JRIIE Journal of Research Innovation and Implications in Education
Center for Research Implications & Practice

Website:www.jriiejournal.com ISSN 2520-7504 (Online) Vol.9, Iss.1, 2025 (pp. 52 - 64)

Assessment of Aflatoxin Contamination in Malted Maize and Finger Millet at Msundwe Market, Malawi

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***Abstract**: Mycotoxins such as aflatoxin have a great effect on both nutrition and economic activities. In the food supply chain, these need to be controlled by training farmers in the post-harvest handling of the crop hence improving the exports as well as nutrition impact. Grain crops are the most prone to the aflatoxin challenge. As one way of disseminating information on aflatoxin in malted maize and finger millet, random sampling was done on selected malt sellers of the two crops at Msundwe market under Mpingu EPA. The collected samples were analyzed to assess and quantify the aflatoxin levels in these crops. These crops were purposively selected because most local farmers use them as raw material for the production of beer hence posing a risk to the consumers. According to the results, fermented malt had high levels of aflatoxin of 2.45 ppb and 1.44 ppb for maize and finger millet respectively. While freshly, germinated malt had a low level of aflatoxin of 1.125ppb and 0.75ppb for maize and finger millet respectively. This is in agreement with the hypothesis that aflatoxin is available in the sample at market. These results will help to come up with an intervention that will help to train farmers' proper methodologies of processing these crops to produce high-quality malted maize and finger millet.*

***Keywords**: Aflatoxin, Malt, Post-harvest handling, Processing, Finger millet*

How to cite this work (APA):

Kampete, A., Msowoya, L. & Phiri, C. K. (2025). Assessment of Aflatoxin Contamination in Malted Maize and Finger Millet at Msundwe Market, Malawi. *Journal of Research Innovation and Implications in Education, 9*(1), 52 – 64. **https://doi.org/10.59765/saia9859**.

1. Introduction

Aflatoxin contamination in grains, especially maize, is a significant global concern due to its toxic effects (Ponce-García et al., 2021). Aflatoxins are toxic compounds produced by Aspergillus species, including Aspergillus flavus and Aspergillus parasiticus, and can lead to cancer, mutagenesis, immune suppression, and interference with nutrition in humans and animals (Kumar et al., 2021). In Malawi, maize and finger millet are crucial cereals widely consumed as staple foods and used in the production of traditional beers (Ministry of Agriculture and Food Security (MoAFs), 2020). However, the process of malting maize and millet, the main raw materials for brewing, is susceptible to aflatoxin contamination (Matumba et al., 2011), resulting in serious health problems such as liver cancer, immune suppression, and reproductive disorders. The economic impact is also significant, as aflatoxin reduces crop yield, jeopardizing food security, decreasing market value, and affecting animal and human growth, leading to lower yields of milk and eggs (Ngigi et al., 2021). Addressing aflatoxin contamination is crucial to mitigate these health and economic consequences.

Wu, (2015) reported that aflatoxin contamination is a widespread issue in tropical and subtropical regions, particularly in countries like Kenya, where it poses significant risks to both human and animal health. The prevalence of aflatoxin contamination in cereals, including maize and finger millet, and their derived products is higher in developing countries (Kirui et al., 2014) compared to Europe. Cereals have been identified as prone to contamination by toxigenic fungi, and the consumption of aflatoxin-contaminated cereals can lead to illness and even death. It is imperative to address this issue to safeguard the health and well-being of individuals and mitigate the economic consequences associated with aflatoxin contamination.

Aflatoxin contamination in crops occurs through pre-harvest and post-harvest processes (MoAFs, 2020). Pre-harvest contamination is caused by the presence of Aspergillus in the soil, while post-harvest contamination is facilitated by heat and humidity, which promote fungal growth and spread (Torres et al., 2014). In regions like Malawi, where temperatures around 28 degrees Celsius and relative humidity of about 90% are common during agricultural production, these conditions favor mold growth (Matumba et al., 2014). Inadequate drying and processing of crops like maize and finger millet are primary contributors to aflatoxin production and grain contamination. Factors such as drought and insect infestation can weaken crops, increasing their susceptibility to contamination. Aflatoxin is commonly found in cereals like maize and finger millet due to both pre-harvest and post-harvest activities.

