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The Dual Burden of Mycotoxin Contamination in Sub-Saharan Africa: Public Health, Economic Consequences, and Implications for Food Security

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Abstract

Mycotoxin contamination is a significant yet frequently under-recognized threat to food safety, public health, agricultural livelihoods, and food security in Sub-Saharan Africa (SSA). This systematic review synthesizes evidence on the occurrence and determinants of mycotoxin contamination in the region and evaluates its interconnected health, economic, and food-security consequences. Literature was systematically searched using combinations of mycotoxin-related terms. Eligible studies were published in English and addressed contamination, human or animal health, economic consequences, food security, or control strategies. Study selection and reporting were guided by PRISMA 2020. The evidence identifies maize, groundnuts, and other staple foods as major sources of exposure. Climatic conditions, inadequate drying, insect damage, poor storage, and limited surveillance contribute to contamination across production and post-harvest stages. Chronic exposure is associated particularly with hepatocellular carcinoma, impaired childhood growth, and immune dysfunction. Economic consequences include crop and quality losses, lower market value, trade restrictions, reduced livestock productivity, and healthcare costs. These effects extend across all four dimensions of food security: availability, access, utilization, and stability. The findings support integrated management combining good agricultural practices, biological control, and improved drying and storage. Future research should prioritize exposure biomarkers, estimation of the economic burden, climate-related risk prediction, and evaluation of cost-effective interventions suited to smallholder farming systems across diverse agroecological settings using locally feasible monitoring systems. Strengthening surveillance and linking prevention across the food chain may improve intervention targeting and reduce exposure. However, the evidence base remains dependent on available studies and warrants context-specific assessment to guide implementation and resource allocation.

Keywords
Mycotoxins;
Aflatoxin;
Food;
Safety;
Security

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INTRODUCTION

Food security and safety remain supreme global challenge, as food products are progressively contaminated by biological and chemical agents, with climate change worsening these risks posing momentous economic and health issues to both humans and animals (Gbashi et al., 2021; Njobeh et al., 2010). Of these contaminants are mycotoxins, which are toxic chemicals naturally produced by molds mainly from the *Aspergillus, Fusarium*, and *Penicillium* families (Awuchi et al., 2022; Xiang et al., 2020). These fungal secondary metabolites cause numerous adverse economic and health effects from severe poisoning to cancer, and can even resist food processing including cooking (Njobeh et al., 2009; Penagos-Tabares et al., 2021).

Mycotoxins frequently contaminate everyday crops like grains, nuts, seeds, spices, and animal feed (Makun et al., 2012; Ramadan et al., 2022; Dabuo et al., 2022). Because many of these toxins can withstand standard heat and food processing methods, they often remain in our food supply long after harvest (Xiang et al., 2020; Awuchi et al., 2022).

Out of hundreds of mycotoxins documented in food and feed in the previous studies, the most concerning ones from a public health standpoint include aflatoxins, ochratoxin A, fumonisins, zearalenone, and deoxynivalenol (Ali et al., 2023; Mafe and Büsselberg, 2024) with aflatoxins which is produced by *A. flavus* and *A. parasiticus* being the most significant. Depending on the level and duration of exposure, they can cause wide range of cases from immediate toxicity to long-term health issues like cancer, immune system damage, reproductive harm, and childhood growth stunting (Ali et al., 2023; Mafe and Büsselberg, 2024).

Several reports revealed that, aflatoxins cause greatest concern due to their widespread presence and extreme toxicity (Makun et al., 2012; Ramadan et al., 2022; Dabuo et al., 2022). Aflatoxin B1 is a known cause of liver cancer, particularly in areas where hepatitis B is previously existing (Benkerroum 2020; Dabuo et al., 2022). In children, long-term exposure is linked to poor growth and weakened immune systems (Belasli et al., 2023). Several previous studies show that contamination in African corn and peanuts is so widespread that a significant portion of the population faces daily exposure to these toxic substances through their diet (Belasli et al., 2023).

