

Research Article

Assessment of knowledge, attitude, and practices of maize farmers following post-intervention programs to mitigate aflatoxin contamination in Chamwino, Dodoma, Tanzania

Riziki Salehe Msangi*, Abdulsudi-Issa Zacharia, Lucy Mlipano Chove

Department of Food Science and Agro-processing, School of Engineering and Technology, Sokoine University of Agriculture, P.O. BOX 3006, Morogoro, Tanzania

Abstract

Aflatoxin contamination poses a significant threat to agricultural systems and public health, particularly in regions such as Dodoma, where favorable climatic conditions promote the growth of aflatoxin-producing fungi. Various interventions were initiated to address the problem of aflatoxin contamination among maize farmers in Dodoma. This study aimed to assess maize farmers' knowledge, attitudes, and practices (KAP) following intervention programs designed to mitigate aflatoxin contamination in Chamwino district, Dodoma. A cross-sectional survey was conducted in five wards of Chamwino District: Chilonwa, Msanga, Chamwino, Majeleko, and Buigiri. A semi-structured questionnaire was administered to 300 maize farmers to assess their KAP related to aflatoxin contamination. Data were analyzed using SPSS version 26, with significance set at $p \leq 0.05$. Among 300 farmers surveyed, 221 (73.7%) demonstrated awareness of aflatoxin-related interventions, whereas 79 (26.3%) did not exhibit such awareness. Of the 221 informed farmers, 123 (55.7%) demonstrated good knowledge, 51 (23.1%) exhibited medium knowledge, and 47 (21.3%) displayed poor knowledge regarding aflatoxin contamination and its mitigation. Of the participants, 186 (84.2%) exhibited positive attitudes, 34 (15.4%) displayed medium attitudes, and only 1 (0.5%) demonstrated poor attitudes. Of the participants, 157 (71.0%) exhibited good practices, while 64 (29.0%) were categorized as having medium-level practices. No farmers demonstrated poor practices regarding aflatoxin contamination and mitigation. The interventions effectively enhanced awareness, knowledge, attitudes, and practices regarding aflatoxin mitigation among maize farmers in Chamwino District. Future interventions should strengthen collaboration between government agencies, Non-Government Organizations, farmer groups, and local communities to sustain and expand these gains.

Keywords: Aflatoxin; Farmers' Knowledge; Farmers' Attitudes; Farmers' Practices; Intervention Programs; Tanzania.

Introduction

Cereals are the world's largest crops, including rice, wheat, rye, oats, barley, millet, and maize. They are members of the graminaceous family, yielding grains

for food, feed, seed, and industrial purposes such as ethanol production (Verma et al., 2023). More than 50% of the world's daily caloric intake is derived directly from cereal grain consumption. Most of the grain used for human food is milled to remove the

* **Correspondence:** R. S. Msangi (msangiriziki5@gmail.com).
<https://doi.org/10.30466/fsp.2025.56686.1020>

Received: 24 October 2025 **Accepted:** 14 November 2025

Available online: 15 November 2025

© 2025 Urmia University. All rights reserved.

bran (pericarp) and germ, primarily to meet the sensory expectations of consumers (Salazar-López et al., 2020). However, cereals are prone to mycotoxins, toxic secondary metabolites produced by fungi that infect plants and pose a significant threat to human health (Khodaei et al., 2021). These toxins can contaminate cereals throughout the production chain, both before and after harvest. According to the Food and Agriculture Organization database, around 25% of cereal crops are contaminated by mycotoxins. The most common mycotoxins in cereals include aflatoxins, fumonisins, deoxynivalenol, zearalenone, and ochratoxin (Wan et al., 2020).