Consuming foods contaminated with aflatoxins can have severe health consequences, including liver cancer, immune suppression, appetite loss, stunted growth, and reproductive disorders (Ismail et al., 2021). Kensler et al. (2011) reported a tragic incident in Kenya that resulted in 125 deaths and numerous illnesses after people consumed maize contaminated with aflatoxin levels ranging from 20 ppb to over 1000 ppb. Apart from these health risks, aflatoxin contamination also poses economic challenges. It reduces crop yields, leading to food insecurity, lowers the market value, and hinders animal growth, resulting in decreased yields of by-products like milk and eggs. The European Commission mandates the absence of all aflatoxins in agricultural products intended for human consumption (van Egmond et al., 2007). However, aflatoxins are highly stable during food processing, even under cooking temperatures, making their elimination difficult. The Joint Expert Committee on Food Additives (JECFA) recommends keeping aflatoxin levels in foods and fruit products below permissible limits (Otsuki et al., 2001). Developing countries are particularly vulnerable to aflatoxin contamination, necessitating the implementation of effective preventive measures to reduce its incidence. However, the Common Market for Eastern and Southern Africa (COMESA), including Malawi, has set legal limits for total aflatoxins in food, ranging from 4 to 20 parts per billion (ppb) globally (Ngwira, 2019; Hoffmann et al., 2020).

Given the aflatoxin contamination concerns in Malawi, this study aimed to assess the levels of aflatoxin in malted maize and finger millet. Furthermore, the study sought to understand the handling process, processing method of malted maize and finger millet, shelf life, and regulation followed. By analyzing partially germinated and fermented samples of these crops, the study aimed to provide valuable insights into the extent of aflatoxin contamination. While malt seller response shed more light on the handling and management. The knowledge is crucial for developing effective strategies to manage aflatoxin during the processing of malt, ultimately reducing health and economic risks associated with consuming contaminated foods. The findings from this analysis will help determine the prevalence of highly contaminated food in local markets and support the development of new technologies to improve malt processing techniques. The study focused on samples obtained from malt sellers at Msundwe market, thereby providing valuable information.

2. Literature Review

2.1Aflatoxin overview

Aflatoxins, produced by Aspergillus Flavus and Aspergillus parasiticus, are invisible threats as they lack odor, colour, and flavor (Li et al., 2021; Syamilah et al., 2022). These mycotoxins pose a significant risk as they commonly infest crops like maize, millet, nuts, potatoes, and other grains (Niyibituronsa et al., 2020). COMESA set legal limits for total aflatoxins in food, ranging from 4 to 20 parts per billion (ppb) globally (Hoffmann et al., 2020). Similarly, the US Food and Drug Administration (FDA) action guideline sets the limit at 20 ppb for food products intended for consumption (Nachman et al., 2012) and for human consumption in the United States, the acceptable range is 4 to 20 ppb, while farm animals like cows, pigs, and chickens can safely consume feeds containing up to 100 ppb. However, cereals and their derivatives have been identified as particularly susceptible to contamination by potentially toxic fungi (Hoffmann et al., 2013; Bryła et al., 2018). However, the prevalence of aflatoxin contamination in cereals and related food products is notably higher in developing regions, particularly in Africa, compared to Europe (Anitha et al., 2019). Malawi's crop products are among the susceptible ones which threaten healthwise of consumers thereby increasing chronic situations.

2.2 Aflatoxin on malted maize and finger millet

Aflatoxin contamination is a significant concern in various food crops, including malted maize and finger millet (Ayelign et al., 2020). Malted maize, which is commonly used in the production of malted beverages and infant porridge, can be susceptible to aflatoxin contamination if proper handling and storage practices are not followed. Pandey et al. (2019) revealed that aflatoxins can develop during pre-harvest, post-harvest, and storage stages due to the growth of Aspergillus fungi, particularly Aspergillus flavus and Aspergillus parasiticus. Similarly, finger millet, a nutritious cereal crop consumed in many regions, is also prone to aflatoxin contamination if not managed effectively (Akello et al., 2021). The presence of aflatoxins in finger millet grains can occur due to inadequate drying methods, poor storage conditions, and exposure to moisture. These factors create favorable conditions for fungal growth and aflatoxin production. Consumption of aflatoxin-contaminated malted maize and finger millet can pose significant health risks. Aflatoxins are potent carcinogens and can have detrimental effects on human health, including liver damage, immune system suppression, and growth impairment (Sirma et al., 2018). Ingesting high levels of aflatoxins over time can increase the risk of liver cancer and other related health complications.

