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Maize Handling and Contamination by Mycotoxins for Imports and Local Markets in Eswatini

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Abstract

Due to local production issues stemming from poor practices and climate, and imported maize facing contamination risks from long-distance transport, Eswatini's overall maize supply presents a high risk of mycotoxin contamination for consumers. This study assessed the prevalence and diversity of mycotoxins in imported and local market maize within Eswatini's six agro-climatic regions. Samples were collected from formal markets, informal markets, and National Maize Cooperation (NMC) delivery trucks supplying imported maize. A total of 100 samples were analyzed out of 195 collected. The results demonstrated a significant difference in mycotoxin contamination based on the source and handling practices. Maize from imported sources was the safest, with 95% of samples showing no presence of the targeted mycotoxins (Aflatoxins B1, B2, G1, G2, and Zearalenone). Formal markets, which source all their stock from NMC, had 91.7% of samples testing negative. In stark contrast, informal markets, which source most of their maize directly from local farmers, had only 46.7% of samples testing negative, making them significantly riskier for consumption. The Lubombo plateau was identified as the region most affected, exhibiting the highest diversity of mycotoxins in informal market samples. These findings highlight the urgent need for proper maize regulation guidelines and intensive monitoring to manage the risk posed by mycotoxin-contaminated maize, particularly in the informal sector.

Keywords: Agro-climatic regions, Imported Maize, Local maize, Risk.

1. Introduction

Maize is the primary staple grain in the Kingdom of Eswatini. Low local productivity often leads to food insecurity Mkhwanazi et al., 2024), a situation that prompted the Eswatini government to establish the National Maize Corporation (NMC) in 1985 (NMC, 2019). The NMC, a government parastatal, plays a crucial role by providing an all-year-round market for local maize producers and holding the sole importer right to supplement local production with imported maize. This ensures maize availability for local consumers. The NMC operates from the Matsapha industrial area, where imported maize is delivered and from which local formal markets, informal markets, and individual consumers typically source their stock. However, formal and informal markets, along with individual consumers, also purchase maize directly from local farmers.

Consumers of maize and maize products are exposed to mycotoxin health risks. Mycotoxins are toxic secondary metabolites produced by filamentous fungi, and their co-occurrence in food is a common phenomenon (Dlamini et al., 2022). Mycotoxin causes damage to food which has a significant impact on trade through failure to meet market requirements or international standards for export or human consumption (Moss, 1991). Chronic exposure to these toxins is implicated in severe outcomes, including liver cancer and growth-related issues in children (Ankwasa et al., 2021). The most critical mycotoxins in eswatini are Aflatoxins (B1, B2, G1, G2) and Zearalenone (Earnshaw et al., 2022).

Globally, only a limited number of countries have proper regulatory standards for mycotoxins, and Eswatini lacks mandatory regulation on maximum residue limits in foodstuffs (Dlamini et al., 2022). This absence of clear and enforceable guidelines is concerning, as mycotoxin contamination remains a high-percentage risk in developing countries where food handling and storage are often inadequate (Nji et al., 2022). Early risk management involving farmers, distributors, and millers is therefore crucial for risk mitigation (Nji et al., 2022). Mycotoxins, particularly Aflatoxins, are common in locations with higher temperatures and high relative humidity, conditions favorable for the growth of the *Aspergillus* genera of fungi (Donnelly et al., 2022). Similarly, Zearalenone production is highly influenced by high humidity and moderate temperatures (*Fusarium* species) (Dlamini et al., 2022; Nji et al., 2022).

Eswatini's reliance on imports, especially from neighboring South Africa, increases the risk of importing contaminated maize (Dlamini, 2016). Given that Eswatini and South Africa share similar climatic conditions (Sam et al., 2021), they face similar challenges; recent studies in South Africa have confirmed that Fumonisins (FBs) and Aflatoxins (AFs) are the main mycotoxins affecting commercial maize (Nji and Mwanza 2024). The lack of border testing capacity and a shortage of regulatory enforcement in Eswatini signals an easy entry for contaminated maize (FAO, 2019). Studies confirm that the country has historically neglected mycotoxin estimates due to limited expertise and infrastructure (Dlamini et al., 2022). Even without prior contamination data, the co-occurrence of mycotoxins in maize supplied to Eswatini consumers has been documented (Dlamini et al., 2022). The purpose of this study was to assess the prevalence and diversity of mycotoxins on imported maize and in formal and informal maize markets across Eswatini.

