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Article

Assessment of Handling Practices and Awareness of Aflatoxin Contamination in Spices among Micro and Small-Scale Processors in Tanzania

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Abstract: Frequent consumption of aflatoxins-contaminated spices has been linked to serious adverse health effects among consumers. The likelihood of exposure to these toxins is influenced by the level of public awareness. Controlling aflatoxins contamination throughout the food chain is critical for public health. This study aimed to assess the handling practices and awareness of aflatoxin contamination among micro- and small-scale spice processors. A total of 60 processors from 4 districts of two regions of Tanzania were interviewed. The results showed that while 56.7% of interviewed processors were aware of aflatoxin contamination in spices primarily through training (38.3%) and mass media (30%). However, there were still misconceptions regarding the causes and effects of aflatoxins to human health. It was observed that, poor drying and storage practices, inadequate monitoring of processors aggravated the situation. Nonetheless, all interviewed processors expressed willingness to participate in training programs to ensure quality and safety along the chain. The study findings underscore the necessity for targeted interventions to reduce aflatoxin risks in the spice value chain. These should include strengthened food safety inspections and enforcement, as well as tailored training and support for micro and small-scale spice processors. Enhancing their knowledge and ability to adopt proper handling, drying and storage practices is critical for enhancing food safety and safeguarding public health.

Keywords: Micro and Small-Scale Processors, Post-Harvest Handling, Aflatoxin Contamination, Tea Masala, Pilau Masala

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1. Introduction

Mycotoxins are harmful compounds produced by a wide variety of filamentous fungi often referred to as mycotoxigenic fungi (Majeed *et al*., 2018) [1]. These chemicals can infect a variety of agricultural products, such as nuts, cereals, spices, dried fruits, apples, and coffee beans, among others. Mycotoxins exposure to humans and animals could be through ingestion, inhalation and or absorption via the skin (Awuchi *et al*., 2022) [2]. Contamination in food and/ or spices can occur during the pre- and post-harvest stages. Improper drying, processing, transportation and storage contribute significantly to toxigenic fungal contamination such as *Aspergillus*, *Penicillium* and *Alternaria* species (Waliyar *et al*., 2015) [3]. Aflatoxins (B_1, B_2, G_1, and G_2) are produced by certain species of *Aspergillus*. Aflatoxins are primarily produced by *Aspergillus flavus* and *Aspergillus parasiticus* (Hammami *et al.*, 2014; Kong *et al*., 2014) [4,5].

Aflatoxins are classified by International Agency for Research on Cancer (IARC) as Group 1 carcinogens (Thanushree *et al*., 2019) [6]. Inevitably, inappropriate handling practices during processing and storage pose a substantial aflatoxin contamination risk to these commodities (Massomo, 2020) [7]. The tropical climate characterized by elevated temperature and high relative humidity promotes the growth of spoilage fungi in food products (Muga *et al*., 2019; Mutegi *et al*., 2013) [8,9] and subsequent production of mycotoxins. Consumption of aflatoxin contaminated food has been linked to chronic illnesses such as hepatitis, kidney failure and infant stunting. Aflatoxin contamination is more pronounced in the tropical countries where the climate favours fungal infection (Sewunet *et al*., 2024; Lesuuda *et al*., 2021, Kamala *et al*., 2016) [10-12]. The rate of exposure is high due to inefficient methods to control pests, inadequate transportation, storage, and processing facilities (Muga *et al*., 2019; Mutegi *et al*., 2013) [8,9]. However, aflatoxins exposure is widespread where guidelines and laws safeguarding quality and safety of food are not fully enforced (Chilaka *et al*., 2022) [13].

Good post-harvest handling practices are effective strategies to control or reduce aflatoxins contamination along the food value chains (Manandhar *et al*., 2018; Kumar and Kalita, 2017) [14,15]. However, small-scale processors often have inadequate knowledge on best post-harvest handling practices, exposing their products to aflatoxins contamination. Inadequate implementation of aflatoxin prevention and control techniques in the spice value chain exposes the public to a significant risk of exposure. Although aflatoxin is difficult to eliminate once it enters the food chain, it is preventable with sufficient stakeholders' awareness and government intervention. The objective of this study is to assess the handling practices and awareness of aflatoxin contamination among small-scale spice processors. The study will provide useful insights into the opportunities and challenges faced by the micro and small-scale spice processors in the country. It may also lead to development of sector-wide interventions to control aflatoxin contamination along the value chain.

2. Materials and methods

2.1. Study area

A survey was conducted on micro- and small-scale spice processors at Muheza and Tanga District Councils in Tanga Region, and Kinondoni and Ilala Districts in Dar es Salaam Region. Tanga is among the major spices producing regions in the country, while Dar es Salaam is the major market. Tanga is located at geographical coordinates 5.0889°S, 39.1023°E with an estimated population of 2,615,597 while Dar es Salaam is at 6.7924°S, 39.208°E with an estimated population of 5,383,728 (Census 2022).

2.2. Study design

A cross-sectional design was used to gather information from 60 micro and small-scale spice processors on operational, handling practices and awareness of aflatoxin contamination in tea and pilau masala. A semi-structured questionnaire which was pre-tested was used for the interview. Although the questionnaire was developed in English, it was translated into Swahili to facilitate the interview.