The mycotoxins damage, however, goes far beyond health. Contaminated crops lose their market value and fail to meet safety standards for local and international trade, cutting into the income of smallholder farmers and food vendors (Grace 2015). Rejecting or throwing away of unsafe foods, directly worsens food losses in regions already struggling with hunger (Thompson et al., 2023; Dong 2021; Kizis et al., 2021). This creates a double burden by jeopardizing the safety of the food and simultaneously shrinking the overall food supply and weakening the economy in rural areas (Belasli et al., 2023).

Food security rests on four main pillars: availability, access, utilization, and stability (FAO, 2008). Mycotoxins disrupt every single one (Thompson et al., 2023; Dong 2021). They reduce the amount of safe food available, diminish household income needed to buy food, undermine body health through toxin exposure, and make trade and farm incomes unpredictable (Xiang et al., 2020).

Sub-Saharan Africa faces a disproportionately high risk from mycotoxin contamination (Nji et al., 2022). A combination of warm temperatures, high humidity, drought stress, pest damage, late harvests, insufficient crop drying, and poor storage facilities creates the ideal environment for molds to thrive (Nji et al., 2022). Making matters worse, dietary staples across the region rely heavily on highly susceptible crops like corn and peanuts, which are essential to both daily meals and farm livelihoods (Nji et al., 2022). While existing research has looked at mycotoxins and aflatoxins in Africa, only few studies fully connect the health risks, economic costs, and food security

impacts together. With growing challenges like climate change alongside new solutions in biocontrol and crop monitoring, this review was designed to take a comprehensive look at the dual burden of mycotoxins on health and economic sectors in Sub-Saharan Africa, exploring its root causes, overall impacts, and practical management strategies.

METHODOLOGY

Study Design

This systematic review was conducted and reported in accordance with the PRISMA 2020 guidelines. This ensures full transparency across all stages, including data sources, selection criteria, search protocols, screening, data extraction, and synthesis.

Data Sources and Search Strategy

We searched five major academic databases for relevant reports related to food safety and security. These databases include PubMed, Scopus, Web of Science, Google Scholar, and CAB Abstracts. The search strategy combined keywords related to mycotoxins, geography, and impacts across health, economics, and food safety. The core search string was built around toxins ("mycotoxin" OR "aflatoxin" OR "fumonisin" OR "ochratoxin" OR "zearalenone" OR "deoxynivalenol"), region ("Sub-Saharan Africa" OR "Africa" OR "West Africa" OR "East Africa" OR "Central Africa" OR "Southern Africa"), and impacts ("food security" OR "health" OR "disease" OR "cancer" OR "economic" OR "trade" OR "livelihood" OR "contamination" OR "exposure").

Inclusion and Exclusion Criteria

Only studies published in English, focused on mycotoxin contamination or human exposure within one or more Sub-Saharan African countries, examined impacts on human/animal health, agriculture, trade, livelihoods, or general food security, evaluated control, surveillance, or policy strategies applicable to the region, and within the timeframe (2000 – 2025) were included in the study.

Studies conducted outside Sub-Saharan Africa, papers on non-food fungal metabolites, opinion pieces, editorials lacking original evidence, or articles with insufficient data were excluded.

Study Screening

Imported records were uploaded to reference management software to eliminate duplicates. Titles and abstracts were screened against the eligibility criteria, followed by a full-text review of candidate studies. A total of 256 studies were considered eligible for selection (Figure 1).