2. Materials and Methods

2.1. Study Area

The study was conducted across all four geographic regions of the Kingdom of Eswatini, which are further defined by six agro-ecological zones (Highveld, Upper Middleveld, Lower Middleveld, Western Lowveld, Eastern Lowveld, and Lubombo Plateau

2.2. Sample Collection and Procedure

Maize samples were systematically collected from delivery trucks carrying imported maize and from both local formal and informal markets. Before sample collection, a semi-structured questionnaire was administered to the survey population to gather additional data for analysis. A total of 195 samples were collected across imports and local markets. A subsample of 100 samples was then analyzed using the Thin-Layer Chromatography (TLC) method.

The sampling distribution is detailed in Table 1, covering all six agro-ecological zones within the local market categories and specifying the collection point for imported maize.

Table 1. Agro-ecological zones visited and numbers of maize samples collected and analyzed.

Source	Agroclimatic /Place	Number of Samples	Samples Analyzed (TLC)
A. Informal Markets	Highveld	12	5
	Upper Middleveld	12	5
	Lower Middleveld	12	5
	Western Lowveld	12	5
	Eastern Lowveld	12	5
	Lubombo Plateau	12	5
	Subtotal	72	30
B. Formal Markets	Highveld	12	5
	Upper Middleveld	12	5
	Lower Middleveld	12	5
	Western Lowveld	12	5
	Eastern Lowveld	12	5
	Lubombo Plateau	12	5
	Subtotal	72	30
C. Imports	NMC – Matsapha	51	40
Totals		195	100

2.3. Sample Preparation and TLC Analysis

The Thin-Layer Chromatography (TLC) steps followed the procedure outlined by Lee et al. (1980). For preparation, 500 grams of each maize sample was ground into a fine powder capable of passing through a 0.85 mm sieve using a Ramtoms blender. Next, 50 grams of the powdered sample were transferred to a blender, where 250 ml of methanol was added and blended for two minutes. 50 ml of hexane and sodium chloride were then added to continue the polarization process. The resulting mixture was placed in a funnel and shaken, with fumes periodically released via a knob. Finally, the bottom layer of the sample was extracted for analysis (Figure 1).

Figure 1. Extraction of Mycotoxins from Samples Using Soxhlet Extractor.

125 ml of the extract was put into a separating funnel followed by the addition of 50ml of chloroform, 5 grams of cupric carbonate and 5 grams of sodium sulphate. Anti-bumping granules were added into a round bottom flask to the vial and filtered through a 12.5 filter paper which was then heated until it disappeared on a heating mantle. 2 ml of chloroform were added to the vial and then taken to a dark room for 5 minutes shaking on a shaker. It was then plotted on a TLC plate (Thin Layer Chromatography plate) to figure out the presence of mycotoxins (B1, B2, G1, G2 and Zearalenone). The TLC plate was then inserted into a developing tank until it was fully soaked, and ultraviolet light was used to detect presence of mycotoxins. The presence of mycotoxin was found using visual comparisons with mycotoxin standards.

2.4. Data Analysis

The data obtained was analyzed using descriptive statistics. Percentages and frequency counts were used in analyzing the presence of mycotoxins in imported and local market maize.

3. Results

3.1. Informal Markets

3.1.1. Maize Sourcing

Most informal markets (83.3%) source their maize directly from farmers with about 16 % using NMC and other retailers as stock sources (Table 2). All the informal markets claim to grade stock at sourcing although 20.8% rely on visible molds as a test for the presence of mycotoxins (Table 2).

Table 2. Maize Sourcing Practices for Formal Informal Markets.

	Lubombo Plateau	**Highveld**	**Upper Middleveld**	**Lower Middleveld**	**Eastern Lowveld**	**Western Lowveld**	**Average**
Source of Maize							
Local Individual Farmer	91.70	83.30	91.70	91.70	58.30	83.30	83.30
NMC	0.00	16.70	0.00	8.30	33.30	8.30	11.10
Retailors	8.30	0.00	8.30	0.00	8.30	8.30	5.50
Maize Grading Before Sourcing							
Yes	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Parameters considered at Grading							
Moisture	50.00	25.00	50.00	25.00	25.00	25.00	33.30
Weevil	25.00	25.00	16.70	25.00	50.00	25.00	27.80
Cleanliness	0.00	8.30	8.30	8.30	0.00	8.30	5.60
Uniformity of colour	8.30	8.30	8.30	0.00	0.00	8.30	5.60
Visible molds	8.30	25.00	16.70	25.00	25.00	25.00	20.80
Kernels	8.30	8.30	0.00	16.70	0.00	8.30	6.90

3.2. Maize Handling

Many informal markets ensure maize is sold within 2 months after sourcing although about 29.2% take about 3-5 months to finish each maize stock (Table 3). About 37% have no proper protection from direct sunlight at the selling locations (none or partial) with the majority of 72.2% using polythene bags for storage purposes. An average of 13.5 % of the informal markets use plastic containers to keep the maize stock (Table 3).

