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Exploring Aflatoxin Contamination in Nigerian Vegetables: A Comprehensive Review of Current Insights, Drivers, and Management Strategies

Yusuf, A. U, Haruna, S. G., Sanda, N. B., Adamu, S. H

Department of Crop Protection, Bayero University, Kano, Nigeria.

***Corresponding Author**

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ABSTRACT

Aflatoxins are cancer-causing secondary metabolites of *Aspergillus flavus* and *A. parasiticus*. Aflatoxins are toxic mycotoxins that are a significant food safety issue globally, especially in tropical and subtropical regions like Nigeria, where environmental conditions are favorable for fungal growth. Chronic dietary exposure to aflatoxin has the potential to cause severe health problems, particularly among pregnant women and children, such as stunted growth, immune suppression, and hepatocellular carcinoma risk. Whereas cereal and legume contamination with aflatoxins has been well researched, vegetables remain a less studied crop and a new target for aflatoxin infestation. Vegetables stored in traditional storage facilities are the most vulnerable to higher amounts of aflatoxins. Fresh and dried vegetables have recently been known to contain a wide presence of aflatoxins contamination attributable to inadequate good farming practices, inferior post-harvest handling, unhygienic drying, poor storage facilities, and weak regulation enforcement. In this review, there is a summary of current information on the prevalence, sources, risk factors, detection, and public health effect of aflatoxin contamination of vegetables in Nigeria. It also identifies new options for mitigation, such as the use of Aflasafe, improved solar and mechanical dryers, and inexpensive, rapid detection kits suitable for farmers' markets and decentralized markets. The review calls for a joint, multi-stakeholder action among farmers, traders, consumers, scientists, and policymakers to reduce aflatoxin contamination in Nigeria. Raising awareness, strengthening food safety infrastructure, and regulation enforcement are essential factors in decreasing aflatoxin concentrations and enhancing vegetable safety in the Nigerian food system.

Keywords: Aflatoxins, Aspergillus flavus, Food safety, Nigeria, Vegetables

INTRODUCTION

Aflatoxins are among the cosmopolitan naturally occurring mycotoxins, produced by *Aspergillus flavus* and *A. parasiticus*, especially under warm, humid conditions typical of tropical and subtropical regions, resulting in serious health and economic risks in Africa, mainly due to contamination in staple foods (Shabeer *et al*., 2022; Akinniyi 2025). Aflatoxin B1 (AFB_1) is the most toxic and common, known for its liver toxicity, immune suppression, mutagenic, and cancer-causing effects in both humans and animals (Marchese *et al*., 2018; Mahato *et al*., 2019; Bunny *et al*., 2024). Aflatoxins contamination is threatening almost 70% population of the world and about 4.5 billion people living in Asia and Africa are exposed to these mycotoxins (Umar *et al*., 2023). Africa has the highest rate of mycotoxin contamination of food, which is a major contributor to the region's high liver cancer prevalence (Nji *et al*., 2022). Yet, most actors in food production chain are not sensitized to severe health and economic impacts that result from consuming contaminated foods. In Nigeria, people's exposure to aflatoxins through diet is serious public health concern because the region's climate favors fungal growth and there are widespread issues with post-harvest handling and storage (Ezekiel *et. al*., 2018; Misihairabgwi, *et. al*., 2017). While many researches have focused on aflatoxin contamination in staples such as maize and groundnuts, studies on vegetables are still limited (Ojuri *et al*., 2019; Warth *et. al*., 2012). Compounding the issue is low awareness among farmers and traders regarding aflatoxin risks, safe handling practices, and importance of food hygiene (Atehnkeng *et al*., 2008; Bandyopadhyay *et al*., 2016). This is concerning, as vegetables are vital part of Nigerian diet, eaten both fresh and dried, play a key role in food and nutritional security, and contribute substantially to the economic livelihoods, particularly in rural communities (Odebode, 2006). New data indicate

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that vegetables including leafy vegetables and fruit vegetables including tomatoes and okra are becoming increasingly prone to aflatoxin infestation during post-harvest processing and storage under suboptimal conditions (Ezekiel *et. al*., 2014; Ezekiel *et. al*., 2019; Imade *et al*., 2021). In this review, current information regarding the existence and severity of aflatoxin infestation among vegetables across Nigeria is synthesized with an emphasis placed on related risk factors, detection as well as quantification procedures, available mitigative strategies, as well as general public health impacts. It also indicates some knowledge gaps as well as suggests future areas that can be taken to enhance foodsafety as well as aflatoxin management across vegetable value chains.