Aflatoxin issues in malted maize and finger millet can be addressed through the implementation of effective agricultural and post-harvest practices (Kumar et al., 2022). This includes proper drying methods, ensuring moisture control during storage, regular monitoring for fungal growth, and adopting appropriate processing techniques to minimize aflatoxin levels. Omara et al. (2021) suggested that raising awareness among farmers, processors, and consumers about the importance of aflatoxin prevention and mitigation strategies is essential for ensuring the safety and quality of malted maize and finger millet products.

2.3 Why high chance of aflatoxin on malted maize and finger millet

Malted maize and finger millet are highly susceptible to aflatoxin contamination due to a combination of environmental conditions, improper handling, and inherent vulnerabilities (Kaela, 2021). These crops are predominantly grown in warm and humid regions, providing an ideal environment for aflatoxin-producing fungi to thrive. Oyebamiji et al. (2023) demonstrated that higher risk of aflatoxin contamination in malted maize and finger millet due to the conducive climatic conditions prevalent in such regions. Improper drying and storage practices significantly contribute to aflatoxin contamination in these crops. If harvested grains are not adequately dried to the appropriate moisture levels before storage, residual moisture can create an ideal breeding ground for fungal growth and subsequent aflatoxin production (Kumar et al., 2022). In addition, suboptimal storage conditions, including poor ventilation and exposure to moisture, further increase the risk of aflatoxin contamination. Omara et al. (2021) reported that insect damage poses another threat to malted maize and finger millet crops. Insects, such as beetles and weevils, can cause physical damage to the grains, creating entry points for aflatoxin-producing fungi (Vignesh et al., 2022). These fungi can then infect the damaged grains and produce aflatoxins, as reported by Birgen et al. (2020) in their recent study on insect damage and aflatoxin contamination in maize and millet. Crop damage and stress during growth also heighten the susceptibility of malted maize and finger millet to aflatoxin contamination. Insect infestations, drought, excessive rainfall, or other stressors can weaken the plant's defense mechanisms, making them more vulnerable to fungal infections and subsequent aflatoxin production (Awuchi et al., 2021). These challenges require the implementation of good agricultural practices, including proper crop management, timely harvesting, effective drying methods, and appropriate storage conditions. A comprehensive approach that integrates pest control measures, improved post-harvest handling techniques, and enhanced farmer training is necessary to mitigate aflatoxin contamination in malted maize and finger millet (Leslie et al., 2021).

2.4 The influence of marketing on malted maize and finger millet aflatoxin levels

Marketing activities have a significant influence on the supply chain management and safety of malted maize and finger millet (Wanjala et al., 2016). Krska et al. (2022) reported that effective supply chain management is crucial for minimizing the risk of aflatoxin contamination throughout the production, processing, storage, and distribution stages. By implementing proper handling practices such as monitoring and controlling moisture levels, conducting quality control measures, and ensuring timely processing and storage, marketers can prevent fungal growth and reduce aflatoxin contamination. Moreover, marketing plays a pivotal role in establishing and enforcing quality control standards (Clark & Hobbs, 2018). By promoting and adhering to rigorous standards, marketers can help mitigate the risk of aflatoxin contamination. This can involve regular aflatoxin testing, implementing quality assurance programs, and ensuring compliance with regulatory limits. Effective marketing strategies also contribute to consumer awareness and education about aflatoxin contamination (Ortega-Beltran & Bandyopadhyay, 2021). Provision of information on proper storage, handling, and preparation techniques, marketers empower consumers to make informed choices and reduce the likelihood of aflatoxin exposure. Garaus & Treiblmaier, (2021) emphasized that traceability and transparency in marketing efforts enable consumers to trace the origin and production processes of these products, instilling confidence in their safety and quality. By creating a market demand for aflatoxin-free or low-aflatoxin products, marketers can incentivize producers and processors to implement measures to reduce aflatoxin contamination. Unnevehr, (2022) reported that increased consumer demand for safer products can drive the adoption of best practices in production, processing, and storage, resulting in lower aflatoxin levels and enhanced food safety.