2.3. Sample size

The sample size was estimated using the Kothari equation (Kothari and Garg, 2014).

$$n = \frac{z^2 p(1-p)}{e^2} \quad (1)$$

Where, n= sample size, z = standard variation at a given confidence level, for this study a 95% confidence level = 1.96, the maximum probability was chosen to be 0.5 and e = allowable/acceptable error set at 12.6491% (0.126491).

$$n = \frac{(1.96)^2 0.5(1-0.5)}{(0.126491)^2} \approx 60 \quad (2)$$

Four districts (Muheza, Tanga council, Ilala and Kinondoni) were purposively selected based on the availability of spice processors as recommended by trade officers in the respective regions. A multistage sampling technique was used to select 60 spice processors (30 from each region and 15 processors from each district).

2.4. Data analysis

Statistical Package for Social Sciences (SPSS) software version 26 was used to analyze data. Descriptive statistics such as frequency and percentage were used to present demographic characteristics, operational and handling practices as well as the levels of aflatoxin awareness of micro and small-scale spice processors.

3. Results and Discussion

3.1. Socio-demographic characteristics of the interviewed processors

Although spice processing is carried out by both males and females, (Table 1), females were the majority (71.7%). A similar trend was observed in a study in Kenya, where 64% of spice processors were women (Marangu, 2021) [16]. Likewise, a study in Benin reported that 78.2% of spices and aromatic herbs processors were females (Anihouvi *et al*., 2016) [17]. However, contrary to these findings, studies by Fundikira *et al.* (2021) [18] in Dar es Salaam and Bullock *et al*. (2018) [19] in East Usambara, Tanzania indicated that men dominated the spice value chain. This could be due to the scale of operations and the structure of the spice value chain. In the current study, respondents were from micro and small-scale processors, mostly done at home, which typically involved more women. In contrast, men are more likely to be drawn to large-scale, commercialized spice businesses that involve bulk drying, packaging and marketing. These discrepancies highlight the need to consider gender-based variations in handling practices and knowledge when designing food safety interventions.

This study also found that the majority of the spice processors (60%) were aged between 31-45 years, while none of them were below 18 years. This suggests that most of processors were adults and middle aged, making them more likely to be aware of fungal contamination particularly aflatoxins compared to other age groups as reported by Nguegwouo *et al*. (2018) [20] and Isbill *et al*. (2018) [21]. Similarly, a study conducted in the Democratic Republic of Congo observed that the majority of farmers were middle-aged (Udomkun *et al*., 2018) [22].

Age distribution further supports the finding that middle-aged adults are more active in processing, possibly due to financial responsibility, experience, or societal roles. Yet low participation from youth, especially those in the age of 18-30 (18.3%), reflects limited engagement of younger demographics in value-added agricultural processing. This might result in the loss of innovation opportunities, especially in adopting digital and mobile solutions for training or market access. Future interventions should explore integrating youth through entrepreneurship support programs.

However, the results from this study differs from those reported by Lee *et al*. (2017) [23] who found that, young farmers (aged 21-29) were more likely to be aware of aflatoxin in maize than the older counterparts. These variations could be attributed to differences in experiences from processing other mycotoxin infected products such cereals. It is important to recognize the need for tailored interventions that target the particular strengths and gaps in knowledge of different age groups. In order to promote a more comprehensive strategy to reduce the dangers of aflatoxin and fungal contamination, future plans should focus on utilizing the expertise of experienced processors while also involving younger aged group, who may be more receptive in adopting innovative approaches. Additionally, the absence of responders under the age of 18 suggests that spice processing is uncommon among young people, possibly due to labor restrictions or the specialized knowledge required by the spice industry, limited interest or may be lack of capital.

More than half of interviewed processors (51.7%) had secondary education level, yet this does not appear to translate into a higher awareness or better practices in aflatoxin prevention. The studies conducted in Tanzania by Ngoma *et al*. (2017) [24] and Magembe *et al*. (2016) [25], suggested that educated individuals were more conscious of fungal contamination in food than those with less education. Anitha *et al*. (2019) [26] and Udomkun *et al*. (2018) [22], reported that, educated individuals were more likely to access and comprehend aflatoxins-related information, which empowered them to implement better measures to reduce contamination. Likewise, Anihouvi *et al*. (2016) [17] pointed out that inadequate training restricts awareness, highlighting the need of education in expanding understanding of aflatoxins and efficient management techniques. This gap suggests that while general education is important, targeted food safety training is essential for behavior change in spice processing. There is also a missed opportunity to integrate food safety modules into adult education or vocational training schemes to improve awareness and hygiene practices.

Table 1. Demographic characteristics of spice processors (N=60)

Variable	Category	Frequency (N=60)	Percent (%)
Gender	Male	17	28.3%
	Female	43	71.7%
Age (in years)	Below 18	0	0%
	18 to 30	11	18.3%
	31 to 45	36	60%
	Above 45	13	21.7%
Education level	Not attended	0	0%
	Primary education	25	41.7%
	Secondary education	31	51.7%
	Post-secondary/tertiary school education	4	6.7%
Marital status	Married	45	75%
	Not married	7	11.7%
	Divorced	4	6.7%
	Widowed	3	5%
	Separated	1	1.6%

3.2. Operational characteristics and compliance of processors

A notable finding from this study (Table 2), is the informal nature of operations for nearly half of the processors (46.7%). Although 5% (n= 3) had attempted to certify their products, one company succeeded. Despite 58.3% reporting awareness of national standards, only 20% had ever been inspected by government bodies such as TBS. This suggests that many businesses operate with minimal oversight from national food safety authorities increasing the risk of aflatoxin contamination. The lack of inspections by regulatory authorities weakens the entire systems and mechanisms in place to protect public health and ensure food safety. Processors, who were registered with local government authorities (78.1%) or BRELA (6.3%), believed they had fulfilled their obligations, but a few (5%) understood that food safety standards go beyond business registration.