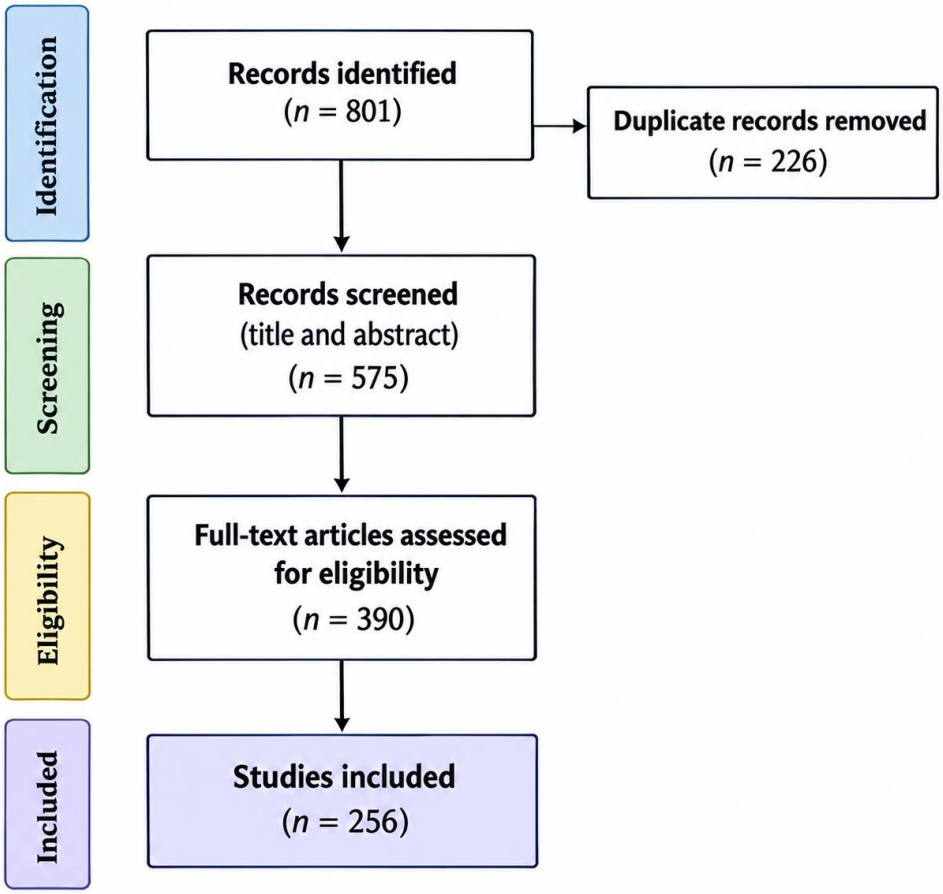


Figure 1: PRISMA Flowchart of the Study

Data Extraction

A standardized form was used to collect relevant data from each included study, including study details (authors, year, country or region, study design), sample specifics (target populations or commodities, toxins evaluated, testing method used), key outcomes (contamination levels, health impacts, economic costs, food security consequences), intervention insights (prevention or control strategies evaluated), and methodological limitations and potential sources of bias.

Data Synthesis

Given the significant variability across study designs, test methods, target commodities, and reported outcomes, quantitative meta-analysis was not feasible. Instead, we performed a qualitative narrative synthesis. Results were grouped into five core themes including contamination and exposure levels, public health impacts, economic consequences, food security implications, and prevention and control strategies.

MYCOTOXIN CONTAMINATION IN SUB-SAHARAN AFRICA

Aflatoxins, fumonisins, ochratoxin A (OTA), zearalenone (ZEN), and deoxynivalenol (DON) have been reported to be the main mycotoxins affecting Sub-Saharan Africa (Makun et al., 2012; Ramadan et al., 2022; Dabuo et al., 2022). Aflatoxins present the greatest challenge in warmer areas, where *Aspergillus* molds easily infect crops like corn and peanuts. Fumonisins are most commonly found in corn, while *Fusarium* produced toxins like ZEN and DON typically contaminate small grains when weather conditions favor fungal growth (Kamle et al., 2019; Kamle et al., 2022).