2.5 Prevalence of Aflatoxin Contamination in Africa

Inadequate post-harvest handling and storage practices, along with the challenges of controlling environmental factors facilitate the growth of toxigenic molds and mycotoxin production (Daniel et al., 2011; Niyibituronsa et al., 2020). Research indicates that young children in Africa are at a high risk of aflatoxin exposure through the consumption of contaminated cereals and cereal-based foods, either as complementary feeding or as breakfast options (Niyibituronsa et al., 2020). The detrimental effects of aflatoxins on human health, particularly in children, include immune suppression, low birth weight, and growth impairment (Alamu et al., 2018). Chronic exposure to aflatoxins has also been linked to various types of cancer (Pokhrel, 2016).

In Nigeria, maize (*Zea mays* L.), millet (*Pennisetum glaucum* L.), and sorghum (*Sorghum bicolor* L.) are commonly used cereals, particularly in the preparation of "pap," a popular fermented porridge consumed as a complementary and breakfast food (Odo et al., 2019). Improper post-harvest handling and storage conditions in Africa contribute to widespread contamination of these cereals by potentially toxigenic fungi and their associated toxins, necessitating thorough examination before use in making pap and breakfast beverages (Leslie et al., 2021). The susceptibility of these cereals to aflatoxin contamination poses a significant obstacle to their utilization in Africa (Bandyopadhyay et al., 2022). Furthermore, the European Commission mandates the absence of all aflatoxins in agricultural products intended for human consumption (Sirma et al., 2018). However, aflatoxins exhibit stability in foods during various processing conditions, including cooking, making them difficult to eliminate (Jallow et al., 2018). These challenges highlight the urgent need for effective strategies and interventions to mitigate aflatoxin contamination and protect the health and well-being of individuals reliant on cereal-based foods in Africa.

2.6 Aflatoxin outbreak and their implication

Outbreaks of aflatoxicosis, resulting from aflatoxin poisoning, were first observed in the 1960s in England when a significant number of turkeys died on poultry farms after consuming contaminated feed (Guchi, 2015; Negash, 2018). In response, regulatory limits on acceptable aflatoxin concentrations in crops used for food and animal feed have been imposed by the U.S. Food and Drug Administration and many countries (Meneely et al., 2022). The standards for animal feed are generally more lenient than those for human consumption. The extent of aflatoxin contamination varies depending on geographical location, agricultural practices, and the susceptibility of crops to fungal activity during pre-harvest, storage, and processing stages (Anitha et al., 2019; Dövényi-Nagy et al., 2020). Fungal growth can begin before harvest and proliferate under production and harvest conditions. The severity of symptoms resulting from aflatoxin exposure depends on factors such as the specific fungus species, concentration of aflatoxins consumed, duration of exposure, age, sex, weight, and overall health of the affected individual or animal. Aflatoxicosis can be transmitted from mother to offspring through milk secretions.

Aflatoxins have been linked to liver cancer and liver failure, with acute and chronic manifestations of aflatoxicosis. Pratap et al. (2022) reported that acute aflatoxicosis occurs when a large amount of aflatoxin is consumed within a short period, leading to hemorrhages, severe liver damage, edema, gastrointestinal dysfunction, altered digestion, disrupted absorption and metabolism of nutrients, and some cases, death. Animals affected by acute aflatoxicosis often exhibit signs such as depression, loss of appetite, and diarrhea (Jain et al., 2021). Negash, (2018) reported that chronic aflatoxicosis, on the other hand, occurs when small amounts of aflatoxin are consumed over an extended period, even at concentrations as low as 1 ppb. Aflatoxin binds to nucleic acids and impairs protein production, resulting in slower metabolic rates, reduced growth, compromised immune function, and liver damage. Identifying chronic aflatoxicosis can be challenging due to its subtle symptoms (Alamu et al., 2018). Livestock affected by aflatoxicosis show observable signs such as slowed growth, decreased egg and milk production, and yellowing of the whites of their eyes due to liver damage. Small animals are more susceptible to aflatoxicosis in some studies (Jallow et al., 2018). Both humans and animals exhibit similar reactions to aflatoxins, although the specific symptoms may vary. Humans may experience pulmonary edema, convulsions, coma, vomiting, and even death accompanied by cerebral edema and fatty involvement of the liver, kidneys, and heart. The presence of other liver diseases such as Hepatitis B or parasitic infections can exacerbate the effects of aflatoxin (Alamu et al., 2018).