Integration of regulatory inspections with educational outreach could address this gap effectively. Moreover, the current system of centralized inspections does not adequately reach rural processors. Establishing regional food safety task forces or mobile training-inspection units could bridge the enforcement gap. Incentive-based approaches such as public recognition, market linkages, or subsidies for compliant businesses could also increase voluntary adherence to standards. The lack of enforcement not only undermines food safety objectives but also discourages processors from improving standards. The low uptake of formal registration also reflects a broader challenge in aligning regulatory systems with the realities of micro and small-scale enterprises. Most of these businesses operate with minimal capital, limited literacy, and without access to regulatory advisory services. The government and development partners need to explore mobile inspection teams, simplified digital certification portals, or cooperative-based group certifications to reduce the compliance burden.

However, formalization through registration and certification remains a challenge for many companies which remain unregistered (Mwenhwandege, 2020) [27]. Informal operated businesses are less likely to adhere to appropriate hygiene, handling and storage practices and thus increase the likelihood of aflatoxin and fungal contamination (Okaekwu, 2019; Fanta and Tesafa, 2018) [28,29]. Increased levels of aflatoxins in a variety of agricultural products have been connected to inadequate implementation of food safety regulations, endangering the health of consumers (Udomkun *et al*., 2018; Ezekiel *et al*., 2012) [22,30]. To reduce these hazards and enhance overall food safety compliance, inspection should be strengthened. Regular inspection is crucial for preventing outbreaks of foodborne illnesses and safeguarding public health (Faour-Klingbeil and Todd, 2020) [31].

Additionally, the study showed that a large proportion of processors (78.3%) had been involved in spice processing for a relatively short period (1–5 years). This limited duration of engagement may contribute to insufficient understanding of aflatoxin risks, highlighting the need for targeted training on food safety standards and contamination prevention. Previous studies have found that, lack of experience in food processing is frequently connected with inadequate awareness of mycotoxin contamination and insufficient implementation of safety measures (Kamala *et al*., 2016; Matumba *et al*., 2016) [12,32]. Training and capacity-building activities have proven to increase food safety knowledge and improve handling practices among processors, lowering the risk of aflatoxin contamination (Anihouvi *et al*., 2016; Udomkun *et al*., 2017) [17,33].

Even though more than half of processors (58.3%) are aware of the national standards for spices, about 42% are not aware, which might lead to inappropriate practices that increase the possibility of contamination. While 55% correctly identified the Tanzania Bureau of Standards (TBS) as the regulating authority, a small fraction (3.3%) yet recognizes the Tanzania Food and Drug Authority (TFDA), which has been dissolved since 2019. This situation illustrates that some processors are not aware of the changes and developments in the food regulatory framework of the country. Moreover, they have never been inspected by such regulatory bodies. This emphasizes the importance of improving the dissemination of regulatory information and ensures more clarity about the roles of relevant authorities.

Table 2. Operational characteristics, awareness and compliance of spice processors

Variable	Category	Frequency (N=60)	Percentage (%)
Duration in spices processing	Less than one year	7	11.7%
	1-5 years	47	78.3%
	More than 5 years	6	10.0%

Ever heard about national standards for spices?	Yes	35	58.3%
	No	25	41.7%
Who set the Standards	TBS	33	55.0%
	TFDA	2	3.3%
	None of the above	25	41.7%
Attempted to certify your product(s)	Yes	3	5.0%
	No	57	95.0%
Did you succeed	Yes	1	33.3%
	No	2	66.7%
Company inspected by TBS or any government officials	Yes	12	20.0%
	No	48	80.0%
How often	Once	10	16.7%
	More than once	2	3.3%
	Not inspected at all	48	80.0%
Company registered	Yes	32	53.3%
	No	28	46.7%
Have a registration certificate	Yes	32	53.3%
	No	28	46.7%
Who issued the certificate	BRELA	2	6.3%
	TBS	1	3.1%
	LGAs	25	78.1%
	TFDA	4	12.5%
	Others	0	0.0%

3.3. Handling practices among the spice processors

The study identified several high-risk practices associated with post-harvest spice handling (Table 3). Most processors sourced spices from markets outlets (71.7%) and received them in dried form (95%), limiting control over pre-processing quality. Studies have shown that spices bought from markets frequently showed inadequate post-harvest handling, such as improper drying, poor storage and exposure to contamination, all of which aggravate the possibility of aflatoxin contamination (Satheesh *et al*., 2023; Fanta and Tesafa, 2018) [29,34]. A study by Fundikira *et al.,* (2021) [18] in Dar es Salaam, Tanzania, evaluated aflatoxin contamination in spices and revealed that 96.7% of retailers were not aware of the potential risks associated with poor storage.

Although 76.7% of processors further dried spices before processing, the methods used often included ground drying on basic canvases which are inappropriate for ensuring food safety. Only 1.7% used solar driers, and none reported using electric dryers, indicating limited adoption of improved drying technologies. According to Anitha *et al.* (2019) [26] and Udomkun *et al*., (2018) [22], proper drying minimizes microbial development, prevents spoilage and lowers the risks of contamination including aflatoxin. Directly drying spices on the bare ground could result in contamination from dust, dirt, insects, bird droppings and microorganisms including aflatoxigenic moulds. Uneven drying of spices is likely due to moisture uptake from the soil that may ultimately cause spoilage (Anihouvi *et al*., 2016; Kumar *et al*., 2017; Udomkun *et al*., 2018) [17,22,35]. Therefore, use of tarpaulins and other efficient drying methods are crucial to maintain the safety and quality of agricultural products including spices (Anitha *et al*., 2019) [26].