Aflatoxins are the most predominant and highly toxic mycotoxins produced by the fungi *Aspergillus flavus* and *Aspergillus parasiticus* (Kenei et al., 2023). There are nearly 18 different forms of aflatoxins, of which aflatoxin B1, B2, G1, G2, M1, and M2 are the most important. They are considered to be carcinogenic, mutagenic, and teratogenic, whereas aflatoxin B1 is considered the most predominant and potent carcinogen in nature (Martínez et al., 2023). Importantly, aflatoxin contamination poses risks not only to human health but also to livestock production. In humans, chronic exposure contributes to liver cancer, immunosuppression, stunted growth in children, and acute aflatoxicosis outbreaks (Awuchi et al., 2022). In animals, exposure leads to reduced productivity, impaired immunity, organ damage, and contamination of animal products such as milk with aflatoxin M1, directly affecting food safety and consumer health (Ramani et al., 2025). Thus, aflatoxin contamination affects the entire food chain, making it a critical public health and agricultural challenge. Aflatoxin contamination in cereals is particularly concerning due to its widespread consumption as a staple food in many regions, including sub-Saharan Africa (Benkerroum, 2020). The rate and extent of aflatoxin contamination depend on various factors, including temperature, humidity, water activity (a_w), the simultaneous presence of several mycotoxin-producing fungi, physical damage, and storage and maintenance conditions (Peivasteh-Roudsari et al., 2022).

In Tanzania, mycotoxin contamination in cereals is a significant concern. It is caused by various factors, such as poor storage conditions, inadequate drying practices, and lack of awareness among farmers and consumers (Kimario et al., 2022). Like other tropical countries, Tanzania has high temperatures (annual average 28 to 31 °C) and high relative Humidity (50 to 60% and 70 to 80% during the dry and wet seasons, respectively) (Tanzania Meteorological Authority, 2019). These temperatures and the humid environment are optimal for the growth of toxic fungi and the subsequent production of mycotoxins in the produce. The Dodoma region in Tanzania has experienced lethal incidences of food poisoning outbreaks linked with the consumption of homegrown maize contaminated with aflatoxin (Kinyenje et al., 2023). However, the climatic conditions prevalent in Dodoma, characterized by high temperatures and humidity, create an ideal environment for the growth of aflatoxin-producing molds. This situation is exacerbated by inadequate post-harvest handling practices among farmers, leading to increased susceptibility to contamination. In June 2016, 68 aflatoxicosis cases were reported from the Chemba, Chamwino, Dodoma, and Kondoa districts. Of these, 20 died on the scene a short while after the consumption of food contaminated with aflatoxin, and 48 were hospitalized at Dodoma Regional Hospital (Kamala et al., 2018).

In response to the 2016 aflatoxicosis outbreak, several interventions were initiated to address the problem of aflatoxin contamination among maize farmers in Dodoma. These interventions have primarily focused on increasing awareness and improving agricultural practices to reduce the risk of aflatoxin contamination. These interventions often include training programs focused on proper agricultural practices, such as timely harvesting, appropriate drying techniques, and safe storage methods that minimize mold growth (Mutiga et al., 2019). One of the primary strategies employed has been education campaigns to raise awareness among farmers about the dangers of aflatoxin and mitigation strategies. These campaigns have been conducted through various channels, including community meetings, radio broadcasts, and the distribution of educational materials (Onesmo et al., 2024).

Several projects have been implemented with support from both governmental and non-governmental organizations. For instance, the Tanzanian government collaborated with international partners to launch initiatives that provide farmers with access to improved storage facilities, such as hermetic bags that inhibit mold growth by creating an oxygen-free environment (Hatibu et al., 2022). Mutua et al. (2021) reported that a total of 27 projects in East Africa focused on mitigating aflatoxin risk, with the most common approach being the development and implementation of mitigation measures and detection technologies. These include the Partnerships for Aflatoxin Control in Africa and the Tanzania Initiative for Preventing Aflatoxin Contamination, and the Global Agriculture and Food Security Program. Community-based interventions and farmer groups facilitate peer learning and collective action towards better farming practices. These groups often receive training from

agricultural extension officers who focus on best practices for crop management and post-harvest handling (Mkuki & Msuya, 2020).

Although several interventions have been implemented in Dodoma since the 2016 aflatoxicosis outbreak, including awareness campaigns, improved storage initiatives, and community trainings, there remains a lack of empirical evidence evaluating how these programs have shaped farmers' knowledge, attitudes, and practices towards aflatoxin contamination and mitigation. This study aims to assess the knowledge, attitudes, and practices of maize farmers' post-intervention programs designed to mitigate aflatoxin contamination in Chamwino District, Dodoma. The findings of this study will help policymakers, extension officers, and development partners to identify which aspects of the interventions have been effective, where gaps persist, and what targeted strategies are needed to strengthen farmer capacity for long-term aflatoxin mitigation.

