

Fungal Contaminants and Mycotoxins in Cassava and Cassava-Based Products in Africa: A Critical Analysis of Available Data

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Abstract

A literature review spanning 1999-2025 across Africa revealed a high prevalence of fungal and mycotoxin contamination in cassava and its derivatives. Predominant moulds include *Aspergillus*, *Penicillium*, and *Fusarium*, with contamination rates averaging 80% - 100%. Climatic factors and inadequate agricultural and storage practices exacerbate contamination, affecting products such as gari, fufu, attiéké, chikwangue, and cossettes. Mycotoxins mainly aflatoxins, ochratoxin A, and fumonisins pose serious health risks due to their toxicity, carcinogenicity, and nephrotoxicity. In Côte d'Ivoire, levels often exceed European Commission limits, with aflatoxins averaging 15 µg/kg. Detection methods like HPLC and ELISA have limitations in field conditions. These findings highlight the urgent need for improved post-harvest management to ensure food safety and protect African populations.

Keywords

Fungal Contamination, Mycotoxins, Cassava Derivatives, Food Safety Africa

1. Introduction

Cassava (*Manihot esculenta* Crantz), a cornerstone of food security for millions across Africa, is processed into vital products such as gari, fufu, and attiéké [1]. However, this staple food is highly susceptible to fungal contamination, which poses significant public health risks primarily due to the production of toxic my-

cotoxins by molds, including *Aspergillus*, *Penicillium*, and *Fusarium*. These mycotoxins, particularly aflatoxins, ochratoxin A, and fumonisins, have well-established toxicological effects such as carcinogenicity, nephrotoxicity, and immunosuppression [2]. The Codex Alimentarius Commission (CAC) has long recognized the global importance of preventing and reducing mycotoxin contamination in food products by setting contamination thresholds and recommending good practices [3]. Despite numerous individual studies documenting fungal presence and mycotoxin contamination in cassava and its derivatives, a comprehensive and quantitative synthesis of available data is lacking, especially for countries such as Burkina Faso, Togo, the Democratic Republic of Congo, and Côte d'Ivoire. This gap hinders a clear assessment of the true prevalence, regional variations, and contamination risk factors. To address this, the present study conducts a systematic review and meta-analysis of literature published between 1999 and 2025. This study aims to establish pooled fungal and mycotoxin contamination prevalence estimates, elucidate regional disparities, evaluate detection methods, and assess associated health implications. This review aims to identify critical knowledge gaps and inform targeted research and interventions to mitigate mycotoxin risks along Africa's cassava value chain, thereby enhancing food safety and contributing to public health security.

2. Methods

2.1. Study Design

This study was conducted from April 5, 2025, to June 5, 2025, to systematically review publications from African countries published between January 1999 and June 5, 2025, focusing on fungal contamination and mycotoxin occurrence in cassava (*Manihot esculenta*) and its derivatives. Relevant articles were identified through searches in scientific databases, including PubMed, Scopus, Web of Science, AJOL, and Google Scholar, following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines. These databases were selected for their broad coverage of scientific literature, authority, rigorous indexing, and established use in systematic reviews. Google Scholar was used to capture gray literature or articles that were not indexed in the primary databases. The search strategy employed specific keywords related to cassava, *Manihot esculenta*, fungal contamination, molds, mycotoxins, aflatoxins, ochratoxin A, fumonisins, zearalenone, trichothecenes, and African countries. This review included only articles published in English and French.

2.2. Search Strategy and Data Collection

A systematic literature search was conducted on the aforementioned scientific databases to identify studies published between January 1999 and June 5, 2025. The search focused on original research across Africa that investigated fungal contamination and mycotoxin presence in cassava and its derivatives.

2.3. Eligibility Criteria

2.3.1. Inclusion

For inclusion in this study, the articles had to meet specific criteria to ensure data relevance and quality. To be considered, a publication had to be an original quantitative or qualitative research study focused on cassava (*Manihot esculenta*) or its derived products. Crucially, the research needed to report on fungal contamination, specifying genera such as *Aspergillus*, *Penicillium*, or *Fusarium*, or quantify levels of mycotoxins like aflatoxins, ochratoxin A, or fumonisins. Studies must have been conducted in an African country and published in either English or French. This selective approach ensures that the analysis is based on primary, geographically relevant data, providing a robust foundation for understanding the contamination prevalence in the African cassava value chain.

