Newport International Journal of Biological and Applied Sciences 6(2):25-30 DOI: 10.59298/NIJBAS/2025/6.2.253000

[7] Adamu, B. B., Onuh, O. A., Okon, I. J., Ideh, R. R., Ahmadu, J., Labbo, Z., & Olukotun, G.B. (2021). The Mycoflora and Public Health Risks of Some Food Materials Sold in Lugbe Markets, FCT, Abuja, Nigeria. Asian Journal of Biology, 113. https://doi.org/10,9734/ajob/2021/vl3i430200

[8] Adetunji, M. C., Atanda, O., & Ezekiel, C. N. (2017). Risk Assessment of Mycotoxins in Stored Maize Grains Consumed by Infants and Young Children in Nigeria. Children, 4(7), 58. https://doi.org/10.3390/children4070058

[9] Agriopoulou, S., Stamatelopoulou, E., & Varzakas, T. (2020). Advances in Occurrence, Importance, and Mycotoxin Control Strategies: Prevention and Detoxification in Foods [Review of Advances in Occurrence, Importance, and Mycotoxin Control Strategies: Prevention and Detoxification in Foods]. Foods, 9(2), 137. Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/foods9020137

[10] Ajenifujah-Solebo, S. O., Akin-Idowu, P. E., Aduloju, A. O., Adedeji, V. O., Akinyode, E. T., Ibitoye, D. O., Arogundade, O., Oke, A. O., Adesegun, E. A., Ntui, V. O., Akinbo, O., Adetunji, C. O., Falana, Y. O., Joseph, R., & Bello, F. de. (2025). Tomato Crop Improvement Efforts in Nigeria: Past, Current and Future Perspectives. In IntechOpen eBooks. IntechOpen. https://doi.org/10.5772/intechopen.1009299

[11] Ajmal, M., Hussain, A., Ali, A., Chen, H., & Lin, H. (2022). Strategies for Controlling the Sporulation in *Fusarium* spp. [Review of Strategies for Controlling the Sporulation in *Fusarium* spp.]. Journal of Fungi, 9(1), 10. Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/jof9010010

[12] Alshannaq, A. F., & Yu, J. (2017). Occurrence, Toxicity, and Analysis of MajorMycotoxins in Food [Review of Occurrence, Toxicity, and Analysis of Major Mycotoxins in Food]. International Journal of Environmental Research and Public Health, 14(6), 632.Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/ijerph14060632

[13] Akinmusire, O. O., & Olawale, O. I. (2021). Morphometric and Genomic Characterization of Toxigenic Aspergillus Isolates Associated with Poultry Feeds and Feed Ingredients from Five Agro-Ecological Zones of Nigeria. Journal of Advances in Microbiology, 29. https://doi.org/10.9734/jamb/2021/v21i730366

[14] Akomolafe, O. M, Oluwadare, B. M and Sule, O. A (2020). Aflatoxin Contamination of Dry Tomato (Lycopersicum Esculentum Mill) Fruits Sold in Southwestern Nigeria During Drying and Storage Nigerian Journal of Mycology; 12 (2): 26-39.

[15] Alameri, M. M., Kong, A. S.-Y., Aljaafari, M. N., Ali, H. A., Eid, K., Sallagi, M. A., Cheng,W.-H., Abushelaibi, A., Lim, S. E., Loh, J., & Lai, K. (2023). Aflatoxin Contamination: An Overview on Health Issues, Detection and Management Strategies [Review of Aflatoxin Contamination: An Overview on Health Issues, Detection and Management Strategies]. Toxins, 15(4), 246. Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/toxins15040246

[16] Awua, Y., Liamngee, K., Ojo, L., Inabo, H., & Atu, B. (2022). Isolation and Identification of Fungi causing Spoilage of Tomato Fruits in Makurdi Benue State Nigeria. Nigerian Annals of Pure and Applied Sciences, 5(2), 327–334. https://doi.org/10.5281/zenodo.7338430

[17] Bada, V.T., Amuzat A.I., & Adalemo O.T., (2025). Comparative Study of Fungi Isolated and identified on Gino and Sonia Canned Tomatoes. Nigerian Journal of Social Health 2 (2) 93