Aspergillus Species and Mycotoxin Production

The principal fungal species responsible for aflatoxin biosynthesis in Nigeria are *Aspergillus flavus*, A. *parasiticus*, and, less frequently, A. *nomius* (Shabeer *et al*., 2022; Okoth, 2016). These fungi are capable of producing four major types of aflatoxins: B_1, B_2, G_1, and G_2, with aflatoxin B_1 (AFB_1) being the most toxic, genotoxic, and frequently occurring variant in both agricultural products and food systems (Ahmad *et al*., 2022; Bunny *et al*., 2024). The optimal environmental conditions for aflatoxin production by *Aspergillus* species include temperatures between 25°C and 32°C and relative humidity levels exceeding 80% (Gemede, 2025) which are typical of Nigeria's agroecological zones, particularly during the wet season. Aflatoxigenic fungi can infect crops at both pre-harvest and post-harvest condition, especially when produce is inadequately dried, physically damaged, attacked by insects, or stored in poorly ventilated or humid environments (Hell *et. al*., 2008; Kumar *et al*., 2021; Bereziartua *et. al*., 2025). While vegetables are not traditionally considered major hosts for aflatoxigenic fungi, mounting evidence suggests they can become contaminated via several routes. These include contact with aflatoxin-laden dust particles, the use of contaminated irrigation water, exposure to unclean harvesting or processing surfaces, and co-storage with already infected grains or plant materials (Abdullahi and Dandago, 2022; Daou *et al*., 2022). Additionally, the convergence of non-traditional processing practices, non-optimal drying practices, restricted regulation, and a lack of frequent monitoring and testing serves to increase exposure risks to consumers. Of particular concern with respect to such vegetables are leafy vegetables and fruit vegetables, which commonly are stored or dried under open or uncontrolled environmental conditions. As vegetables have been seen to be widely consumed throughout Nigeria and contribute increasing percentages to household nutrition and agricultural food security, recognizing their possible susceptibility to aflatoxin contamination is most relevant to informing effective interventions to ensure food safety.

Factors Accountable for High Prevalence Cases of Mycotoxin Infestation among African Foods

Mycotoxin infection in foods from Africa is stimulated mostly by prevailing tropical climatic conditions within the continent that promote fungal growth and toxin production. High surrounding temperatures (25–35 °C) and relative humidities over 70% support ideal conditions for aflatoxin producing fungi within crops (Darwish *et al*., 2014). Sporadic rains, frequent drought stress, and climate-driven changes in agroecological zones additionally increase crop vulnerability by compromising defenses among plants as well as changing fungal ecology (Bunny *et al*., 2024; Medina *et al*., 2015). Infestation by pests and mechanical injury occurring during growth periods add additional infection avenues to boost fungal colonization with resultant accumulation of subsequent toxin.

Agricultural and post-harvest practices within most African smallholder systems also add to levels of contamination. Restricted access to resistant varieties of crops, low fertility soils, and inefficient pest management make it easy for pre-harvest invasion by fungi (Ezekiel *et al*., 2014). Post-harvest losses are aggravated by inefficient drying, storage in humid environments, and permeable storage packs with resulting moisture penetration (Darwish *et al*., 2014; Kamala *et al*., 2018; Xu *et al*., 2018). Older processing practices, including sun-drying on open ground and intermixing fresh commodities with old stock supplies, invite cross-infection and carry-over of aflatoxin from one season to the next (Adeyeye *et al*., 2021 In the absence of efficient sorting and grading systems, commodities that appear to be moldy or damaged often find their way into local markets or into stores domestically, especially among communities with food insecurity.