A total of 92 samples from Malawi and 88 samples from Zambia were collected between 2008 and 2009, including Makaka, Flour, kanyakaska, kadonoska, scrapes, dried cassava chips, and grates had significantly lower levels of aflatoxin contamination compared to Malawi (Anitha et al., 2019). Okoth, (2016) reported that samples of locally processed and imported maize and groundnut-based therapeutic foods, instant baby cereals, and de-hulled maize flour were collected from popular markets in Lilongwe, Malawi. Notably, no aflatoxins were detected in the samples of imported baby cereals and locally de-hulled maize flour. However, all locally processed maize-based baby foods exceeded the European Union's maximum tolerable level of 20 ppb for aflatoxins (Matumba et al., 2014). These findings emphasize the need for continuous monitoring of aflatoxin levels in commercially available processed products to mitigate the health risks associated with dietary aflatoxin intake.

3. Methodology

3.1 Study area

The study samples were collected from selected malt sellers at Msundwe markets, located within the Mpingu Extension Planning Area in Lilongwe, Malawi. The market was selected as a representative location for sample collection. Subsequently, the collected samples were sent to the laboratory at Chitedze Research Station for aflatoxin analysis. The Chitedze Research Station laboratory is well-equipped and suitable for conducting precise aflatoxin analyses, ensuring reliable results for the study.

3.2 Sampling procedure

Fermented and partially germinated samples were procured randomly (Acharya et al., 2013) from Msundwe. Upon arrival at these markets, the researchers introduced themselves and explained the main objective of purchasing malted maize and finger millet. The farmers who were selling malted maize and finger millet were engaged in a brief conversation, where they provided insights into the malting process for maize and finger millet. This included information on the time required for germination, drying, maximum days on the market, and proper storage methods. To ensure a representative sample, 1kg of each malted maize and finger millet sample was purchased randomly from the malt sellers. A total of eight samples were collected from Msundwe market and they were composed of four malted finger millet and malted maize samples. Out of these, four samples were partially germinated, and the remaining four samples were fermented. Each sample was carefully packed into individual sampling bags, with proper labeling that included the date of sampling, sample number, sample name, market, and EPA. These sampling bags were appropriately labeled to ensure traceability and accuracy throughout the analysis process. Subsequently, all samples were stored in laboratory refrigerators, maintaining proper temperature conditions, in anticipation of further analysis.

3.3 Aflatoxin analysis

3.3.1 Aflatoxin analysis ingredients

The following ingredients were used for the aflatoxin analysis:

- Sodium chloride: 5g
- Methanol (70%)
- Distilled water: 30%
- Sample to be analyzed: 25g
- Methanol and water solution for blending the sample: 125ml/sample
- Distilled water for sample dilution: 30ml

These ingredients were carefully measured and utilized in the analysis process to ensure accurate and reliable results.