In the field, crops become vulnerable due to heat, drought stress, insect damage, and physical plant

injuries (Nji et al., 2022; Zheng et al., 2024). Post-harvest factors including high humidity, insufficient drying, poor ventilation, pest activity, and long storage periods cause mold to spread rapidly (Zheng et al., 2024). Even if grain looks dry on average, localized moisture pockets inside storage containers can create ideal micro-environments for fungal growth (Nji et al., 2022; Zheng et al., 2024).

The burden varies expressively across regions. West and East Africa have documented extensive evidence on aflatoxin contamination, whereas data remains relatively scarce for parts of Central and Southern Africa (Meijer et al., 2021). These regional differences stalk from varying climates, staple crop preferences, storage habits, regulatory enforcement, and local research capacity (Meijer et al., 2021).

Corn and peanuts were reported to be at the highest risk because they are highly susceptible to contamination and serve as main food staples and income sources (Temitope et al., 2026). Other vulnerable crops include sorghum, millet, rice, cassava, and livestock feed (Temitope et al., 2026). Evidence across the continent confirms that corn and peanut contamination is widespread, leading to high daily dietary exposure for millions of people (Meijer et al., 2021).

PUBLIC HEALTH BURDEN

Exposure Pathways

Eating contaminated food is the primary way people consume mycotoxins. This includes directly eating infected grains, nuts, and processed foods, or indirectly consuming meat, eggs, and dairy when livestock are fed contaminated grain. While farm workers can also inhale airborne toxins when handling dusty grains, dietary intake remains the primary public health concern (Wu et al., 2022; Ben Miri et al., 2024).

This leads to harmful effects exerted by mycotoxins through miscellaneous biochemical mechanisms that disturb the important cellular processes, leading to a range of acute and chronic health conditions (Assunção and Viegas, 2020). The sternness of health consequences as a result of the exposure to mycotoxins depends on manifold factors, counting exposure duration, toxin type, dosage, nutritional status, age, and possible synergistic effects between mycotoxins co-occurring (McKeon et al., 2024). Numerous mycotoxin induced health conditions that manifest years after first exposure, frequently leading to underestimation of their real health impact and complicating epidemiological associations (Kępińska-Pacelik and Biel, 2021).

Acute Mycotoxicosis

Consuming foods with exceptionally high toxin levels leads to acute poisoning (mycotoxicosis). Symptoms include severe stomach pain, jaundice, liver damage, fluid retention (edema), and, in extreme cases, rapid liver failure and death. Historical outbreaks across Africa demonstrate that severe spikes in exposure can be fatal—especially during periods of food scarcity when communities have little choice but to eat damaged grain (Pickova et al., 2020; Xiang et al., 2020).

Chronic Health Impacts

The most serious long-term risk of chronic aflatoxin exposure is liver cancer (hepatocellular carcinoma). Aflatoxin B1 (AFB1) breaks down in the liver into reactive compounds that damage DNA and cause cancerous mutations (Awuchi et al., 2022; Alameri et al., 2023). This risk multiplies dramatically in individuals with chronic Hepatitis B (HBV) infections, by way of the virus and toxin act synergistically to quicken tumor growth and liver failure (Belasli et al., 2023; Zhang et al., 2023).

Early childhood exposure is linked to growth stunting and impaired development, though this is also shaped by broader factors like nutrition, poverty, and co-occurring infections (Ekwomadu et al., 2022; Li et al., 2025). Other toxins bring distinct dangers, for example OTA target kidneys and acts as a potential carcinogen (Beia et al., 2024). These mechanisms

motivate its connotation with Balkan endemic nephropathy, a broadminded tubulointerstitial kidney disease branded by fibrosis and ultimate renal failure (Szőke et al., 2022). The oncogenic potential of OTA stalks from its DNA-binding properties and inhibition of DNA repair enzymes, with IARC classifying it as a possible human carcinogen (Adaku Chilaka and Mally, 2020). Other studies have revealed additional effects including neurotoxic effects, with OTA crossing the blood-brain barrier and potential cause of neurodegenerative disorders through neuronal apoptosis and microglial activation (Awuchi et al., 2021; Plewa-Tutaj et al., 2024).