Table 3. Handling of Maize by Informal Markets.

	Lubombo Plateau	**Highveld**	**Upper Middleveld**	**Lower Middleveld**	**Eastern Lowveld**	**Western Lowveld**	**Average**
How fast do you sell your maize							
0 - 2 Months	75.00	25.00	83.30	66.70	91.70	83.30	70.80
3 - 5 Months	25.00	75.00	16.70	33.30	8.30	16.70	29.20
Availability of shade in the market							
Yes	41.70	75.00	66.70	66.70	75.00	50.00	62.50
None	8.30	8.30	8.30	0.00	0.00	8.30	5.50
Partial	50.00	16.70	25.00	33.30	25.00	41.70	32.00
Type of storage							
Bags	66.60	75.00	75.00	75.00	75.00	66.60	72.20
Bins	16.70	8.30	8.30	16.70	16.70	16.70	13.90
Plastic containers	16.70	16.70	16.70	8.30	8.30	16.70	13.90

3.3. Handling Mycotoxin Contaminated Maize by Informal Markets

Most informal markets (70.90%) sell maize that develop mold at storage as animal feed although at least (5.5%) still use it for home consumption (Table 4). Only 30.5% of the markets do not mix different stocks when selling but the larger part (69.5%) does not shun away from the practice (Table 4).

Table 4. Contaminated Maize Handling Practices by Informal Markets.

	Lubombo Plateau	**Highveld**	**Upper Middleveld**	**Lower Middleveld**	**Eastern Lowveld**	**Western Lowveld**	**Average**
Handling of maize that develop mold at storage							
Dispose off	41.70	25.00	25.00	33.40	8.30	8.30	23.60
Self-	8.30	0.00	0.00	8.30	8.30	8.30	5.50

consumption							
Use/ sell for animal feed	50.00	75.00	75.00	58.30	83.40	83.40	70.90
Mixing Different Stocks							
Yes	75.00	66.70	58.30	58.30	75.00	83.40	69.50
No	25.00	33.30	41.70	41.70	25.00	16.60	30.50

3.4. Mycotoxin Analysis for Informal Markets

Almost half (53.3%) of the samples analyzed from informal markets tested positive for the presence of the targeted mycotoxins with Lubombo Plateau and eastern lowveld having the highest number of positive samples (80%) and the lowest being highveld at 20% for positive samples (Figure 2).