3.3.2 Laboratory analysis procedure

The study adopted the procedure that Christensen et al., (2012), Dai et al., (2013) and Wang et al., (2015) used where the samples were ground into a fine powder using a thoroughly cleaned motor grinder. To ensure accuracy, an analytical balance was calibrated using metal weights to achieve the required measurement unit. Subsequently, exactly 25g of each sample was carefully weighed using a weighing boat and transferred into clean 125ml conical flasks. In order to enhance extraction, 5g of sodium chloride ($NaCl_2$) was added to each conical flask containing the 25g sample. To prepare the blending solution, a 70% methanol-water solution was created. This involved combining 700ml of methanol and 300ml of distilled water to obtain a total volume of 1 liter. The mixture of 25g sample and 5g sodium chloride was then poured into a blender, and 125 ml of the 70% methanol-water solution was added to achieve a homogeneous solution suitable for mycotoxin extraction. The blending process was conducted for 2 minutes. Following blending, the homogeneous solution was filtered using two types of filter papers, starting with fluted filter paper. Subsequently, 15 ml of the filtered solution was transferred into a clean bowl, to which 30 ml of distilled water was added for dilution. The final filtration was performed using microfiber filter paper, which has finer pores compared to the fluted filter paper. Next, 15 ml of the filtered sample was poured into a 20 ml graduated glass syringe that had been securely inserted into the aflatoxin column. The sample was then gradually pumped through the aflatoxin column using an aflatoxin pump, allowing approximately 1 to 2 drops of sample per second to pass through. To ensure thorough cleaning, the samples were passed through 20ml of distilled water, which helped remove any mycotoxins that may have adhered to the walls of the syringe and aflatoxin column. Afterward, 1 ml of concentrated HPLC-grade methanol was added through the aflatoxin column. This step aimed to elute the toxins trapped by antibodies present in the aflatoxin column into a clean glass vial. Subsequently, 1 ml of Aflatest developer was added to the glass vial, facilitating the exposure of mycotoxins for easy detection using a fluorimeter machine. The final step of the analysis involved detecting the levels of aflatoxin using the fluorimeter. Before sample analysis, the machine was calibrated using three standards: green, red, and yellow. Each standard represents a different level of aflatoxin, producing distinct results. These standards are solutions with known levels of aflatoxin, serving as a reference for calibration. Once the machine provides the required results when tested with these standards, it is considered ready for use. The machine guides the user through the process, generating results every minute after the sample is inserted.

3.4 Data collection

The study collected data on the number of samples collected, processing methods used for malt maize and millet, the number of individuals employing these methods, and aflatoxin levels (ppb) in the analyzed samples. This comprehensive data enabled a thorough assessment of processing techniques, individual involvement, and aflatoxin contamination, enhancing understanding of the quality and safety of malted maize and millet products.

3.5 Data analysis

GenStat® 18 Edition (VSN International, Hemel Hempstead, UK) was used to perform analyses of variance (ANOVA) on aflatoxin level. Microsoft Office was utilized for calculating the percentage of individuals utilizing each processing method. Differences between means of significant variables were separated using a least significant difference (LSD) at 5%.

4. Results and discussion

4.1 What were the handling, processing methods; storage conditions of maize and finger millet Malt for sellers?

The participants reported that the germination process of malting cereals was only controlled by a small percentage, with an average of 10 individuals (2%) actively involved, while the majority allowed the cereals to fully germinate without regulation. Additionally, it was observed that the drying process was not adequately managed, as the malted cereals were still moist when packed and stored in sack bags, awaiting the market day. Malt sellers mentioned that their products usually take a maximum of two weeks to be sold. However, the lack of controlled processing during malting can result in mold growth and increase the risk of aflatoxin contamination.

4.2 What is the commonly consumed maize and finger millet malt type at Msundwe Market?

In the current study, the consumption patterns of malted finger millet and maize were examined. It was found that 39% of consumers preferred partially germinated malted finger millet, while the majority of consumers (62%) favoured fermented malted finger millet (Table 1). This indicates that fermented finger millet is associated with the production of higher-quality sweet beer (Cadenas et al., 2021) compared to partially germinated millet. Similarly, among malted maize consumers, 25% opted for partially germinated malted maize, while the majority (75%) preferred fermented malted maize. The percentage of consumers choosing fermented malted maize and finger millet was higher compared to those selecting the partially germinated varieties. This preference for fermented products can be attributed to the fact that they yield high-quality sweet beer, which is characterized by a brown colour (Su et al., 2021).

Table 1: Commonly consumed maize and finger millet malt type at Msundwe Market

Type of product	Number of malt sellers	Method used	Many people used the method	Percentage usage of the method
Malted finger millet	13	Partially germinated	5	39%
		Fermented	8	62%
Malted maize	16	Partially germinated	4	25%
		Fermented	12	75%

4.3 Aflatoxin levels in malted maize and finger millet sourced from Msundwe market

The study findings indicated that both crop type and processing method did not have a significant impact on the levels of aflatoxin (ppb) (Table 2). This suggests that the levels of aflatoxin were comparable between maize and finger millet, despite some individual crop samples showing higher levels of aflatoxin. Additionally, no interaction was observed between crop types and processing methods, suggesting that the influence of processing methods on aflatoxin levels was consistent across both crops.