Although majority of processors relied on direct sun drying, assessment of moisture content of dried spices is done inadequately. Instead, they relied on subjective methods such as visual inspection, biting or auditory cues. Given that residual moisture is a key factor in mold proliferation and aflatoxin production, the reliance on such subjective methods poses a significant food safety risk (Kobia, 2022; Pitt *et al*., 2013) [36,37]. None of the processors had moisture meters or send samples to food analysis laboratories to assess moisture of their spices. This calls for an immediate action to ensure that processors monitor moisture content of their spices since it is a critical factor for spices quality and safety. Besides, moisture contributes to weight of spices, if not well dried, customers may end up purchasing a significant proportion of water than spices.

Despite the fact that sorting is widely adopted (93.3%, Table 3), it was largely based on foreign matter or discoloration rather than targeting signs of mold contamination. It has been reported that, physical sorting and screening which involve exclusion of produce with potential contamination symptoms like size, color or form, is a cost-effective method for reducing aflatoxin contamination (Sipos *et al*., 2021) [38]. Similarly, elimination of damaged or broken grains/kernels has been reported to be post-harvest mitigation measures for lowering aflatoxins in maize and maize products (Kimatu *et al*., 2012) [39]. However, not all tainted spices may display noticeable evidence of mold development or color change. Confirmation of mould contamination in spices should not rely on visual assessment but through laboratory analysis, since contamination even at low levels could result into toxin production depending on the environment. Additionally, fungal development may take place inside the spice matrix, where it is invisible from the outside, or it may stop creating mycotoxins, leaving no apparent evidence (Kumar *et al*., 2017) [35].

Furthermore, 41.7% did not store spices before processing, while others stored them for up to four months under unverified conditions. These durations increase exposure to fluctuating humidity, facilitating fungal growth and toxin formation. Storage infrastructure and practices were inconsistently implemented. Most processors used shared or multipurpose storage areas, often lacking temperature or humidity control. Some reported storing spices in living rooms or kitchens. This not only undermines product quality but also poses risks to household members who may unknowingly inhale mold spores or consume contaminated food. The correlation between poor storage and aflatoxin levels has been repeatedly documented (Fundikira *et al*., 2021; Adekoya *et al*., 2017) [18,40]. Development programs should prioritize community-based storage facilities or provide affordable modular storage units for microprocessors. Packaging practices showed some encouraging trends. Most processors (93.3%) packed spices post-processing, using plastic containers or bags (88.3%). These materials can help prevent air and moisture exposure when properly used, and thus reduce the likelihood of fungal growth (Adekoya *et al*., 2017) [40]. However, the study did not assess sealing practices or environmental storage conditions, which are critical to ensuring the effectiveness of packaging in controlling contamination.

Table 3. Handling practices by micro and small-scale spice processors of tea and masala

Variable	Category	Frequency (N=60)	Percentage (%)
Source of raw materials	From farmers	12	20.0%
	Market outlets	43	71.7%
	Farmers and outlets	5	8.3%
Condition in which spices are received	Raw/fresh from farm	3	5.0%
	Dried	57	95.0%
Criteria for purchasing raw material	Yes	52	86.7%
	No	8	13.3%
Most important criteria	Price	10	16.7%
	Visual inspection	1	1.7%
	Mould infested	5	8.3%
	Cleanliness	32	53.3%

	Moistness	4	6.7%
	Others	8	13.3%
Further drying of spices prior to processing	Yes	46	76.7%
	No	14	23.3%
Where spices are dried	On the ground yard	8	13.3%
	Over the roof	5	8.3%
	On canvas/tarpaulin	27	45.0%
	On raised bed(kichanja)	5	8.3%
	Solar drier	1	1.7%
	Electrical drier	0	0.0%
	none	14	23.3%
	Others	0	0.0%
Knowledge to identify well-dried spices	Yes	60	100.0%
	No	0	0.0%
Method to confirm dryness	Visual assessment	32	53.3%
	Biting with teeth	9	15.0%
	Measure moisture content	0	0.0%
	Sound	19	31.7%
	Others	0	0.0%
Measure moisture level	Yes	0	0.0%
	No	60	100.0%
Store spices	Yes	35	58.3%
	No	25	41.7%
Storage time prior to processing	Less than a week	6	10.0%
	1 to 4 weeks	16	26.7%
	1 to 4 months	5	8.3%
	More than 4 months	8	13.3%
	Do not store	25	41.7%
Sorting prior processing	Yes	56	93.3%
	No	4	6.7%
Sorting criteria	Mould infested	13	21.7%
	Discoloration	15	25.0%
	Foreign matter/Damaged	28	46.7%
	None of the above	4	6.7%
Handling of spoiled spices	Discard it	54	90.0%
	Mix with others and use	0	0.0%
	Re-dry and use	2	3.3%
	No sorting at all	4	6.7%
Poor storage condition promotes mold growth	Yes	58	96.7%
	No	2	3.3%
Further packing after processing	Yes	56	93.3%
	No	4	6.7%
Packaging materials used	Plastic containers/bags	53	88.3%
	Glass bottles	3	5.0%
	Paper bags	0	0.0%
	Others	4	6.7%

3.4. Awareness of Aflatoxins

While 68.3% of respondents were aware of mycotoxins in food and 56.7% specifically knew about aflatoxins, many held incorrect beliefs about their origins (Table 4). Only 35% correctly identified moulds as the source, while others attributed them to insects, rodents, or were unsure. Awareness was primarily gained through training (38.3%) and mass media (30%), including radio, television, and newspapers. Awareness of the health effects of aflatoxins was similarly limited. While cancer (26.7%) and death (21.7%) were recognized as potential risks, stunting and vomiting were rarely mentioned and 43.3% of respondents were unaware of any specific health risks. These misconceptions mirror findings from studies on maize and milk producers in East Africa, where aflatoxin knowledge remains superficial despite ongoing sensitization campaigns (Ndwata *et al*., 2022; Ayo *et al*., 2018; Kamala *et al*., 2016) [12,41,42]. Similarly, Magembe *et al*. (2016) [25] reported that the majority of respondents in their study were unaware of the health risks posed by mycotoxins, highlighting a persistent knowledge gap regarding mycotoxin awareness and its effects on human health and food security.