Socio-economic and institutional reasons also contribute to widening the problem. Limited knowledge about mycotoxin health hazards among farmers, traders, and consumers diminishes uptake of protective actions, while poverty and economic incentives for sales motivate sales and usage of tainted produce (Eskola *et al*., 2020; Adeyeye *et al*., 2021). Regulations remain weak or erratic; fewer than one-third of African nations have established national mycotoxin levels, a majority being imports from developed nations with disregards for native eating habits (Matumba *et al*., 2017). Infrastructure for testing is low, as surveillance programs cover only a small portion of a nation's area; tainted foods thus move undetected throughout a nation's markets. To overcome these drivers calls for a comprehensive strategy incorporating climate-proof farming practices, better post-harvest handling, low-cost detection technologies, as well as regionally tailored regulations.

Mechanisms and Risk Factors for Aflatoxin Contamination in Vegetables

Aflatoxin contamination in vegetables mainly occurs after harvest, especially during drying, transportation, and storage (Bankole *et. al.,* 2006; Onyeke, 2020). While fresh vegetables usually have high moisture content that can initially prevent fungal growth and aflatoxin production, improper drying under unsanitary or humid conditions fosters ideal environments for aflatoxigenic Aspergillus species to grow and produce toxins (Hell *et. al.,* 2008).

In Nigeria, several contextual factors heighten the vulnerability of vegetables to aflatoxin contamination. Traditional sun-drying methods often involve spreading produce on bare ground or other exposed surfaces, a practice that promotes direct contact with dust and insects and results in fluctuating moisture levels conducive to fungal proliferation (Adetunji *et al*., 2017). Conditions in many open-air markets are similarly problematic: the absence of raised platforms, coverings, or other hygienic infrastructure leaves vegetables susceptible to rain, rodents, and airborne fungal spores (Kariuki *et al*., 2017). Contamination can also be introduced during handling and distribution. Vegetables are frequently packed in unclean sacks, baskets, or crates and transported in humid, poorly ventilated vehicles, creating microenvironments that favor fungal growth and aflatoxin accumulation (Ojuri *et al*., 2019; Misihairabgwi *et al*., 2017).

Another critical factor is the low level of awareness of aflatoxin risks among farmers, processors, and vendors. Limited knowledge of the sources and health implications of aflatoxin encourages the continuation of unsafe post-harvest practices (Bandyopadhyay *et al*., 2016). Finally, effective surveillance is hindered by poor access to advanced analytical technologies such as liquid chromatography–mass spectrometry (LC-MS/MS) and high-performance liquid chromatography (HPLC), especially in rural and peri-urban laboratories (Gbashi *et al*., 2018).

Together, these interrelated mechanisms and risk factors underscore the need for improved post-harvest handling, targeted education campaigns, and greater investment in diagnostic capacity to reduce aflatoxin contamination of vegetables and protect public health.

Empirically proven Contamination with Aflatoxins in Vegetables

A rising amount of empirical literature corroborates high aflatoxin infestation prevalence among vegetables across Nigeria, primarily open markets where standard post-harvest management practices dominate. Key findings across different zones indicate the scope, intensity, and drivers of infestation among fresh as well as dry vegetables:

Zaria, Kaduna State

A recent analysis by Haruna, (2025) monitored aflatoxin occurrences across nine fresh vegetable samples regularly seen in Samaru Market, Zaria. These were tomato (*Solanum lycopersicum*), cabbage (*Brassica oleracea*), cucumber (*Cucumis sativus*), lettuce (*Lactuca sativa*), spinach (*Spinacia oleracea*), and amaranth (*Amaranthus* spp.). ELISA-based quantification indicated that 55.6% of samples tested contained aflatoxins with cabbage, tomato, and cucumber having amounts beyond NAFDAC's maximum permissible value of 10µg/kg, hence depicting high health hazards in markets around Zaria.

Minna, Niger State

Engormix (2022) established a level of aflatoxin contamination among fresh and dry leafy vegetables in Minna including bitter leaf (*Vernonia amygdalina*) and fluted pumpkin (*Telfairia occidentalis*). Dry bitter leaf showed maximum contamination due to improper ventilation, exposure to direct sunlight with ground surfaces, and hygienic drying practices. Results indicate that drying practices commonly employed amplify risks related to contamination tremendously.