Similarly, fumonisins interrupt metabolism of lipid, leading to poor development and long-term health issues. Also, ZEN threatens reproductive health and hormonal balance by mimicking estrogen. While DON inhibits synthesis of protein, activating immune suppression and gastrointestinal distress (Adaku Chilaka and Mally, 2020; Mafe and Büsselberg, 2024).

Vulnerable Populations

Pregnant women, children, rural farming families, malnourished individuals, and communities relying heavily on corn or peanuts are at greater risk (Xiang et al., 2020; Gherbawy et al., 2025). Children suffer more toxic effects relative to their small body weight, while fetal development is threatened by exposure during pregnancy (McKeon et al., 2024). Also, low-income families lack the financial incomes to buy safer market alternatives or invest in modern storage equipment (Xiang et al., 2020; Gherbawy et al., 2025).

ECONOMIC CONSEQUENCES

Mycotoxins inflict heavy economic damage at every link in the agricultural value chain. Mold contamination lowers crop quality and market price. If toxin levels exceed legal limits, entire harvests are rejected. Farmers lose income even when crops appear healthy, as dangerous toxin levels are not always visible (Meijer et al., 2021).

Many Countries face lost agricultural output, increased healthcare costs, livestock illnesses, and lower export revenues. The financial ripple effect harms producers, food processors, traders, and consumers alike (Adaku Chilaka and Mally, 2020).

Previous studies showed that developing countries with humid and warm climates and inadequate storage facilities are particularly in danger of mycotoxin contamination. This affects trade, food security and livestock production (Nji et al., 2022). The economic impact is higher, causing estimated billions of dollars annual losses due to abridged livestock productivity, crop rejections, and increased healthcare costs as a result of mycotoxin-related problems (Inês and Cosme, 2025).

Furthermore, exporters have been reported to face strict safety thresholds in international markets. Banned or rejected shipments mean immediate financial loss (Nji et al., 2022). While trade restrictions on African exports are well-documented, overall research quantifying the broader healthcare costs remains limited (Ben Miri et al., 2024).
Also, smallholders relying on a single staple crop for food and income suffer the most (Meijer et al., 2021). When crops fail safety standards, reduced household income makes it impossible to invest in clean seeds, proper drying gear, or air-tight (hermetic) storage—trapping families in a cycle of poverty and vulnerability (Meijer et al., 2021).

MYCOTOXINS AND FOOD SECURITY

Mycotoxin contamination impacts every dimension of food security. Food Availability which is one of the key food security figure is seriously compromised as contaminated crops are often downgraded, rejected, or thrown away, directly decreasing the total amount of usable food especially critical where corn and peanuts form the foundation of daily diets (FAO, 2008).

Similarly, food access is highly affected when farmers receive lower prices for compromised crops, their household income drops. This shrinks their purchasing power for nutritious foods, farming inputs, and healthcare (FAO, 2008).

Availability alone is not enough if food makes people sick. Toxin exposure causes gut inflammation, immune suppression, and stunted growth, preventing the human body from properly absorbing nutrients. Contamination creates a qualitative crisis, food may be physically present, but it is unsafe to consume. These greatly affect food utilization in sub-Saharan Africa (FAO, 2008).

Furthermore, weather variability, unpredictable droughts, heavy rain, and pest outbreaks cause toxin levels to fluctuate wildly from season to season, making food supplies and farm incomes unstable. These seriously impacts food stability (FAO, 2008). Controlling mycotoxins is therefore far more than a routine food safety task it is central to rural livelihoods, child nutrition, and broad economic development.