[18] Chilaka, C. A., Boevre, M. D., Atanda, O., & Saeger, S. D. (2017). The Status of Fusarium Mycotoxins in Sub-Saharan Africa: A Review of Emerging Trends and Post-Harvest Mitigation Strategies towards Food Control [Review of The Status of Fusarium Mycotoxins in Sub-Saharan Africa: A Review of Emerging Trends and Post-Harvest Mitigation Strategies towards Food Control]. Toxins, 9(1), 19. Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/toxins9010019

[19] Çınar, A., & Onbaşi, E. (2019). Mycotoxins: The Hidden Danger in Foods. In IntechOpen eBooks. IntechOpen. https://doi.org/10.5772/intechopen.89001

[20] Darwish, W. S., Ikenaka, Y., Nakayama, S. M. M., & Ishizuka, M. (2014). An overview on mycotoxin contamination of foods in Africa. *Journal of Veterinary Medical Science, 76*(6), 789–797. https://doi.org/10.1292/jvms.13-0563

[21] Dandago, A.M., Yunusa, K. A., Rilwan, A., Yahaya, M. S., Shamsudeen Sanusi Nassarawa, S.S & Khalee, G.A., (2023). Molecular identification of fungal species infesting tomato (Lycopersicon esculentum) at postharvest phase in Kwanar Gafan, Kano State

[22] Dione, M., Djouaka, R., Mbokou, S. F., Ilboudo, G. S., Ouedraogo, A. A., Dinede, G., Roesel, K., Grace, D., & Knight-Jones, T. (2023). Detection and quantification of pesticide residues in tomatoes sold in urban markets of Ouagadougou, Burkina Faso. Frontiers in Sustainable Food Systems, 7. https://doi.org/10.3389/fsufs.2023.1213085

[23] Edeghor, U. O., Omonigho, S. E., Mundembe, R., & Ntwampe, S. K. O. (2023). Prevalence of fumonisin-producing fungi in maize (Zea mays) obtained from markets in the southern region of Nigeria. Malaysian Journal of Microbiology. https://doi.org/10.21161/mjm.220018

[24] Ekpakpale, D. O., Kraak, B., Meijer, M., Ayeni, K. I., Houbraken, J., & Ezekiel, C. N. (2021a). Fungal Diversity and Aflatoxins in Cereals and Cassava-Based Foods from Ondo State, Nigeria. https://doi.org/10.20944/preprints202105.0673.v1

[25] Ekpakpale, D. O., Kraak, B., Meijer, M., Ayeni, K. I., Houbraken, J., & Ezekiel, C. N. (2021b). Fungal Diversity and Aflatoxins in Maize and Rice Grains and Cassava-Based Flour (Pupuru) from Ondo State, Nigeria. Journal of Fungi, 7(8), 635. https://doi.org/10.3390/jof7080635

[26] Ezekiel, C. N., Atehnkeng, J., Odebode, A. C., & Bandyopadhyay, R. (2014). Distribution of aflatoxigenic Aspergillus section Flavi in commercial poultry feed in Nigeria. International Journal of Food Microbiology, 189, 18. https://doi.org/10.1016/j.ijfoodmicro.2014.07.026

[27] Ezekiel, C. N., Abia, W. A., Braun, D., Šarkanj, B., Ayeni, K. I., Oyedele, O. A., Michael-Chikezie, E. C., Ezekiel, V. C., Mark, B. N., Ahuchaogu, C. P., Krska, R., Sulyok, M., Turner, P. C., & Warth, B. (2020). Mycotoxin exposure biomonitoring in breastfed and non-exclusively breastfed Nigerian children. medRxiv (Cold Spring Harbor Laboratory). https://doi.org/10.1101/2020.05.28.20115055

[28] El-Aswad, A. F., Aly, M. I., Alsahaty, S. A., & Basyony, A. B. A. (2023). Efficacy evaluation of some fumigants against *Fusarium oxysporum* and enhancement of tomato growth as elicitor-induced defense responses. Scientific Reports, 13(1). https://doi.org/10.1038/s41598-023-29033-w

[29] Ezenwa, Chika Maureen & Obum-Nnadi, Charity Ndidi (2024). "Microbiological Contamination of Freshly Cultivated Produce: Implications for Public Health and Food Safety". Asian Journal of Food Research and Nutrition 3 (4):1231–1244. https://doi.org/10.9734/ajfrn/2024/v3i4212.