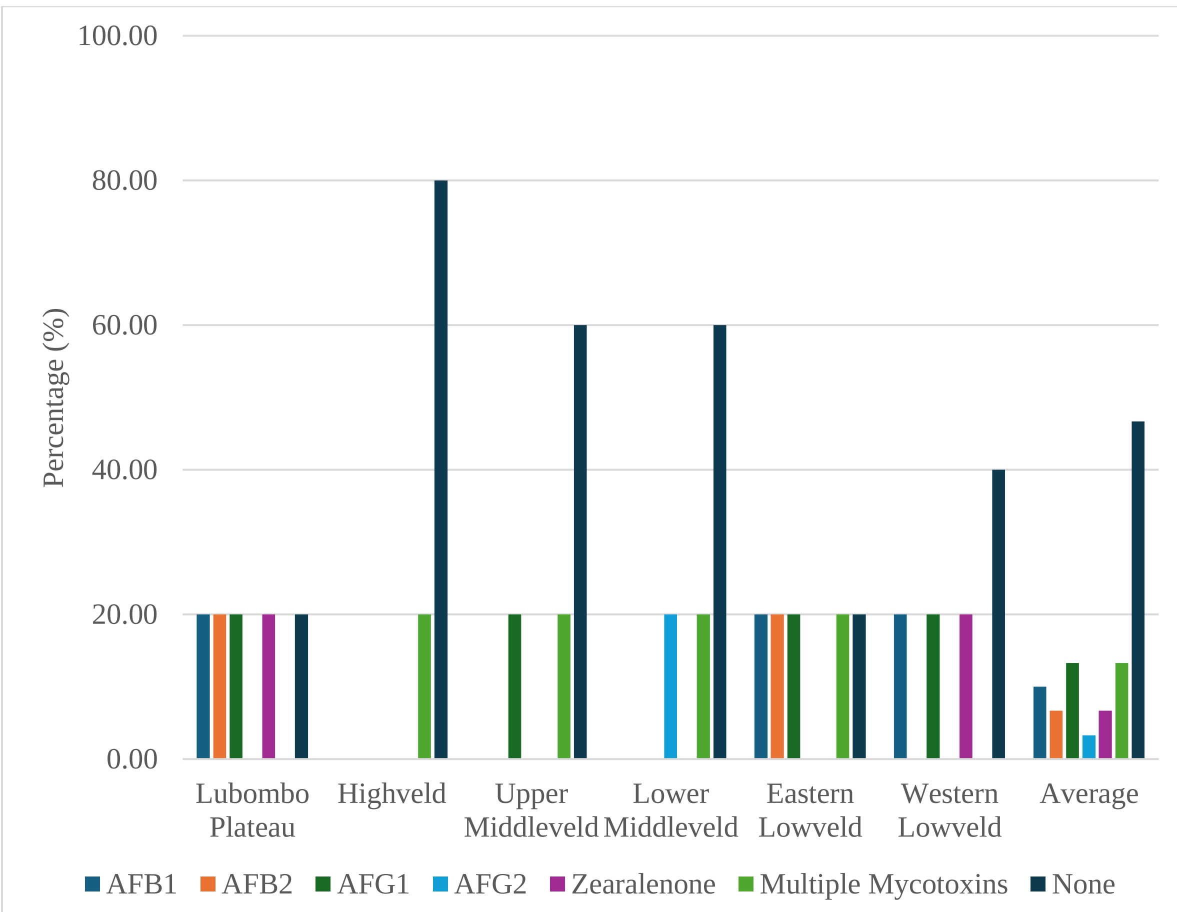

Figure 2. TLC Analysis for Maize Samples Collected from Informal Markets.

3.5. Formal Markets

3.5.1. Business Operations

All formal markets sampled get stock maize supply from the National Maize Corporation (NMC) and rely on NMC grading as they do not do their own grading (Table 5). About two-thirds (61.1%) of formal markets in this study sell maize within two months after stock arrival with the rest having a stock inventory of up to 5 months and all markets using polythene bags as packaging material (Table 5).

Table 5. Business Operations for Formal Markets

	Lubombo Plateau	**Highveld**	**Upper Middleveld**	**Lower Middleveld**	**Eastern Lowveld**	**Western Lowveld**	**Average**
Source of Maize							
NMC	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Maize Grading Before Sourcing							
No	100.00	100.00	100.00	100.00	100.00	100.00	100.00
How fast do you sell your maize							
0 - 2 Months	75.00	25.00	41.70	58.30	83.30	83.30	61.10
3 - 5 Months	25.00	75.00	58.30	41.70	16.70	16.70	38.90
Type of Package							
Bags	100.00	100.00	100.00	100.00	100.00	100.00	100.00

3.6. Mycotoxin Analysis for Formal Markets

The samples which tested positive for single mycotoxin which was present in the samples were aflatoxin B1 (AFB1) at 3.3%, aflatoxin G2 (AFG2) at 1.7%, Zearalenone (Zn) at 3.3% and no combination of more than one mycotoxin (Table 6). Above 90% of the samples tested negative in all the mycotoxins that were tested with the highveld having the highest at 100% for negative samples.

Table 6. TLC Results for Maize Samples Collected from Formal Markets

	Lubombo Plateau	Highveld	Upper Middleveld	Lower Middleveld	Eastern Lowveld	Western Lowveld	Average
Presence of Myctoxins							
AFB1	10.00	0.00	0.00	0.00	10.00	0.00	3.30
AFB2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AFG1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AFG2	0.00	0.00	0.00	0.00	0.00	10.00	1.70
Zearalenone	0.00	0.00	10.00	10.00	0.00	0.00	3.30
Multiple mycotoxins	0.00	0.00	0.00	0.00	0.00	0.00	0.00
None	90.00	100.00	90.00	90.00	90.00	90.00	91.70

3.7. Imports

3.7.1. Supplier Information

NMC was importing maize from two major South African suppliers, which ranged from over 13000 to around 36000 tonnes of white maize (Figure 3).