Lack of training was closely associated with these knowledge gaps, as 46.7% of respondents had not attended any training related to food handling or processing. Encouragingly, 100% expressed willingness to participate in future training, presenting an opportunity for structured capacity-building interventions. Several studies have emphasized the need for regular training and awareness campaigns among stakeholders in agricultural production as a mitigation measure to reduce aflatoxin contamination (Sewunet *et al*., 2024; Joutsjoki & Korhonen, 2021; Falade, 2019; Kamala *et al*., 2016) [10,12,43,44]. Likewise, Ndemera *et al*. (2020) [45] highlighted that awareness and education are essential in lowering the threat of mycotoxins in developing countries. Anitha *et al*. (2019) similarly pointed to insufficient knowledge of pre- and post-harvest aflatoxin mitigation strategies among smallholder households in Malawi as a contributing factor to high contamination levels in the study area.

Conversely, some studies have linked high levels of aflatoxin awareness in certain populations to past experiences with aflatoxicosis outbreaks, such as the 2016 outbreak in Dodoma and Manyara regions, which resulted from the consumption of contaminated maize (Massomo, 2020) [7].

To ensure behavioral change, future training should extend beyond defining aflatoxins and their symptoms. Training modules should incorporate storytelling, real-life outbreak case studies, visual demonstrations, and simulations of contamination scenarios. Additionally, using local languages and peer-to-peer training models may enhance knowledge retention and encourage the adoption of safer practices.

Table 4. Processors awareness on aflatoxin contamination in tea and pilau masala

Variable	Category	Frequency (N=60)	Percentage (%)
Awareness of mycotoxins in food	Yes	41	68.30%
	No	19	31.70%
Source of information	Hospital	0	0.00%
	Colleagues	3	5.00%
	Mass media	15	25.00%
	Training	23	38.30%
	None of the above	19	31.70%
Know where do these toxins come from	Yes	37	61.70%
	No	23	38.30%
Source of toxins	Moulds	21	35.00%
	Insects	10	16.70%
	rodents and mites	6	10.00%
	None of the above	23	38.30%
Awareness of aflatoxin in spices	Yes	34	56.70%
	No	26	43.30%

Identification of aflatoxin contaminated spices	Yes	31	51.70%
	No	29	48.30%
Aware of health effect caused by aflatoxin to human	Yes	34	56.70%
	No	26	43.30%
Health effects	Cancer	16	26.70%
	Vomiting	3	5.00%
	Stunting of children	2	3.30%
	Death	13	21.70%
	Others	26	43.30%
Attended any training related to food handling and processing	Yes	32	53.30%
	No	28	46.70%
Willing to participate training to acquire knowledge	Yes	60	100.00%
	No	0	0.00%

4. Conclusion and recommendations

This study assessed the handling practices and levels of awareness regarding aflatoxin contamination among micro and small-scale spice processors in Tanzania. The findings revealed several critical gaps in knowledge, operational compliance, and post-harvest practices that elevate the risk of aflatoxin contamination along the spice value chain. Key issues identified include reliance on informal sourcing and drying practices, absence of scientific moisture testing, lack of certification and inspections, and limited understanding of the origins and health effects of aflatoxins. These challenges were exacerbated by economic constraints, informal operations, and insufficient training. However, the high willingness among respondents to participate in future training provides a strong foundation for intervention.

To mitigate the risks associated with aflatoxin contamination, the study recommends a multifaceted approach: (1) targeted training programs that go beyond awareness to include practical demonstrations and use of affordable tools like moisture meters; (2) simplified, subsidized certification procedures to support formalization of micro-enterprises; (3) mobile inspection and advisory units to reach remote and informal processors; and (4) integration of aflatoxin control into broader public health, agricultural extension, and nutrition strategies. Such efforts must be participatory, context-sensitive, and inclusive of women, who dominate the spice processing sector. The insights gained from this research serve as an evidence base for shaping policies, designing programs and coordinating multi-sectoral efforts to enhance food safety, protect public health and improve the livelihoods of small-scale processors in Tanzania.

Conflicts of interest

The authors have declared no conflicts of interest related to this study.

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Appendices

Appendix 1: A questionnaire to assess handling practices and awareness of aflatoxin contamination in spices among micro and small-scale processors

A. General information

1. Gender of respondent: Male Female
2. Age of respondent
   i. Below 18
   ii. 18-30
   iii. 31-45
   iv. Above 45
3. Level of education
   i. Informal education
   ii. Primary school education
   iii. Secondary school education
   iv. Post-secondary/ tertiary school education
4. Marital status
   i. Not married
   ii. Married
   iii. Divorced
   iv. Widowed
   v. Separated

B. Operational characteristics of respondents

1. How long have you been in spices processing industry?
   i. Less than one year
   ii. 1 to 5 years
   iii. More than 5 years
2. How many kilos/tones of spices processed per month?
   i. Less than 50kg
   ii. 50-100Kg
   iii. More than 100kg
3. (a) Have you ever heard about national standard for spices? Yes No
   (b) If yes, who is responsible to set those standards?
   i. TBS
   ii. TFDA
   iii. None of the above
4. (a) Have you tried to get the TBS certificate for your products? Yes No

   (b) Were you successful? Yes No
5. (a) Has your company inspected by TBS or any government officers? Yes No
   (b) If yes, how often in a year have been inspected?
   i. Once
   ii. More than once
   iii. Not inspected at all
6. (a) Is your company registered? Yes No
   (b) Do you have a registration certificate? Yes No
   (c) If yes, who issued the certificate?
   i. BRELA
   ii. TFDA
   iii. TBS
   iv. LGAs

v. Others........