Table 2: Summary of Analysis of variance for Aflatoxin level (ppb) in processed maize and millet

Source of variation	DF	S.S	M.S	vr	F prob.
Rep stratum	1	1.9801	1.9801	8.77	
Crop type	1	0.9660	0.9660	4.28	0.130
Processing method	1	1.3122	1.3122	5.81	0.095
Crop type *processing method	1	0.0265	0.0265	0.12	0.755
Residual	3	0.6775	0.2258		
Total	7				4.9622

Note: DF=degree of freedom; S.S= Sum of Squares due to the source; M.S= sum of squares due to the source; vr= variance ratio; F pr.= F Probability

4.4 Effect of crop type * processing method interaction on aflatoxin levels (ppb)

The interaction between crop type and processing method did not have a significant effect on aflatoxin levels in the current study (Table 3). However, the results revealed that fully germinated and fermented maize showed higher levels of aflatoxin contamination (2.25 ppb), followed by fermented finger millet (1.44 ppb). Conversely, partially germinated finger millet had a significantly lower level of aflatoxin contamination (0.74 ppb). These findings suggest that the processing of malting maize and finger millet, from germination to the selling stage, can contribute to contamination which is in agreement with Torres et al. (2014) and Embashu, (2020) on post-harvest contamination and therefore requires careful monitoring. However, moisture plays a crucial role in aflatoxin contamination, and as maize retains more moisture during fermentation, it provides favorable conditions for fungal growth and subsequent increase in aflatoxin levels (Williams et al., 2014; Jallow et al., 2021). The differences in aflatoxin levels may also be attributed to various factors such as crop management practices and soil conditions in which the crops were grown (Seetha et al., 2017; Negash, 2018), post-harvest handling (Pandey et al., 2019; Kumar et al., 2022), as these factors can introduce the fungus. Qin et al. (2022) reported that malted finger millet and maize are key ingredients in the production of local sweet beer, so it is crucial to control aflatoxin contamination to ensure consumer health. Therefore, it is imperative to emphasize the importance of reducing aflatoxin levels in marketplace ingredients through appropriate measures and care.

Table 3: Crop type * processing method interaction on aflatoxin levels (ppb)

	Processing method	
Crop type	Partially germinated	Fully germinated
Finger millet	0.74	1.44
Maize	1.32	2.25
SED	0.475	

4.5 Effect of crop type on aflatoxin level (ppb)

Crop type did not have a significant effect on aflatoxin levels (ppb); however, maize samples exhibited a significantly higher mean of 1.7 ppb compared to finger millet samples (Table 4). This difference can be attributed to the post-harvest handling of maize (Pretari et al., 2019), which often involves poor storage practices, leading to increased aflatoxin levels during fermentation. These findings align with a previous study by Leslie et al. (2021), which indicates that aflatoxin contamination occurs both during pre-harvest stages and post-harvest activities, including the processing of malting grains. The results of this study also support the findings of Okoth, (2016) and Chiona et al. (2014) where 88 samples of processed products, including maize flour, makaka flour, kanyakaska, kadonoska, scrapes, dried cassava chips, and grates, were collected in Malawi and Zambia in 2008 and 2009. The study demonstrated significantly higher levels of aflatoxin in maize compared to other products in Malawi, compared to Zambia products. These results indicate that the drying practices for maize in Malawi are inadequate in effectively reducing aflatoxin levels which relates to Anitha et al. (2019) suggestions on aflatoxin management.