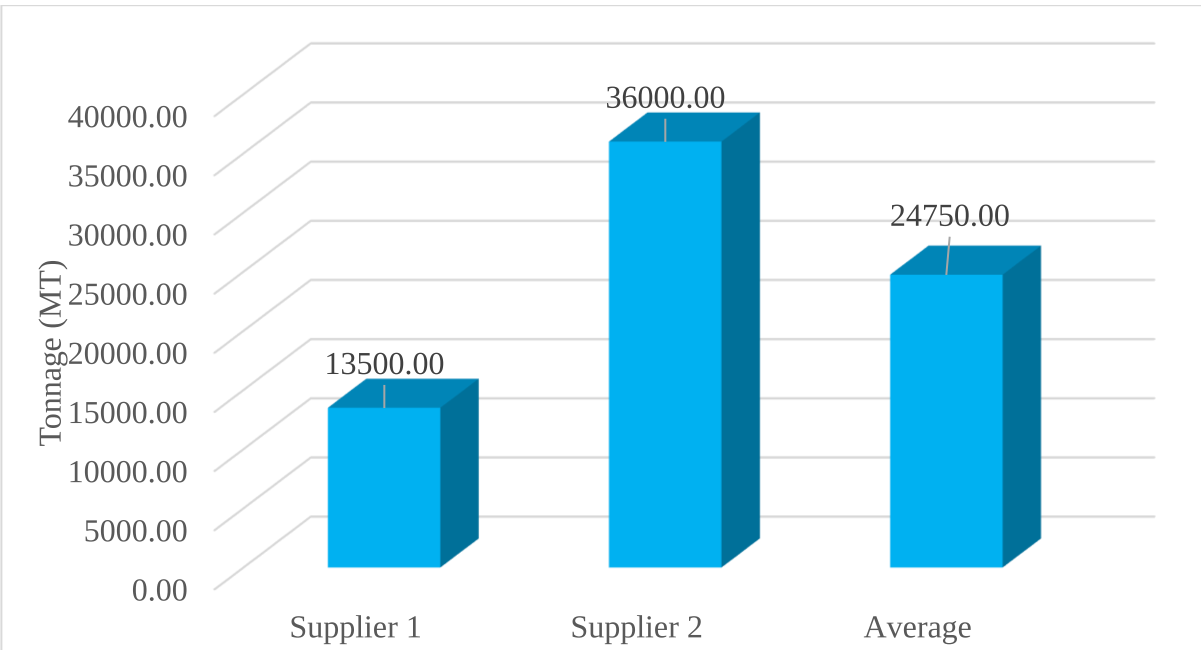

Figure 3. Annual Maize Tonnages Supplied to Eswatini.

3.8. Import Supplier Sourcing Information

Supplier 2 boots 30 years of experience of supplying NMC with white maize. All suppliers have clear sourcing procedures of rejecting broken maize kernels above 7%, rejecting maize about 16%, test for the presence of mycotoxins at sourcing and rejecting maize contaminated with mycotoxins at levels above the acceptable levels (Table 7).

Table 7. Suppliers for Imported Maize' Sourcing Information

	Supplier 1	Supplier 2	Average
Experience of business partnership			
Years	6.00	30.00	18.00
Handling of broken Kernels			
Reject above 7% but sieve less than 7% and sell broken kernels as screening for animal feed	100.00	100.00	100.00
Handling of Maize with High Moisture			
Reject above 16% but dry 12.6-16%	100.00	100.00	100.00
Testing for the Presence of Mycotoxins			
Yes	100.00	100.00	100.00
If yes, how do you manage the maize with mycotoxins?			
Reject or accept acceptable levels	100.00	100.00	100.00

3.9. Import Supplier Sourcing

The import maize suppliers in this study get all their maize from commercial maize producers, keep records of their suppliers, are familiar with suppliers' farming methods and sell their stock within 6 months after buying (Table 8).

Table 8. Import Supplier Sourcing.

	Supplier 1	Supplier 2	Average
Source of maize			
Commercial farmer	100.00	100.00	100.00
Keeping records about producers			
Yes	100.00	100.00	100.00
Knowledge on producers' farming methods			
Yes	100.00	100.00	100.00
Duration of maize in storage before selling			
0 - 6 Months	100.00	100.00	100.00

3.10. Imported Maize Mycotoxin Analysis

The only present mycotoxin in the samples was zearalenone (5%) with an average of 95% of the samples testing negative for all the targeted mycotoxins (Table 9).