PREVENTION AND MITIGATION

Preventing mold growth before harvest is far more effective than trying to clean up toxins after crops are already contaminated. Farmers can reduce risk by selecting crop varieties adapted to their climate, planting on time, managing pest infestations, avoiding crop injury, and harvesting promptly once mature. These are reported to be the most effective pre-harvest controls to mycotoxins (Hassouna et al., 2023; Opoku et al., 2023).

Studies showed that the post-harvest management and biocontrol to mycotoxins are paramount. Studies recommended that crops should be thoroughly dried right after harvest to strip molds of moisture. Also, storing grain in sealed, airtight bags deprives insects and fungi of oxygen, preventing mold spikes (Hassouna et al., 2023; Opoku et al., 2023).

An important African innovation uses non-toxic strains of *Aspergillus flavus* (such as AflaSafe) which when applied in the field, these harmless fungi outcompete and displace toxin-producing strains. This is considered as a good example of biocontrol of mycotoxins (Senghor et al., 2020; Nešić et al., 2021).

EMERGING TECHNOLOGIES AND FUTURE DIRECTIONS

New technologies offer promising ways to track and reduce contamination. Previous studies identified field biosensors and portable testing kits as a good technology that allow extension workers and farmers to test grain safety on site before buying or selling (De Baere et al., 2023; Huang et al., 2025). Another way of detecting mycotoxins is by IoT (Internet of things) monitoring where wireless sensors installed in granaries can track humidity and temperature in real time, alerting farmers before mold takes root (De Baere et al., 2023; Huang et al., 2025).

Furthermore, climate change monitoring has been recognized among the best way of detectiang and preventing spread of mycotoxins, as rising temperatures, erratic rainfall, and shifting pest ranges would alter where and how severely mold strikes. Therefore, integrating climate data into food safety surveillance would be vital (De Baere et al., 2023; Huang et al., 2025)

KEY CHALLENGES AND RESEARCH GAPS

Progress in Sub-Saharan Africa remains hindered by weak laboratory infrastructure, inconsistent surveillance, unenforced safety regulations, low farmer awareness, and fragmented government mandates (Meijer et al., 2021). Major evidence gaps identified by this study still remain. Few studies quantify the exact healthcare costs or measure the return on investment for control methods. Similarly, research heavily targets aflatoxins, leaving the combined effects of multiple co-occurring toxins understudied. Lastly, data is heavily concentrated in a few well-studied countries, leaving large parts of the continent unmonitored.

POLICY IMPLICATIONS

Managing mycotoxins requires cross-sector collaboration between agriculture, public health, trade, and environmental agencies, food safety monitoring must be woven directly into national health and agricultural extension services. Also, standardizing safety regulations across regional trade blocks will prevent clean shipments from being turned away unnecessarily. Similarly, small farmers need affordable access to airtight storage bags, biocontrol products, credit, and market rewards for selling safe grain. Finally, governments and private companies should co-invest in regional drying centers, testing labs, and supply-chain tracking.

STRENGTHS AND LIMITATIONS

This review takes a holistic approach by examining the health, economic, and food security impacts together rather than treating contamination as an isolated farming issue. It also reviews both traditional post-harvest methods and cutting-edge technologies. However, differences in study design, test methods, and local climates prevent a direct quantitative meta-analysis. Geographic coverage across Sub-Saharan Africa is uneven, and publication bias may overrepresent high contamination events. These should be acknowledged as the limitations of the study.

CONCLUSION

Mycotoxin contamination is a complex issue at the intersection of public health, agriculture, trade, and food security across Sub-Saharan Africa. The current study recorded various health and economic effects of mycotoxins including; liver cancer, acute poisoning, child stunting, and immune damage, harm to the kidney, reproductive issues, and digestive health problems. Beyond health, mycotoxins degrade crop value, trigger export rejections, reduce farm income, and disrupt all four pillars of food security. Addressing this dual burden requires an integrated approach: combining climate-resilient farming, rapid crop drying, airtight storage, biocontrol, reliable field testing, and strong market regulations.

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