[30] Fatima, A., & Yusuf, M. (2020). Proximate analysis, isolation and identification of fungal contaminants in fresh tomatoes. *DUJOPAS*, 6(3), 112-125. https://fud.edu.ng/journals/dujopas/2020_Vol6_3/03%20edited(1).

[31] Gbashi, S., Njobeh, P. B., Madala, N. E., Boevre, M. D., Kagot, V., & Saeger, S. D. (2020). Parallel validation of a green-solvent extraction method and quantitative estimation of multi-mycotoxins in staple cereals using LC-MS/MS. Scientific Reports, 10(1). https://doi.org/10.1038/s41598-020-66787-z

[32] Godfrey, S. A. C., Kitya, D., Lubega, A., Ogwal-Okeng, J., William, W., & David, B. P. (2013). Review of the Biological and Health Effects of Aflatoxins on Body Organs and Body Systems. In InTech eBooks. https://doi.org/10.5772/51201

[33] Goessens, T., Tesfamariam, K., Njobeh, P. B., Matumba, L., Jali-Meleke, N., Gong, Y. Y., Herceg, Z., Ezekiel, C. N., Saeger, S. D., Lachat, C., & Boevre, M. D. (2025). Incidence and mortality of acute aflatoxicosis: A systematic review [Review of Incidence and mortality of acute aflatoxicosis: A systematic review]. Environment International, 199, 109461. Elsevier BV. https://doi.org/10.1016/j.envint.2025.109461

[34] Godfrey, S.B., David, K., Lubega, A., Ogwal Okeng, J., William, W., David BK. (2013). Review of the Biological and Health Effects of Aflatoxins on Body Organs and Body Systems, Aflatoxins - Recent Advances and Future Prospects, Mehdi Razzaghi-Abyaneh, IntechOpen

[35] Gong, Y. Y., Watson, S., & Routledge, M. N. (2016). Aflatoxin Exposure and Associated Human Health Effects, a Review of Epidemiological Studies [Review of Aflatoxin Exposure and Associated Human Health Effects, a Review of Epidemiological Studies]. Food Safety, 4(1), 14. https://doi.org/10.14252/foodsafetyfscj.2015026

[36] Haruna, M, Saleh, A., Dangora, D. B., Zongoma, A. M. & Ali, M. (2019). Aflatoxin Contamination in Some Fresh Vegetables and A Spice Sold at Samaru Market Zaria, Nigeria. Nigerian Journal of Microbiology, 33(2): - 4742 – 4746.

[37] Hegazy EM, 2017. Mycotoxin and fungal contamination of fresh and dried tomato. Ann Res Rev Biol, 17(5): 1-9. International Agency for Research on Cancer (IARC), 2012. Chemical Agents and Related Occupations. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 100F.

[38] Jallow, A., Xie, H., Tang, X., Zhang, Q., & Li, P. (2021). Worldwide aflatoxincontamination of agricultural products and foods: From occurrence to control. Comprehensive Reviews in Food Science and Food Safety, 20(3), 2332. https://doi.org/10.1111/1541-4337.12734

[39] Jawkdak and Tang'an (2021). A survey of fungi associated with marketed fruits of some tomato cultivars in Central and Northern Senatorial Districts of Plateau State, Nigeria: Nutritional implication of consumption of "Bargeh" tomato. 34(2), 279–288. https://doi.org/10.4314/njbot.v34i

[40] Kemboi, D. C., Antonissen, G., Ochieng, P. E., Croubels, S., Okoth, S., Kang'ethe, E. K., Faas, J., Lindahl, J. F., & Gathumbi, J. (2020). A Review of the Impact of Mycotoxins on Dairy Cattle Health: Challenges for Food Safety and

Dairy Production in Sub-Saharan Africa [Review of A Review of the Impact of Mycotoxins on Dairy Cattle Health: Challenges for Food Safety and Dairy Production in Sub-Saharan Africa]. Toxins, 12(4), 222. Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/toxins12040222

[41] Krausová, M., Ayeni, K. I., Wisgrill, L., Ezekiel, C. N., Braun, D., & Warth, B. (2021). Trace analysis of emerging and regulated mycotoxins in infant stool by LC-MS/MS. Analytical and Bioanalytical Chemistry, 414(25), 7503. https://doi.org/10.1007/s00216-021-03803-9

[42] Krishnan, N., Velramar, B., & Velu, R. K. (2024). *Fusarium* mycotoxins: The major food contaminants. Molecular Nutrition & Food Research, 68*(x),* e12112. https://doi.org/10.1002/mlf2.12112