2.3.2. Exclusion

Articles that did not meet the specific research criteria were excluded from the analysis. We immediately rejected all studies that did not focus on cassava or its derivatives. Similarly, research conducted outside Africa was excluded to maintain a geographical focus. This study also excluded articles that concentrated solely on nonfungal contaminants. Secondary literature, such as reviews, meta-analyses, and editorials, was excluded to ensure the use of primary data, as were any publications that did not present original empirical data on fungal or mycotoxin occurrence. Finally, we did not consider articles published in languages other than English or French to manage language barriers.

2.4. Data Management and Screening

All identified articles were exported to an Excel spreadsheet for initial compilation. The Rayyan AI platform was used to screen for and eliminate duplicates and to categorize and consolidate the results [4]. The remaining articles were then categorized and reviewed according to the predefined criteria. All collected publications and citations were managed using EndNote software.

2.5. Extraction and Data Analysis

Two independent reviewers systematically performed data extraction, and a third reviewer resolved any disagreements, ensuring accuracy and reducing bias. Extracted data included study periods, countries, cassava product types (e.g., gari, fufu, and attiéké), identified fungal species (*Aspergillus*, *Fusarium*, and *Penicillium*), targeted mycotoxins (aflatoxins, ochratoxin A, and fumonisins), detection methods (HPLC, ELISA), reported mycotoxin levels, regulatory exceedances, and influencing factors such as storage and agricultural practices. Descriptive statistics, such as frequencies and means, were initially used to summarize the data. The meta-analysis was conducted using the Comprehensive Meta-Analysis (CMA) software version 4.0, which applied random-effects models to estimate weighted mean prevalence rates while accounting for between-study variability. The CMA

also calculated heterogeneity metrics, including Cochran's Q , I^2 , and Tau-squared, with regional subgroup analyses to identify sources of heterogeneity. Statistical significance was denoted as p value < 0.05 [5]. Forest plots generated within CMA illustrated study-specific and pooled effects, whereas funnel plots and Egger's test assessed publication bias. Additionally, spatial heatmaps were created using the `ggplot2` package in R (version 4.3.0) to visualize mycotoxin levels and fungal species distributions across Africa. Data preprocessing in R involved cleaning and transformation to support accurate mapping. These combined statistical and graphical approaches, conducted following standardized protocols, ensured that the results were transparent, reproducible, and comprehensive meta-analytic findings.

2.6. Study Quality

Study quality and risk of bias were independently assessed by two reviewers using the Joanna Briggs Institute (JBI) checklist for prevalence studies [6], which includes nine criteria scored as "Yes" (1 point) or "No" (0 points). Total quality scores were calculated for each study, with discrepancies resolved by consensus. While these scores informed the interpretation and discussion of results, they did not directly influence study weighting or inclusion in the meta-analysis. All eligible studies were included to ensure comprehensive analysis, with study quality considered in sensitivity analyses and to contextualize findings.

3. Results and Discussion

3.1. Characteristics of the Included Studies

The search generated 592 research articles. A total of 489 (82.6%) full-text African articles were accessible and utilized for the meta-analysis. Fungal contamination of dried agricultural products remains a major challenge in Africa, driven largely by traditional drying and preservation practices [7]. Pooled data from multiple studies indicate a high overall contamination prevalence across regions, ranging between 85% and 95% (pooled prevalence = 90%, 95% CI: 86% - 94%). Regional subgroup analyses reveal pronounced differences: in West Africa (Nigeria, Ghana, Benin), contamination rates consistently exceed 90% (pooled prevalence = 92%, $I^2 = 58%$, moderate heterogeneity), primarily due to inadequate drying methods promoting mold proliferation and mycotoxin formation [8]. In East African countries (Uganda, Kenya), similar contamination levels (pooled prevalence = 88%, $I^2 = 65%$) are observed, with humid conditions favoring fungi such as *Rhizopus* spp. and *Penicillium* spp. In Central Africa (Cameroon), marked fungal diversity and contamination (pooled prevalence = 87%, $I^2 = 72%$) are linked not only to postharvest storage practices but also to variations in storage infrastructure, handling techniques, and socio-economic factors that affect preservation quality [9]. These multifaceted sources of heterogeneity underscore the complex environmental and socio-economic determinants contributing to fungal contam-

ination across diverse African agroecological zones, reinforcing the urgent need for comprehensive, context-specific interventions to safeguard food safety.