Ibadan,Oyo State

Okunola *et al*. (2018) showed a comparison between aflatoxin residue content between dried okra (*Abelmoschus esculentus*) and tomato from market outlets in Ibadan. Dried okra had significantly higher contents than tomato. These were accounted for by differences in pH and water activity that influence fungal development. *Aspergillus flavus* and *A. parasiticus* were repeatedly isolated to reaffirm their status as chief aflatoxigenic fungi among foods from Nigeria.

Osogbo and South-Western Nigeria

Although scientific investigation in Osogbo and surrounding areas has hitherto concentrated essentially on cereals and pulses, a few recent studies reveal that vegetables kept together with commodities in mixed stores also fall vulnerable. Osho *et al*. (2023) cited an instance where cross-infections resulted between vegetables kept alongside stored yams packed together with others without ventilation. These conditions facilitate dissemination of fungal spores with resultant mycotoxin accumulation among vegetables.

Calabar and the Niger Delta

Preliminary surveys undertaken in humid southern regions such as Port Harcourt and Calabar reveal that garden egg (*Solanum aethiopicum*) and some leafy vegetables available from street-side markets contain detectable amounts of aflatoxin. Eshola *et al*. (2020) confirmed that vegetable specimens from such regions up to the value of 30% contained amounts higher than EU standard 4 µg/kg safe threshold due to improper storage, high relative humidity levels, and being neither properly packaged nor having a protective cover upon display for resale.

Kano and Dry Northern Zone

Contamination has been high especially in semi-arid zones such as Kano where vegetables are usually preserved by drying because refrigerating is limited. Suleiman *et. al*. (2017) found *Aspergillus* species to be present together with AFB1 residues in dry pepper (*Capsicum* spp.), okra, and roselle leaves (*Hibiscus sabdariffa*). Employing TLC and ELISA protocols, aflatoxin levels were discovered to be between 3.5 to 45 µg/kg with higher occurrences in samples that were dried with an absence of hygienic supervision.

Market-wide Surveillance and Surveillance Gaps

Notwithstanding mounting documentation of vegetable contamination, comprehensive country-level data for aflatoxin in vegetables of Nigeria remain scarce. There are location-specific published papers using diverse detection tests - most commonly enzyme-linked immunosorbent assay (ELISA) and thin-layer chromatography (TLC) - with very rare uses of high-performance liquid chromatography (HPLC). Few inquiries chronicle seasonality or trace the entire value chain from farm to market with critical knowledge gaps. Standardized surveillance using next-state methodologies such as liquid chromatography–mass spectrometry (LC-MS/MS) is necessary to establish a credible national baseline across the nation's diverse agroecological zones (Adetunji *et al*., 2022; Ojuri *et al*., 2019).

Throughout our review of studies, some recurring trends become evident. Dried vegetables are more likely to contain higher levels of aflatoxin than their fresh counterparts, and leafy and fruit vegetables such as okra, spinach, and tomato are among the most vulnerable. Fungal isolates virtually invariably include *Aspergillus flavus* and *A. parasiticus*, which highlight their primary responsibility for contaminating. Rural drying practices, storage practices, and marketing practices again and again appear to be important causes for higher toxin content.

At a national level, seasonally stratified surveillance programs don't exist anywhere, also longitudinal epidemiological studies to evaluate vegetable-borne aflatoxin exposure in terms of biomarkers for intake or disease outcome are scanty. Cost–benefit assessments for smallholder farmers to evaluate mitigative measures also don't exist. These voids together present a strong justification for integrated surveillance monitoring at a national level, enhanced stakeholder knowledge, and investment into controlled dry storage infrastructure to minimize vegetable-based aflatoxin exposure in Nigeria. Detection and Quantitation of Aflatoxins in Vegetables Appropriate detection and characterization of aflatoxins are important to assessing foodsafety risks, gaining compliance with international and indigenous regulatory mandates, and informing appropriate mitigative controls (Gemede, 2025). In Nigeria itself, a variety of analytical techniques have been applied to detect aflatoxin residues in vegetables with different strengths and weaknesses with respect to sensitivity, selectivity, cost, and usability (Yemisi *et al*., 2023). These comprise standard and high-tech chromatographic protocols and newer technology with correspondingly different hurdles and prospects for deployment. Amongst the traditional methods, thin-layer chromatography (TLC) is one of the most commonly utilized owing to ease of usage, low cost, and ease of application. TLC is capable of detecting various types of aflatoxins by matching retention factor (Rf) value and intensity of fluorescent sample spots with standard known spots (Shephard, 2008). In spite of being suitable for initial screening, the technique is semi-quantitative, has lower sensitivity and reproducibility, and limited ability to resolve very low levels. As such, it is less ideal for rigid regulatory uses but is still utilized by local laboratories and universities for initial vegetable screening (Bankole *et al*., 2006).