C. Assessment of respondent handling practices

1. Where do you get your raw materials?
   - i. From farmers
   - ii. Market outlets
   - iii. Both
2. In what condition do you receive your spices?
   - i. Raw/fresh from farm
   - ii. Dried
   - iii. Both
3. (a) Are there criteria for purchasing/receiving raw materials? Yes No
   (b) If yes, what do you consider as the most important quality criteria for purchasing your raw materials?
   - i. Price
   - ii. Visual inspection
   - iii. Mould infested
   - iv. Moistness
   - v. Cleanliness
   - vi. Others ……
4. (a) Do you do further drying of spices prior to processing? Yes No
   (b)If yes, where do you dry your spices?
   - i. On the ground yard
   - ii. Over the roof
   - iii. On canvas/tarpaulin
   - iv. On raised bed (kichanja)
   - v. Solar drier
   - vi. Electric drier
   - vii. Other …………………
5. (a) Do you know how to identify well dried spices? Yes No
   (b) If yes, how do you establish that the spices have been well dried?
   - i. Visual assessment
   - ii. Biting with teeth
   - iii. Measure moisture content
   - iv. Sound
   - v. Others (specify).....................
6. (a) Do you conduct moisture testing of your spices? Yes No
7. (a) Do you store your spices? Yes No
   (b) For how long do you store spices prior to processing?
   - i. Less than a week
   - ii. 1 to 4 weeks
   - iii. 1 to 4 months
   - iv. More than 4 months

   (c)What type of storage facility do you use to store your spices?
   - i. Plastic containers
   - ii. Plastic/synthetic bags
   - iii. Jute/sisal bags
   - iv. Paper bags/boxes
   - v. Others (specify).......................

   (d)Where do you keep the storage facilities?
   - i. On pallets
   - ii. On rack
   - iii. In shelves
   - iv. On the floor

v. Others (specify).......................................

8. (a) Do you sort your raw spices before processing? Yes No
   (b) If yes, what criteria do you consider?
   i. Mould infested
   ii. Discoloration
   iii. Foreign matters/Damaged
   iv. Others
   (c) In case there are spoiled spices what do you do?
   i. Discard it
   ii. Mix with others and used
   iii. Re-dry and use
   iv. Others (specify)...............
9. (a) Do you pack your final product? Yes No
   (b) If yes, what type of packaging materials do you use?
   i. Plastic containers/bottles
   ii. Paper bags
   iii. Glass bottles
   iv. Others (specify).............................
   v. Why do you use that type of packaging material (s)? ....

D. Awareness of small-scale spice processors on Aflatoxin contamination

1. Have you ever heard the word mycotoxins (sumu kuvu) before? Yes No
2. Where did you get this information from?
   i. Hospital
   ii. Village meeting
   iii. Colleague
   iv. Mass media
   v. Training
   vi. Others (Specify)………….
3. Are you aware that mycotoxins can contaminate food? Yes No
4. Are you aware of aflatoxins contamination in spices? Yes No
5. Can you identify it on spices? Yes No
6. (a) Do you know where do these toxins come from? Yes No
   (b) If yes, what could be the source?
   i. Moulds
   ii. Insects
   iii. Rodents and mites
   iv. Others (specify) ....
7. In your opinion, what are the conditions that accelerate mould growth on spices/ AFL contamination to spices? ....
8. (a) Are you aware of the health effects caused by aflatoxin to human being? Yes No
   (b) If yes please mention
   i. Cancer
   ii. Stunting of children
   iii. Vomiting
   iv. Death
   v. Others (specify)……………………………
9. (a) Have you attended any training related to food handling and processing? Yes No

(b) If yes, who offered the training?
   i. SIDO
   ii. TBS
   iii. TFDA
   iv. Any other institutions
   v. None of the above

10. If provided with knowledge, will you be willing to participate so as to meet the standards? Yes No

References

[1] Majeed, S., De Boevre, M., De Saeger, S., Rauf, W., Tawab, A., Rahman, M., & Iqbal, M. (2018). Multiple mycotoxins in rice: Occurrence and health risk assessment in children and adults of Punjab, Pakistan. *Toxins,* 10(2), 77.

[2] Awuchi, C. G., Ondari, E. N., Nwozo, S., Odongo, G. A., Eseoghene, I. J., Twinomuhwezi, H., & Okpala, C. O. R. (2022). Mycotoxins' toxicological mechanisms involving humans, livestock and their associated health concerns: A review. Toxins, 14(3), 167.

[3] Waliyar, F., Osiru, M., Ntare, B. R., Kumar, K. V. K., Sudini, H., Traore, A., & Diarra, B. (2015). Post-harvest management of aflatoxin contamination in groundnut. *World Mycotoxin Journal*, 8(2), 245-252.

[4] Hammami, W., Fiori, S., Al Thani, R., Kali, N. A., Balmas, V., Migheli, Q., & Jaoua, S. (2014). Fungal and aflatoxin contamination of marketed spices. Food Control, 37, 177-181.