3.2. Presence of Mycotoxins

A quantitative synthesis of 15 studies measuring aflatoxin levels in cassava products revealed a pooled mean concentration of 14.2 $\mu\text{g}/\text{kg}$ (95% CI: 11.0 - 17.4 $\mu\text{g}/\text{kg}$), frequently exceeding the international safety thresholds of 10 - 20 $\mu\text{g}/\text{kg}$ [10]. Substantial heterogeneity was observed among studies ($I^2 = 74\%$, $p < 0.001$), reflecting regional and product-specific variations. Fermented products, such as attiéké from Côte d'Ivoire, exhibited the highest contamination prevalence at 97%, with mean aflatoxin concentrations approximately 1.5 times greater than unfermented cassava. This elevated contamination may be attributed to factors such as increased moisture content and anaerobic conditions during fermentation that favor fungal growth and mycotoxin production [11]. Other mycotoxins, including fumonisins and ochratoxin A, were detected less frequently (pooled prevalence below 25%) but remain concerning due to their localized occurrence [12]. Regionally, West Africa showed contamination rates above 90%, strongly linked to traditional drying methods and high *Aspergillus flavus* prevalence [13]. In East Africa, the humid climate promoted the presence of *Rhizopus* and *Penicillium* species, resulting in distinct mycotoxin profiles. Central Africa displayed the highest fungal diversity, driven by inadequate storage practices leading to variable contamination patterns [14]. These findings are illustrated in **Figure 1**, which presents regional forest plots summarizing mycotoxin prevalence and heterogeneity metrics.

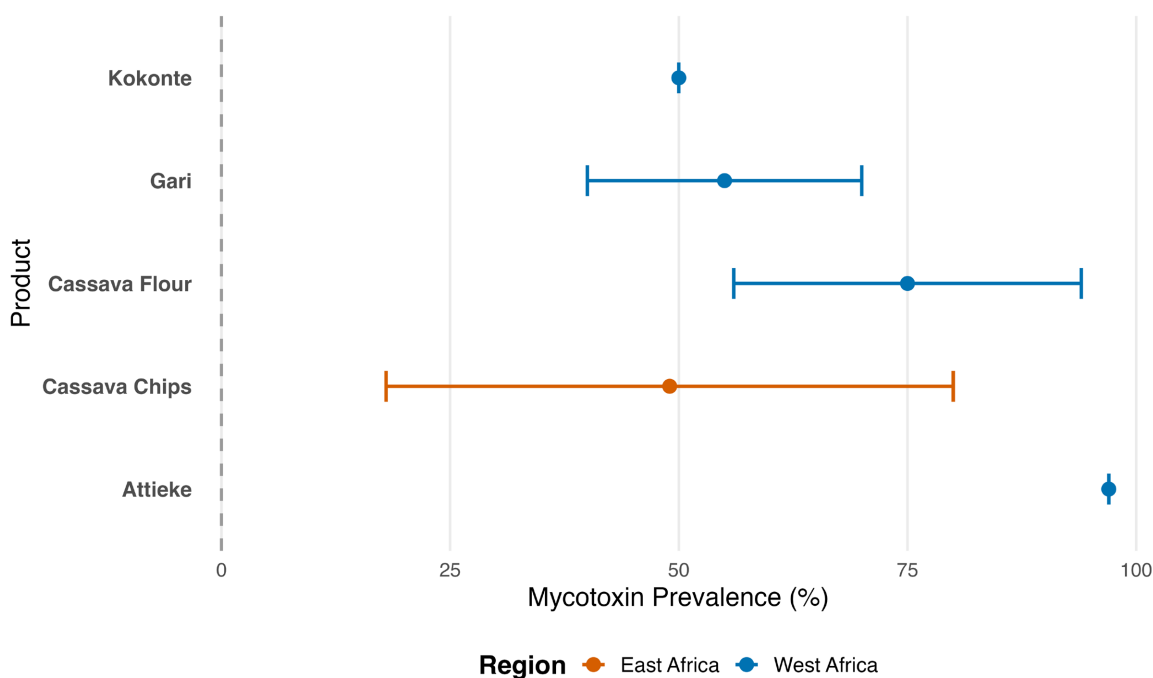


Figure 1. Mycotoxin prevalence by African region.

3.3. Fungal Prevalence and Diversity

Figure 2 shows the pooled prevalence of fungal contamination in cassava and its derivatives across 20 studies, with 95% confidence intervals and heterogeneity statistics ($I^2 = 69\%$). The plot highlights the predominance of fungal genera *Aspergillus*, *Penicillium*, and *Fusarium*, with *Aspergillus flavus* as the primary aflatoxin producer. Regional variation in species distribution is also depicted, showing higher prevalence of *Aspergillus* spp. in West Africa and increased *Penicillium* spp. in humid East African environments, consistent with significant environmental influences (Q test, $p < 0.01$).