Table 9. TLC Results for Imported Maize.

Presence of Mycotoxins	Supplier 1	Supplier 2	Average
AFB1	0.00	0.00	0.00
AFB2	0.00	0.00	0.00
AFG1	0.00	0.00	0.00
AFG2	0.00	0.00	0.00
Zearalenone	10.00	0.00	5.00
Multiple Mycotoxins	0.00	0.00	0.00
None	90.00	100.00	95.00

4. Discussion

The most striking finding of this study is the marked difference in mycotoxin contamination risk between maize sourced through formal/imported channels and that from informal, locally supplied markets. The formal supply chain, including imported maize and local formal markets, demonstrated a significantly higher safety profile, with 95% of imported samples and 91.7% of formal market samples testing negative for the targeted mycotoxins (Aflatoxins B1, B2, G1, G2, and Zearalenone). This low contamination directly reflects the rigorous pre-sourcing controls practiced by international suppliers and the National Maize Corporation (NMC), which include screening for broken kernels, managing moisture content, and specifically rejecting maize with mycotoxin levels above acceptable standards. Adopting appropriate and right strategies for detection and prevention of contaminants was reported to go a long way in insuring safe trade and reducing mycotoxin contamination (Leslie et al., 2021). The 100% adherence of local formal markets to NMC stock suggests a functional and relatively safe formal supply chain, with the few positive cases (a maximum of 3.3% for any single mycotoxin) likely resulting from sporadic contamination or potential post-NMC handling issues. Furthermore, the high safety of imported maize, with only one sample testing positive for Zearalenone, can be attributed to the effective mycotoxin regulation guidelines in the source country, such as South Africa (Van Egmond et al., 2007). Conversely, the absence of clear, enforceable mycotoxin regulations in developing countries like Eswatini poses a continuous and serious threat to consumer health, as noted by Bhat and Vansanthi (2003).

The informal markets, however, present a stark contrast, revealing significant vulnerabilities in their sourcing and post-harvest management, which contributes to increased mycotoxin exposure risk. Over 80% of informal markets source their stock directly from farmers and rely primarily on visible parameters like grain weevils, color uniformity, and visible mold for grading, with only an average of 33.3% considering moisture content measurement to be important. This approach is highly unreliable, as maize grain may appear clean yet still harbor mycotoxins (Fandohan et al., 2005). Compounding this risk is the storage method; over 70% of informal maize is kept in polythene bags and 13.9% in plastic containers, practices that may attract and retain moisture, thereby degrading quality and promoting fungal growth (Hell & Mutegi, 2011). Disturbingly, while 70.9% of informal markets downgrade visibly mold-contaminated maize to animal feed, certain markets in low maize-producing areas, including the Lubombo plateau and eastern lowveld, reported using mold-contaminated maize for home consumption. This practice is strongly correlated with the study's highest contamination rates, where zones like the Lubombo plateau and eastern lowveld had the lowest percentage of negative samples (20% each). These results confirm the established conclusion that hot and dry weather conditions are more conducive to mycotoxin contamination (Mutegi et al., 2009). The presence of mycotoxins like Aflatoxin B1, which can be linked to serious health problems such as cancer and immune system disorganization (Han et al., 2022; Ranjbar et al., 2025), highlights the urgent need for intervention in the informal sector's handling and grading practices. Ultimately, ensuring that maize is properly graded and managed post-harvest is a critical factor in preventing fungal damage and dropping the risk of mycotoxin exposure, as argued by Wangacha and Muthomi (2008).

5. Conclusion

A clear and significant disparity exists in mycotoxin contamination risk between the formal and informal maize supply chains, with the formal sector (including imported maize and stock from the National Maize Corporation) demonstrating high safety standards (>90% of samples tested negative) due to robust pre-sourcing controls and rigorous grading. In sharp contrast, the informal markets pose a critical public health concern, exhibiting high contamination rates, including the presence of cancer-linked Aflatoxin B1, directly attributable to the reliance on subjective visual grading and inadequate post-harvest storage practices. Geographically, the Lubombo plateau was identified as the hotspot for mycotoxin contamination, showing the highest diversity (four different single mycotoxins) in the informal markets, while the Highveld was the safest with the lowest diversity (only one single mycotoxin). These findings underscore an urgent need for targeted intervention focusing on training informal market vendors and smallholder farmers on effective grading (particularly moisture content), implementing safe storage techniques, and establishing and enforcing comprehensive national mycotoxin testing and regulatory standards to protect public health.

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