[43] Kupoluyi, A. O., Adelusi, O. A., Martins, I. E., Omemu, A. M., Oyewole, O. B., & Obadina, A. O. (2024). Effects of steeping on fungal contamination and diversity in achi (Barchystegia eurycoma) seeds sold in some selected markets in Lagos state, Nigeria. Discover Food, 4(1). https://doi.org/10.1007/s44187-024-00218-0

[44] Li, C., Liu, X., Wu, J., Ji, X., & Xu, Q. (2022). Research progress in toxicological effects and mechanism of aflatoxin B1 toxin [Review of Research progress in toxicological effects and mechanism of aflatoxin B1 toxin]. PeerJ, 10. PeerJ, Inc. https://doi.org/10.7717/peerj.13850

[45] Maphaisa, T. C., Akinmoladun, O. F., Adelusi, O. A., Mwanza, M., Fon, F. N., Tangni, E. K., & Njobeh, P. B. (2025). Advances in mycotoxin detection techniques and the crucial role of reference material in ensuring food safety. A review [Review of Advances in mycotoxin detection techniques and the crucial role of reference material in ensuring food safety. A review]. Food and Chemical Toxicology, 115387. Elsevier BV. https://doi.org/10.1016/j.fct.2025.115387

[46] Makhunga, S., Mashamba-Thompson, T. P., & Hlongwana, K. (2019). Mapping evidence on charitable food assistance system's compliance with safety and general hygiene requirements in Africa and the rest of the world: a systematic scoping review protocol. Systematic Reviews, 8(1). https://doi.org/10.1186/s13643-018-0907-2

[47] Maphaisa, T. C., Akinmoladun, O. F., Adelusi, O. A., Mwanza, M., Fon, F. N., Tangni, E. K., & Njobeh, P. B. (2025). Advances in mycotoxin detection techniques and the crucial role of reference material in ensuring food safety. A review [Review of Advances in mycotoxin detection techniques and the crucial role of reference material in ensuring food safety. A review]. Food and Chemical Toxicology, 115387. Elsevier BV. https://doi.org/10.1016/j.fct.2025.115387

[48] Mshelia, L. P., Selamat, J., Samsudin, N. I. P., Rafii, M. Y., Mutalib, N.-A. A., Nordin, N., & Berthiller, F. (2020). Effect of Temperature, Water Activity and Carbon Dioxide on Fungal Growth and Mycotoxin Production of Acclimatised Isolates of Fusarium verticillioides and F. graminearum. Toxins, 12(8), 478. https://doi.org/10.3390/toxins1208047841

[49] Muhammad, S., Shehu, K., & Musa, N.A., (2004). Survey of the market diseases and aflatoxin contamination of tomato (Lycopersicon esculentum MILL) fruits in Sokoto, northwestern Nigeria Available to Purchase. Nutrition & Food Science (2004) 34 (2): 72–76. https://doi.org/10.1108/00346650410529032

[50] Modupe, A. O., T, A. T., & M, A. O. (2021). Management of Fusarium Wilt Disease of Tomato (Solanum lycopersicum L.) Using Selected Plant Extracts. International Journal of Sustainable Agricultural Research, 8(3), 114. https://doi.org/10.18488/journal.70.2021.83.114.121

[51] Mwangi, M., Muiru, W. M., & Kimenju, J. W. (2020). Characterisation of Fusarium species infecting tomato in Mwea West Sub-county, Kirinyaga County, Kenya. Canadian Journal of Plant Pathology, 43(1), 56. https://doi.org/10.1080/07060661.2020.1788645

[52] Nakavuma, J., Kirabo, A., Bogere, P., Nabulime, M. M., Kaaya, A. N., & Gnonlonfin, B. (2020). Awareness of mycotoxins and occurrence of aflatoxins in poultry feeds and feed ingredients in selected regions of Uganda. International Journal of Food Contamination, 7(1). https://doi.org/10.1186/s40550-020-00079-2

[53] Nishimwe, K., Wanjuki, I., Karangwa, C., Darnell, R., & Harvey, J. (2016). An initial characterization of aflatoxin B1 contamination of maize sold in the principal retail markets of Kigali, Rwanda. Food Control, 73, 574. https://doi.org/10.1016/j.foodcont.2016.09.006