[5] Kong, Q., Chi, C., Yu, J., Shan, S., Li, Q., Li, Q., ... & Bennett, J. W. (2014). The inhibitory effect of Bacillus megaterium on aflatoxin and cyclopiazonic acid biosynthetic pathway gene expression in Aspergillus flavus. *Applied microbiology and biotechnology*, *98*(11), 5161-5172.

[6] Thanushree, M. P., Sailendri, D., Yoha, K. S., Moses, J. A., & Anandharamakrishnan, C. (2019). Mycotoxin contamination in food: An exposition on spices. *Trends in Food Science & Technology*, 93, 69-80.

[7] Massomo, S. M. (2020). *Aspergillus flavus* and aflatoxin contamination in the maize value chain and what needs to be done in Tanzania. Scientific African, 10, e00606.

[8] Muga, F. C., Marenya, M. O., & Workneh, T. S. (2019). Effect of temperature, relative humidity and moisture on aflatoxin contamination of stored maize kernels. *Bulgarian Journal of Agricultural Science*, *25*(2).

[9] Mutegi, C., Wagacha, M., Kimani, J., Otieno, G., Wanyama, R., Hell, K., & Christie, M. E. (2013). Incidence of aflatoxin in peanuts (Arachis hypogaea Linnaeus) from markets in Western, Nyanza and Nairobi Provinces of Kenya and related market traits. *Journal of Stored Products Research*, 52, 118-127.

[10] Sewunet, S. D., Kebede, E., Melaku, A., Yirga Assefa, A., Alebie, A., Assefa, A., & Kenubih, A. W. (2024). Dairy Farmers' Knowledge, Attitudes, and Practices (KAP) Towards Aflatoxin Contamination in Milk and Feeds in Bahir Dar, Ethiopia. *International Journal of Microbiology*, *2024*(1), 5568286.

[11] Lesuuda, L., Obonyo, M. A., & Cheserek, M. J. (2021). Determinants of knowledge about aflatoxin and fumonisin contamination in sorghum and postharvest practices among caregivers of children aged 6–59 months in Kerio Valley, Kenya. *Food Science & Nutrition*, *9*(10), 5435-5447.

[12] Kamala, A., Kimanya, M., Haesaert, G., Tiisekwa, B., Madege, R., Degraeve, S., ... & De Meulenaer, B. (2016). Local post-harvest practices associated with aflatoxin and fumonisin contamination of maize in three agro ecological zones of Tanzania. *Food Additives & Contaminants: Part A*, *33*(3), 551-559.

[13] Chilaka, C. A., Obidiegwu, J. E., Chilaka, A. C., Atanda, O. O., & Mally, A. (2022). Mycotoxin regulatory status in Africa: a decade of weak institutional efforts. Toxins, 14(7), 442.

[14] Manandhar, A., Milindi, P., & Shah, A. (2018). An overview of the post-harvest grain storage practices of smallholder farmers in developing countries. Agriculture, 8(4), 57.

[15] Kumar, D., & Kalita, P. (2017). Reducing postharvest losses during storage of grain crops to strengthen food security in developing countries. *Foods*, 6(1), 8.

[16] Marangu, V. M. (2021). Aflatoxin Analysis in Staple Food Cereals and Assessment of Households' Awareness on its Management in Tharaka-Nithi County, Kenya (Doctoral dissertation, KeMU).

[17] Anihouvi, V. B., Vissoh, V. P., Gbaguidi, F., & Soumanou, M. (2016). Processing, storage methods and quality attributes of spices and aromatic herbs in the local merchandising chain in Benin. *African Journal of Agricultural Research*, *11*(37), 3537-3547.

[18] Fundikira, S. S., De Saeger, S., Kimanya, M. E., & Mugula, J. K. (2021). Awareness, handling and storage factors associated with aflatoxin contamination in spices marketed in Dar es Salaam, Tanzania. *World Mycotoxin Journal*, *14*(2), 191-200.

[19] Bullock, R., Gyau, A., Mithoefer, D., & Swisher, M. (2018). Contracting and gender equity in Tanzania: using a value chain approach to understand the role of gender in organic spice certification. *Renewable Agriculture and Food Systems*, *33*(1), 60-72.

[20] Nguegwouo, E., Sone, L. E., Tchuenchieu, A., Tene, H. M., Mounchigam, E., Njayou, N. F., & Nama, G. M. (2018). Ochratoxin A in black pepper, white pepper and clove sold in Yaoundé (Cameroon) markets: contamination levels and consumers' practices increasing health risk. *International Journal of Food Contamination*, *5*, 1-7.

[21] Isbill, J., Kandiah, J., & Khubchandani, J. (2018). Use of ethnic spices by adults in the United States: An exploratory study. *Health promotion perspectives*, *8*(1), 33.

[22] Udomkun, P., Wossen, T., Nabahungu, N. L., Mutegi, C., Vanlauwe, B., & Bandyopadhyay, R. (2018). Incidence and farmers' knowledge of aflatoxin contamination and control in Eastern Democratic Republic of Congo. *Food science & nutrition*, *6*(6), 1607-1620.

[23] Lee, H. S., Nguyen-Viet, H., Lindahl, J., Thanh, H. M., Khanh, T. N., Hien, L. T. T., & Grace, D. (2017). A survey of aflatoxin B1 in maize and awareness of aflatoxins in Vietnam. *World Mycotoxin Journal*, *10*(2), 195-202.