Enzyme-linked immunosorbent assay (ELISA) is a faster, more economical, but relatively sensitive alternative with the ability to detect aflatoxin B_1 down to a level of 1 µg kg^{-1} against complex matrices found in foods (Zinedine *et al*., 2007). ELISA has been effectively utilized in surveys throughout Zaria, Ibadan, and Minna with impressive discoveries of high-level contaminations found amongst leafy vegetables as well as spices (Engormix, 2022; Haruna, 2025; Okunola *et al*., 2018). Matrix effects coupled with cross-reactivity with structurally related compounds diminishes accuracy such that confirmatory chromatographic analysis is preferred. High-performance liquid chromatography (HPLC) is commonly called a gold standard for aflatoxin analysis because it is highly resolving, specific, and reproducible and permits simultaneous quantitation of several aflatoxins in vegetable matrices with high accuracy (Nguyen *et al*., 2023). Greater sensitivity is possible with derivatization steps such as post-column bromination or fluorescence enhancement. In spite of these benefits, HPLC is not fully utilized in Nigeria due to high costs for instrumentation and maintenance and trained personnel (Hameedat *et al*., 2022). Even better is liquid chromatography–mass spectrometry (LC-MS/MS), with potent separation coupled with mass detection to detect and quantify sub-parts-per-billion levels of aflatoxins with low matrix interference. LC-MS/MS is especially useful for regulatory surveillance and multi-mycotoxin detection (Krska *et al*., 2008). Even though LC-MS/MS usage is now restricted to limited bases of cost and infrastructure in Nigerian labs, usage is slowly expanding with international cooperation as well as with export-quality assurance programs at seaports and inspection points across borders (Gbashi *et al*., 2018). New technologies increasingly complement such established procedures. Rapid immunochromatographic (lateral-flow) kits can produce results within several minutes with only a low level of technical expertise required, offering an attractive option for collection sites amidst open markets or out-field conditions. Compared to laboratory-based assays, such kits will be less sensitive and specific but include early-warning function (Wacoo *et al*., 2014). In parallel with such kits, hyperspectral imaging developments, fluorescence spectroscopy, as well as artificial-intelligence algorithms, are providing non-destructive detection in real-time. For example, Liu *et al*. (2024) demonstrated that AI-based hyperspectral imaging allowed reliable separation among aflatoxin-containing dried vegetables. Thus far experimental within Nigeria, such spectroscopic as well as machine-learning adjuncts offer much promise for future incorporation into national surveillance

CHALLENGES AND RECOMMENDATIONS:

Despite increasing awareness of aflatoxin risks, Nigeria continues to face persistent and multifaceted challenges in effectively detecting, controlling, and regulating aflatoxin contamination in vegetables. Laboratory infrastructure remains underdeveloped, with high-sensitivity analytical tools like LC-MS/MS largely confined to urban centers and inaccessible to rural markets where the bulk of vegetables are sold (Ezekiel *et. al*., 2012; Krska *et. al*., 2008). The shortage of trained analysts and technicians further limits the capacity to conduct routine monitoring, while fragmented and inconsistent data across regions hampers coordinated response efforts. National surveillance often neglects vegetables, leaving a significant gap in food safety oversight (Ojuri *et. al*., 2019).

Enforcement of aflatoxin regulations is generally weak, particularly in informal markets that dominate vegetable trade (Robinson, and Yoshida, 2016). Regulatory bodies such as NAFDAC and SON face systemic barriers, including insufficient personnel, inadequate equipment, and limited jurisdiction over decentralized trade systems (Bandyopadhyay *et. al*., 2016; Ezekiel *et. al*., 2020). Public understanding of aflatoxins also remains low.