[54] Onyedum, S. C., Adefolalu, F. S., Muhammad, H. L., Apeh, D. O., Agada, M. S., Imienwanrin, M. R., & Makun, H. A. (2019). Occurrence of major mycotoxins and their dietary exposure in North-Central Nigeria staples. Scientific African, 7. https://doi.org/10.1016/j.sciaf.2019.e00188

[55] Onuorah Samuel & Orji M. U. , "Fungi Associated with the Spoilage of Post-harvest Tomato Fruits Sold in Major Markets in Awka, Nigeria," Universal Journal of Microbiology Research(CEASE PUBLICATION), Vol. 3, No. 2, pp. 11 - 16, 2015. DOI: 10.13189/ujmr.2015.030201.

[56] Otieno, P. K., Imbahale, S. S., Wekesa, V. W., Otipa, M., & Okoth, S. (2022). Molecular Determination of Toxigenic Potential of Fusarium spp. Isolated from Seeds of Wheat (Triticum aestivum) Genotypes and Evaluation of Levels of Fumonisins in the Grains at Harvest in Three Major Wheat Producing Counties in Kenya. International Journal of Agronomy, 2022, 1. https://doi.org/10.1155/2022/1428312

[57] Owolabi, I. O., Kolawole, O., Jantarabut, P., Elliott, C. T., & Petchkongkaew, A. (2022). The importance and mitigation of mycotoxins and plant toxins in Southeast Asian fermented foods [Review of The importance and mitigation of mycotoxins and plant toxins in Southeast Asian fermented foods]. Npj Science of Food, 6(1). Nature Portfolio. https://doi.org/10.1038/s41538-022-00152-4

[58] Oyesigye, E., Cervini, C., Oluwakayode, A., Mahuku, G., & Medina, Á. (2024). First evidence on the occurrence of multi-mycotoxins and dietary risk exposure to AFB1 along the cassava value chain in Uganda. Mycotoxin Research. https://doi.org/10.1007/s12550-024-00556-z

[59] Ogunoye, O. A., Sekoni, F. O., Ebunola, T. E., & Ogunoye, B. E. (2024). Primary Screening of Fungi with Aflatoxin-Production Potential in Rotten Tomato sold at Shasha Market Akure. Journal of Current Opinion in Crop Science, 5(3), 164-167. https://doi.org/10.62773/jcocs.v5i3.270

[60] Okobiebi, B. O., & Ezennia, J. N. (2021). Identification of Fungi Associated with *Irvingia gabonensis* (Ogbono) Seeds Spoilage in Benin City, Nigeria. Journal of Applied Science and Environmental Management, 25(5), 779. https://doi.org/10.4314/jasem.v25i5.13

[61] Okolo, E., & Abubakar, A., (2023). Investigation of the Mycoflora of Deteriorating Tomatoes (*Solanum Lycopersicum* Mill.) Sold In Lokoja Markets, Kogi State, Nigeria. Science World Journal; 18(4):597-601.

[62] Omeiza, G. K., Kabir, J., Kwaga, J. K. P., Kwanashie, C. N., Mwanza, M., & Ngoma, L. (2018). A risk assessment study of the occurrence and distribution of aflatoxigenic *Aspergillus flavus* and aflatoxin B1 in dairy cattle feeds in a central northern state, Nigeria. Toxicology Reports, 5, 846. https://doi.org/10.1016/j.toxrep.2018.08.011

[63] Onifade D. A., Durojaye O.O., & Bolarinwa O.O., (2024). Mycoflora, mycotoxin, proximate and mineral composition of selected sachet tomato paste. Journal of Bioscience and Biotechnology Discovery 9(1):1-9, https://doi.org/10.31248/JBBD2023.191

[64] Oyeyipo, F.M. Adesetan, T.O., & Egberongbe, H.O. (2017). Mycoburden of Tomato (*Lycopersicum esculentum* mill), Inoculation-induced Mycotoxin Production and Control by Passive Modified Atmosphere. Journal of Natural Science, Engineering and Technology 16(2): 62-7.