Table 4: Effect of crop type on aflatoxin levels (ppb)

Crop type	Aflatoxin level (ppb)
Finger millet	1.09
Maize	1.79
Grand Mean	1.44
F-prob	0.130
SED	0.336
CV%	33.0

4.6 Effect of processing methods on aflatoxin levels (ppb) of different crops

Based on randomly collected samples, it was found that fermented maize malt had a significantly higher mean of 1.84 ppb compared to partially germinated samples (Table 5). This difference in aflatoxin levels can be attributed to the poor post-harvest handling and storage practices for maize, which promotes fermentation and subsequently increase aflatoxin levels. These findings align with previous research by Leslie et al. (2021) and Nada et al. (2022), which suggests that aflatoxin contamination can occur during both pre-harvest and post-harvest stages, with the processing of malting grains serving as an example of post-harvest contamination. The presence of aflatoxin contamination in both partially germinated and fermented maize and finger millet malt indicates the widespread presence of the fungus in the air. When favorable conditions occur, such as poor drying and storage practices, the fungus germinates and leads to aflatoxin contamination. The quantity of contamination varied among the samples, suggesting different levels of susceptibility. However, it is important to note that these contamination levels fall within the permissible range of consumption, which is set at 4 ppb (Pandey et al., 2019). Despite the low levels, regular consumption of these contaminated cereals poses a significant risk of aflatoxin exposure to humans. Even small amounts of aflatoxin consumed over a long period can result in chronic aflatoxicosis, with health effects observed at levels as low as 1 ppb (Hoffmann et al., 2013).

Table 5: Effect of processing methods on aflatoxin levels (ppb) of different crops

Processing method	Aflatoxin level (ppb)
Partially germinated	1.03
Fully germinated	1.84
Grand Mean	1.44
F-prob	0.095
SED	0.336
CV%	33

The study findings highlight the importance of advising individuals to exercise control over the germination and drying processes of malting maize and finger millet to minimize the growth of molds and subsequent aflatoxin contamination. This preventive measure can help mitigate health problems such as liver cancer, growth retardation, particularly among young children, suppressed immunity, and even death. Additionally, using partially germinated malt may provide partial protection against the risk of exposure associated with consuming contaminated foods. It is crucial to educate people to avoid using fermented malt during brewing, as normal cooking cannot eliminate aflatoxin. By reducing these health hazards, we can contribute to the growth of the country's economy, as it will alleviate the burden on the government's healthcare expenses and services (Hoffmann et al., 2013; Fung et al., 2018). It is worth noting that malted maize and finger millet are key ingredients in the production of local brews widely consumed in Malawi. Although this study did not directly investigate the presence of aflatoxin in the brews, there is a high likelihood that the toxins can remain unchanged in the brews due to their resistance to normal cooking temperatures.

5.Conclusions and Recommendations

5.1 Conclusion

The study findings revealed that aflatoxin levels were not significantly different between maize and finger millet, although higher levels were detected in maize compared to finger millet. This difference could be attributed to the types of samples collected. All samples obtained from the markets were found to be contaminated. The results indicated that fully germinated and fermented maize had a high contamination level of 2.25 ppb, followed by fully germinated and fermented finger millet with 1.44 ppb. On the other hand, partially germinated maize exhibited a contamination level of 1.32 ppb, while partially germinated finger millet had a lower contamination level of 0.74 ppb. It was observed that only a few individuals controlled the germination of malting maize and finger millet, with most leaving the cereals to fully germinate. Additionally, inadequate drying of the malted cereals resulted in moisture retention, even during the packing and storage process in sack bags before market day. These findings emphasize the need for monitoring the processing of malting maize and finger millet from germination to the point of sale, as it contributes to contamination. The study demonstrated that the malted maize and finger millet being sold at the Msundwe and Ming'ongo markets were contaminated, although the levels were below the permissible consumption limit of 4 ppb. However, considering that these raw materials are frequently used in the production of sweet beer, even lower concentrations of aflatoxin pose a significant risk. It is crucial to provide participatory training for malt sellers on safe production practices to ensure the production of low-aflatoxin malt that can be used to produce sweet beers. This training will help mitigate the risk associated with aflatoxin contamination and ensure the production of safer products for consumers

5.2 Recommendations

The current study did not directly investigate the presence of aflatoxin in the brews, there is a need to conduct a further study which can shed more light. Sellers and farmers should undergo training on maize and finger millet malt handling and processing which will mitigate the risk associated with aflatoxin contamination and ensure the production of safer products for consumers.

Acknowledgments

The first author would like to acknowledge Malawi Adventist University (MAU), LakeView College for supporting this work. Many thanks to MAU Agriculture staff for excellent administrative support and Chitedze Research Station for the aflatoxin analysis.

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