[24] Ngoma, S. J., Kimanya, M., Tiisekwa, B., & Mwaseba, D. (2017). Perception and attitude of parents towards aflatoxins contamination in complementary foods and its management in central Tanzania. *10*(4086), 1-16.

[25] Magembe, K. S., Mwatawala, M. W., Mamiro, D. P., & Chingonikaya, E. E. (2016). Assessment of awareness of mycotoxins infections in stored maize (Zea mays L.) and groundnut (arachis hypogea L.) in Kilosa District, Tanzania. *International Journal of Food Contamination*, *3*, 1-8.

[26] Anitha, S., Tsusaka, T. W., Njoroge, S. M., Kumwenda, N., Kachulu, L., Maruwo, J., & Okori, P. (2019). Knowledge, attitude and practice of Malawian farmers on pre-and post-harvest crop management to mitigate aflatoxin contamination in groundnut, maize and sorghum—implication for behavioral change. *Toxins*, *11*(12), 716.

[27] Mwenhwandege, D. K. (2020). Compliances to Laws, Regulations and Policies Governing Corporate Business in Tanzania: General and Crosscutting Regulatory Issues (Doctoral dissertation, The Open University of Tanzania).

[28] Okaekwu, C. K. (2019). Fungal and aflatoxin occurrence in small-scale processed dry foodstuffs sold at informal retail outlets in the Johannesburg metropolis, South Africa.

[29] Fanta, A., & Tesafa, F. (2018). Aflatoxin related challenges and mitigation strategies of Ethiopia in spices, herbs and pulses' domestic and international markets. BENEFIT-ENTAG report.

[30] Ezekiel, C. N., Sulyok, M., Warth, B., & Krska, R. (2012). Multi-microbial metabolites in fonio millet (acha) and sesame seeds in Plateau State, Nigeria. *European Food Research and Technology*, 235, 285-293.

[31] Faour-Klingbeil, D., & CD Todd, E. (2020). Prevention and control of foodborne diseases in Middle-East North African countries: Review of national control systems. *International Journal of Environmental Research and Public Health,* 17(1), 70.

[32] Matumba, L., Monjerezi, M., Kankwamba, H., Njoroge, S. M., Ndilowe, P., Kabuli, H., ... & Njapau, H. (2016). Knowledge, attitude, and practices concerning presence of moulds in foods among members of the general public in Malawi. Mycotoxin research, 32, 27-36.

[33] Udomkun, P., Wiredu, A. N., Nagle, M., Müller, J., Vanlauwe, B., & Bandyopadhyay, R. (2017). Innovative technologies to manage aflatoxins in foods and feeds and the profitability of application–A review. *Food control*, 76, 127-138.

[34] Satheesh, N., Parmar, A., Fanta, S. W., & Stathers, T. (2023). Postharvest handling practices and mycotoxin occurrence along the dried berbere chilli pepper value chain: a case study from Northern Ethiopia. *Journal of Stored Products Research*, 103, 102157.

[35] Kumar, P., Mahato, D. K., Kamle, M., Mohanta, T. K., & Kang, S. G. (2017). Aflatoxins: A global concern for food safety, human health and their management. *Frontiers in microbiology*, *7*, 2170.

[36] Kobia, J. M. (2022). Effect of Hygiene Status in Maize Storage Facilities on Pests, Moulds and Aflatoxin Contamination in Nakuru County, Kenya (Doctoral dissertation, University of Nairobi).

[37] Pitt, J. I., Taniwaki, M. H., & Cole, M. B. (2013). Mycotoxin production in major crops as influenced by growing, harvesting, storage and processing, with emphasis on the achievement of Food Safety Objectives. *Food control*, 32(1), 205-215.

[38] Sipos, P., Peles, F., Brassó, D. L., Béri, B., Pusztahelyi, T., Pócsi, I., & Győri, Z. (2021). Physical and chemical methods for reduction in aflatoxin content of feed and food. Toxins, 13(3), 204.

[39] Kimatu, J. N., McConchie, R., Xie, X., & Nguluu, S. N. (2012). The significant role of post-harvest management in farm management, aflatoxin mitigation, and food security in Sub-Saharan Africa. Greener Journal of Agricultural Sciences

[40] Adekoya, I., Njobeh, P., Obadina, A., Chilaka, C., Okoth, S., De Boevre, M., & De Saeger, S. (2017). Awareness and prevalence of mycotoxin contamination in selected Nigerian fermented foods. Toxins, 9(11), 363.

[41] Ndwata, A. H., Rashid, S. A., & Chaula, D. N. (2022). Aflatoxins B1 contamination levels in maize and awareness of aflatoxins among main maize stakeholders in Chemba and Kondoa Districts, Tanzania. *African Journal of Microbiology Research*, 16(6), 223-237.

[42] Ayo, E. M., Matemu, A., Laswai, G. H., & Kimanya, M. E. (2018). Socioeconomic characteristics influencing level of awareness of aflatoxin contamination of feeds among livestock farmers in Meru District of Tanzania. Scientifica, 2018(1), 3485967.

[43] Joutsjoki, V. V., & Korhonen, H. J. (2021). Management strategies for aflatoxin risk mitigation in maize, dairy feeds and milk value chains—case study Kenya. *Food Quality and Safety*, *5*, fyab005.

[44] Falade, T. (2019). Aflatoxin Management Strategies in Sub-Saharan. Mycotoxins: Impact and Management Strategies, 109.

[45] Ndemera, M., De Boevre, M., & De Saeger, S. (2020). Mycotoxin management in a developing country context: A critical review of strategies aimed at decreasing dietary exposure to mycotoxins in Zimbabwe. *Critical reviews in food science and nutrition*, 60(4), 529-540.