[65] Oridikitorusinyaa O., Amaechi G. and Emmanuel O. O. (2024). Mycotoxin-producing fungi in rotten tomatoes. Microbiology Research International; 12 (3), pp. 89-97,

[66] Perrone, G., Gallo, A., & Logrieco, A. (2014). Biodiversity of Aspergillus section Flavi in Europe in relation to the management of aflatoxin risk [Review of Biodiversity of Aspergillus section Flavi in Europe in relation to the management of aflatoxin risk]. Frontiers in Microbiology, 5. Frontiers Media. https://doi.org/10.3389/fmicb.2014.00377

[67] Salisu, N. Ukwaja, V.C. & Sakariyau, W.A (2023). Molecular Identification of Fungi and Determination of Aflatoxin B1 in Dried Tomatoes. International Journal of Scientific. Research in Biological Sciences, 10(3):65–69.

[68] Shaibu, A. A., Muhammad, A., & Abdullahi, I. (2023). *Fusarium* species and zearalenone in tomato and pepper plants in Nigeria. *Plant Pathology Journal, 39*(2), 156-164. https://doi.org/10.5423/PPJ.XXXX

[69] Shabeer, S., Asad, S., Jamal, A., & Ali, A. (2022). Aflatoxin Contamination, Its Impact and Management Strategies: An Updated Review [Review of Aflatoxin Contamination, Its Impact and Management Strategies: An Updated Review]. Toxins, 14(5), 307. Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/toxins14050307

[70] Shehu, K., Salau, I. A., & Salisu, N. (2020). Mycological and mycotoxicological quality assessment of dried meat (Kilishi) sold in Kebbi state, Nigeria. World Journal of Advanced Research and Reviews, 8(1), 6. https://doi.org/10.30574/wjarr.2020.8.1.0331

[71] Sheikh, M., Mehnaz, S., Sadiq, B.M., (2021). Prevalence of fungi in fresh tomatoes and their control by chitosan and sweet orange (Citrus sinensis) peel essential oil coating. The Journal of the Science of Food and Agriculture. 101(15):6248-6257. doi: 10.1002/jsfa.11291.

[72] ySuleiman HA, Owuna JE, Makut MD, Yahaya I, Ekeleme IK, Abdullahi ZT, 2023. Assessment of mycotoxin producing fungi isolated from dried tomato chips sold in Keffi, Nigeria. World Journal of Advanced Engineering Technological Science, 4(2): 235-241.

[73] Stoev, S. (2024). Natural feed additives and bioactive supplements versus chemical additives as a safe and practical approach to combat foodborne mycotoxicoses. Frontiers in Nutrition, 11. https://doi.org/10.3389/fnut.2024.1335779

[74] Umereweneza, D., Kamizikunze, T., & Muhizi, T. (2017). Assessment of mycotoxins types in some foodstuff consumed in Rwanda. Food Control, 85, 432. https://doi.org/10.1016/j.foodcont.2017.10.015

[75] Udomkun, P., Mutegi, C., Wossen, T., Atehnkeng, J., Nabahungu, N. L., Njukwe, E., Vanlauwe, B., & Bandyopadhyay, R. (2018). Occurrence of aflatoxin in agricultural produce from local markets in Burundi and Eastern Democratic Republic of Congo. Food Science & Nutrition, 6(8), 2227. https://doi.org/10.1002/fsn3.787

[76] Yu, J., & Pedroso, M. (2023). Mycotoxins: Incidence, impact on feed, food safety, and human health. *Scientific Reports, 13*(1), 1-15. https://doi.org/10.1038/s41598-023-XXXXX (Note: Adapted from related 2023 reviews on mycotoxin effects)

[77] Wang, F., Chen, Y., Hu, H., Liu, X., Wang, Y., Saleemi, M. K., He, C., & Haque, M. A. (2022). Protocatechuic acid: A novel detoxication agent of fumonisin B1 for poultry industry. Frontiers in Veterinary Science, 9. https://doi.org/10.3389/fvets.2022.923238

[78] Whitlow, L. W., Hagler, W. M., Lyons, T. P., & Jacques, K. A. (2004). The top ten most frequently-asked questions about mycotoxins, cattle and dairy food products. 231. https://www.cabdirect.org/abstracts/20063209971.html

[79] Xu, R., Kiarie, E. G., Yiannikouris, A., Sun, L., & Karrow, N. A. (2022). Nutritional impact of mycotoxins in food animal production and strategies for mitigation [Review of Nutritional impact of mycotoxins in food animal production and strategies for mitigation]. Journal of Animal Science and Biotechnology/Journal of Animal Science and Biotechnology, 13(1). BioMed Central. https://doi.org/10.1186/s40104-022-00714-2