Farmers and vendors frequently engage in high-risk practices such as sun-drying produce directly on the ground or storing vegetables with cereals in humid, unventilated conditions (Suleiman, *et. al*., 2017; Adetunji *et. al*., 2022). These behaviors, shaped by financial limitations and entrenched norms, contribute to persistent contamination.

Addressing these challenges requires a holistic, multisectoral approach. Investments in laboratory infrastructure and human capacity must be scaled, while low-cost, rapid diagnostic tools should be deployed to decentralize aflatoxin testing (Wacoo *et. al*., 2014; Shephard, 2008). National extension services and academic curricula should integrate aflatoxin training, ensuring long-term capacity building (Okoth, 2018). Public-private partnerships offer a promising avenue to scale innovations in drying, packaging, and storage, particularly those tailored for smallholder and market-level use (Gbashi *et. al*., 2018). Simultaneously, risk communication strategies must be culturally relevant and inclusive to foster behavioral change. In moving forward, systemic and sustained investment will be essential to ensure safe vegetable consumption and reduce aflatoxin-related health burdens in Nigeria.

Strategic Recommendations:

Nigeria must adopt a coherent and pragmatic strategy to bridge gap between policy design and on-the-ground implementation (FAO/WHO, 2019). A national aflatoxin control program tailored specifically to vegetables should be established under the broader National Mycotoxin Control Strategy (Chilaka *et. al.*, 2022). This program would coordinate surveillance, education, regulation, and response efforts across value chains and regions.

Mobile diagnostic units equipped with rapid aflatoxin testing kits should be deployed in informal markets to enable real-time, decentralized monitoring (Engormix, 2022). This would not only enhance food safety compliance but also generate timely data for public health interventions. Vendor and farmer certification schemes based on adherence to hygiene and aflatoxin safety standards could incentivize behavioral change, especially when linked with consumer awareness campaigns and market premiums (Chilenga *et. al*., 2024).

Decentralized training networks, anchored within agricultural extension offices and vocational training centers, and should be established to enhance knowledge transfer on preventive practices and detection techniques (Bandyopadhyay *et. al*., 2015). Innovation must also be incentivized. Grants and competitions can stimulate the development of local solutions in biocontrol, post-harvest processing, and packaging (Liu *et. al*., 2024).

Nigeria should also align its standards with regional and global food safety protocols. Engagement with ECOWAS, the African Union, and international donor partners can help scale interventions, build technical capacity, and facilitate access to safer trade markets. A unified, inclusive, and forward-looking strategy is imperative to safeguard public health, strengthen trade credibility, and ensure the resilience of Nigeria's vegetable sector.

Future Directions and Research Needs:

Aflatoxin control in Nigerian vegetables requires a forward-looking research agenda that bridges epidemiology, innovation, and policy (Gong, 2002). There is an urgent need for longitudinal studies that explore the relationship between aflatoxin exposure through vegetables and public health outcomes such as hepatocellular carcinoma, immune suppression, and stunting in children (Williams *et. al*., 2004; Liu and Wu, 2010). These studies should employ biomarkers like aflatoxin-albumin adducts and urinary AFM1 to establish exposure-response patterns within high-risk populations (Mézes *et. al.*, 2021).

Research should also focus on co-contamination and synergistic mycotoxin effects, as vegetables often harbor multiple toxins, including ochratoxins and fumonisins (Aliero *et. al*., 2022). Climate-related predictive modeling that incorporates rainfall, humidity, and temperature data could guide early warning systems and enable proactive risk management (Paterson and Lima, 2010). Meanwhile, technological innovation must be driven by local contexts. Community solar dryers, antifungal bio-coatings, and AI-enhanced detection tools like hyper spectral imaging should be prioritized for research and scale-up (Liu *et. al*., 2024).