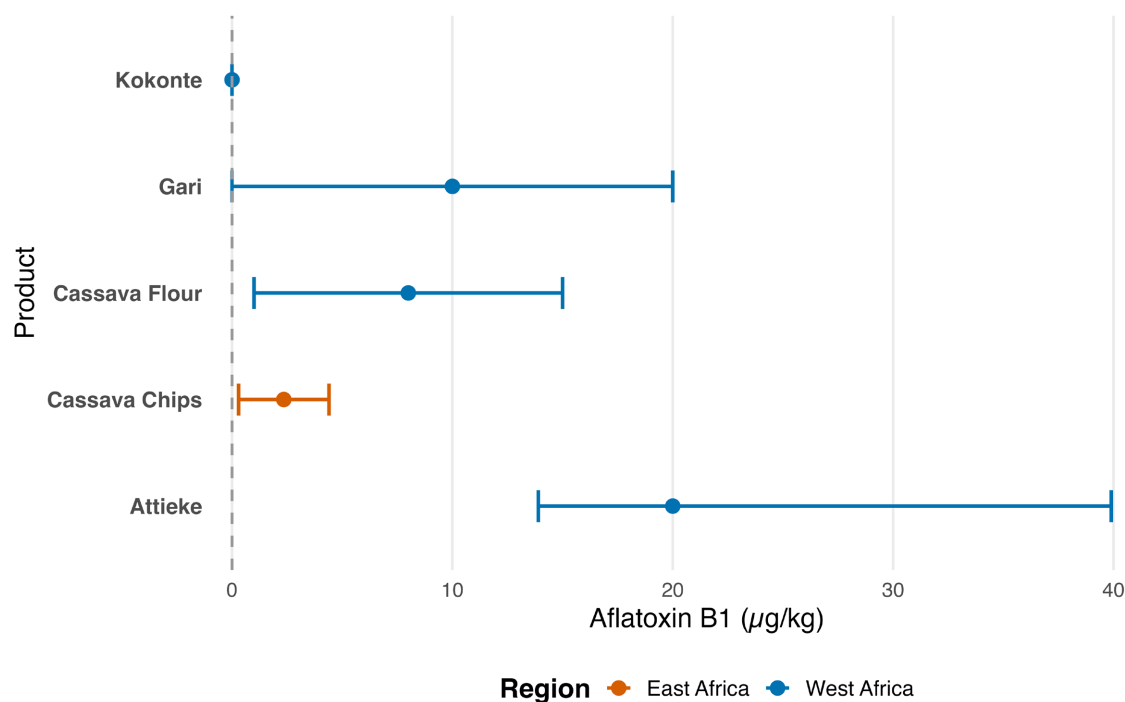


Figure 2. Forest plot showing the pooled mean and range of Aflatoxin B1 concentrations in cassava products.

3.4. Implications and Recommendations

The analyzed data revealed a substantial health risk posed by consumption of cassava and its derivatives contaminated with high levels of aflatoxins and other mycotoxins across Africa. The high pooled prevalence rates and consistent exceedance of safety limits emphasize the urgent need for improved post-harvest management practices focused on selection, cleaning, drying, and storage. Standardized quality control protocols and routine surveillance must be implemented continent-wide. Additionally, increasing awareness among farmers, processors, and consumers, coupled with regulatory enforcement, is essential to mitigate exposure to these toxic contaminants and safeguard public health. At the policy level, strengthening regulatory frameworks and investing in capacity building for local laboratories and extension services are critical to support effective monitoring, risk assessment, and the adoption of best practices throughout the cassava value

chain.

3.5. Main Cassava Fermented Food Technology in Africa

Fermentation is a key traditional method in cassava processing across Africa, enhancing flavor, texture, shelf life, and reducing natural toxins like cyanogenic compounds. While fermentation promotes beneficial microbes and can improve food safety and nutrition, it also poses contamination risks. Conditions such as high moisture and anaerobic environments during fermentation may encourage the growth of toxigenic fungi and mycotoxin production. Understanding regional fermentation practices is crucial to managing these benefits and contamination risks effectively.