To strengthen governance, a National Vegetable Aflatoxin Control Program is proposed, embedded within Nigeria's broader mycotoxin strategy (Chilaka *et. al.,* 2022). This would promote coordinated action across agriculture, public health, and commerce, while drawing on international food safety protocols such as those of Codex Alimentarius and ECOWAS (FAO/WHO, 2019). Hygiene-linked certification for vegetable vendors (Chilenga *et. al.,* 2024) and collaboration with institutions like the African Union and FAO (Chilaka *et. al.,* 2022; FAO, 2022) could enhance compliance and unlock technical support.

Long-term success will depend on expanding research in epidemiology, climate mapping, and biotechnology. Epidemiological studies focused on aflatoxin-related diseases (Gong *et. al*., 2002; Liu and Wu, 2010), climate models to predict high-risk zones (Paterson and Lima, 2010), and artificial intelligence applications for real-time monitoring (Liu *et. al*., 2024) represent promising frontiers. Genetic breeding for fungal resistance in vegetable crops (Munkvold, 2017) and behavioral studies exploring barriers to safe practice adoption (Chilenga *et. al*., 2024) are likewise essential. Outreach programs must also be inclusive, recognizing the pivotal role of women in food value chains and tailoring interventions accordingly.

Improving food safety calls for both technical and behavioral reforms. Affordable screening techniques such as enzyme-linked immunosorbent assay (ELISA) and immunochromatographic test kits can facilitate early detection in community settings (Zinedine *et. al*., 2007; Wacoo *et. al*., 2014). Solar drying units and sealed, ventilated storage systems, developed through public-private partnerships could enhance post-harvest quality and limit fungal colonization (Bandyopadhyay *et. al.,* 2016). Agricultural extension services are crucial in scaling farmer training and outreach, while national policy must commit to sustained investments in capacity building and infrastructure.

Breeding programs targeting resistance to fungal colonization should integrate gene editing and conventional breeding methods to deliver aflatoxin-resistant vegetable varieties (Munkvold, 2017). Behavioral and social science research can deepen understanding of farmer and vendor practices, illuminating barriers to adopting safer handling and storage (Haruna, 2025). Finally, digital tools, including GIS-enabled monitoring platforms should be developed to facilitate real-time surveillance and policy response (Adetunji *et. al*., 2022). These initiatives require robust, multisectoral collaboration among academia, industry, and government, supported by dedicated funding and policy frameworks that recognize the centrality of food safety to national development.

Aflatoxin contamination in vegetables constitutes a silent but increasingly critical threat to Nigeria's food system, carrying serious implications for public health, agricultural productivity, and international trade. Traditionally overlooked in mycotoxin control efforts, vegetables particularly when dried, stored, or marketed under unhygienic conditions are now recognized as significant contributors to chronic aflatoxin exposure. This emerging evidence demands a recalibration of national food-safety priorities.

Despite the availability of global detection tools and mitigation strategies, Nigeria's response has been hampered by fragmented regulatory enforcement, inadequate investment, and limited public awareness. Addressing these gaps requires a comprehensive, cross-sectoral approach. National surveillance systems should be expanded to include vegetables as a priority commodity, while laboratory and diagnostic infrastructure must be strengthened to support routine testing. Training a new generation of food-safety professionals is essential to sustain these efforts.

Interventions must also reach farmers, traders, and consumers through tailored education and incentive programs that encourage safe production, drying, storage, and marketing practices. National campaigns, vendor certification schemes, school-based interventions, and gender-sensitive outreach can all help reshape behaviors across the value chain. In tandem, regional and international collaboration can provide the technical expertise, financial resources, and policy harmonization needed for long-term impact.

To operationalize these goals, Nigeria's regulators could establish a National Vegetable Aflatoxin Control Program within the broader National Mycotoxin Control Strategy. Such a program would deploy mobile diagnostic units equipped with rapid testing kits for real-time market monitoring, link vendor certification to market premiums to reward compliance, and introduce micro-credit schemes that enable farmers to invest in sealed solar dryers. Harmonizing maximum aflatoxin limits with the Economic Community of West African States (ECOWAS) would further facilitate regional trade.

Implementing these integrated measures would reduce aflatoxin exposure, safeguard public health, and enhance Nigeria's trade competitiveness. With sustained political will, coordinated investments, and inclusive partnerships, the country can build a safer, more resilient food system that protects its population while unlocking the full nutritional and economic potential of its

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