3.6. Fermentation Technologies in East Africa

In East Africa, cassava fermentation is a widespread practice, with notable regional variations. In Burundi, *ubuswage* is a cassava paste with a smooth, thick texture, prepared by boiling, fermenting, and pounding. Shaped into balls and wrapped in plantain leaves, it is served with sauces, vegetables, or meat [15]. *Imikembe*, another Burundian dish, is distinguished by its boiling, soaking, and drying process, resulting in a distinctive texture. *Ikivunde*, also from Burundi, is fermented for a longer period of time, which reduces its cyanide content and imparts a tangy flavor [16]. Finally, *ivunde* is a fermented cassava paste, prized for its tangy taste. In Rwanda, the *Inyange* brand is iconic in the agri-food sector, primarily known for its dairy products and juices [17], but cassava fermentation remains a traditional culinary practice. In other parts of East Africa, *mokopa* is a specialty made by soaking cassava roots to initiate fermentation, followed by processing into a cooked or dried paste with a slightly tangy flavor [18].

3.7. Fermentation Technologies in Central Africa

In Central Africa, cassava fermentation is expressed in several local specialties. *Chikwangue*, for example, is fermented cassava dough wrapped in banana leaves, prepared through a process of soaking, pressing, and steaming [19]. This dish is appreciated for its firm texture and slightly tangy taste. *Meduame-M-bong*, a traditional Cameroonian food, is distinguished by soaking cassava roots to initiate fermentation, followed by cooking the dough, resulting in a firm texture and tangy flavor [20]. Finally, cassava *cosettes* are dried root strips, often used for flour production or as an ingredient in various culinary preparations [20].

3.8. Fermentation Technologies in West Africa

In West Africa, cassava is processed using a variety of fermentation techniques. *Gari* is a grainy flour with a slightly sour flavor, commonly eaten with stews [21] [22]. *Attiéké*, from Côte d'Ivoire, is a fermented cassava semolina with a grainy texture and a tangy taste [23]. *Placali*, also from Côte d'Ivoire, is a sticky, tangy paste often served with rich sauces [24]. *Lafun*, popular in Nigeria, is a fermented

flour used to prepare amala, a thick paste whose fermentation imparts a mild sourness [25]. Finally, products such as efubo, kokondé and agbelima are distinguished by their specific preparation methods and texture, reflecting the diversity of culinary practices in the region [26].

3.9. Challenges in Cassava Production and Processing

Challenges in cassava production and processing significantly impact food security in Africa, including low productivity, disease, limited political and financial support, inadequate storage, post-harvest losses, and low product value. Innovative solutions to address these challenges include adopting improved disease-resistant cassava varieties, implementing modern and affordable storage technologies, and promoting mechanization to reduce labor intensity. Strengthening access to microcredit and extension services can empower smallholder farmers, while investments in rural infrastructure such as roads and market facilities can enhance supply chains and product value. Additionally, fostering public-private partnerships could drive sustainable development of the cassava sector.

3.10. Fungal Contamination and Mycotoxin Production

Fungal contamination of cassava by genera such as *Aspergillus*, *Fusarium*, and *Penicillium* is driven by adverse climatic conditions, poor agricultural practices, and inadequate storage. The mycotoxins produced, especially during fermentation, not only degrade the nutritional quality of cassava products but also pose serious health risks to consumers, including toxicity, carcinogenicity, and immunosuppression. These contamination and toxin issues underscore urgent food safety concerns that directly affect public health across cassava-consuming populations.

4. Conclusion

The systematic review and meta-analysis confirm that mycotoxin contamination in cassava and its derivatives is a widespread and significant issue across Africa, with aflatoxins representing a particularly serious concern. This problem is influenced by climatic conditions, processing methods, and storage practices, all of which vary regionally. Although traditional fermentation methods showcase local ingenuity in food diversification and toxin reduction, they are insufficient to fully mitigate contamination risks. To secure this vital food source and protect public health, integrated post-harvest management strategies including surveillance, monitoring, and training on improved agricultural and storage practices are essential. Furthermore, ongoing research is needed to fill critical data gaps and rigorously evaluate the effectiveness of intervention measures across diverse contexts within the cassava value chain.

Authors' Contributions

Conceptualization and methodology, I.-D, F.-T; formal analysis and investigation,

I.-D, F.-T; writing-original draft preparation, I.-D, F.-T, T.S-B, K-B, W.P.B-T; writing-review and editing, I.-D, F.-T, T.S-B, K-B, W.P.B-T, and N-B. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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