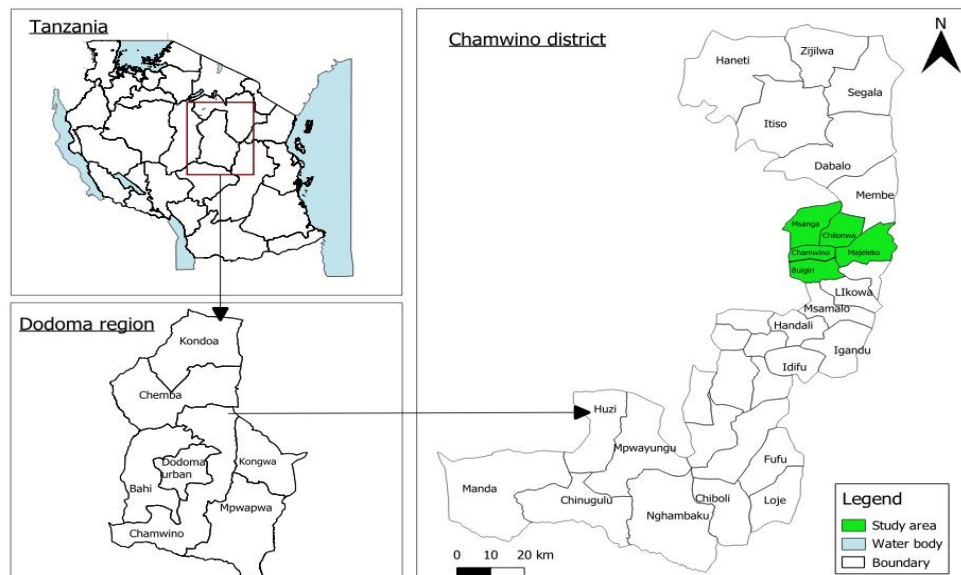


Figure 1: Map shows the study area.

Materials and Methods

Description of the study area

This study was conducted in Chamwino district in Dodoma region (**Fig. 1**). The region was purposively selected because it has experienced lethal cases of aflatoxin poisoning linked to maize consumption. Chamwino district is geographically situated at

latitude 6° 15' South and longitude 35° 42' East. Its borders are defined by Chemba district to the north, Manyara Region, Kongwa district, and Mpwapwa district to the east, Iringa region to the south, and Singida region, Bahi district, and Dodoma district to the west.

According to the national population and housing census report of 2022, the Chamwino district has a

total population of 486,176 (236,583 males and 249,593 females) and a total number of 118,812 households. The district's climate is characterized as semi-arid, featuring a prolonged dry season and a brief, unreliable rainy season, resulting in low and inconsistent precipitation. These dry conditions have important implications for aflatoxin contamination.

Prolonged drought and heat stress weaken crops, making them more susceptible to fungal invasion. The landscape of Chamwino district comprises natural plains interspersed with minor hills. Key crops cultivated in the area include sorghum, maize, groundnuts, and sunflowers.

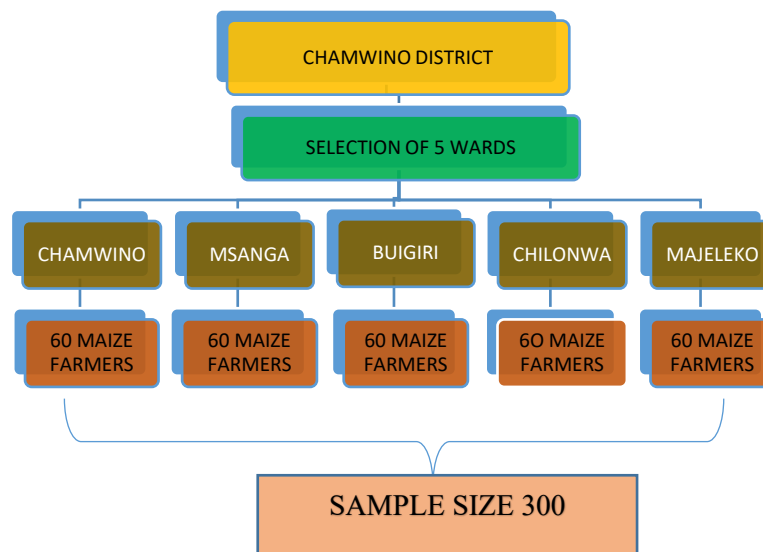


Figure 2. Sampling plan of maize farmers from the selected wards of Chamwino district.

Study design

A quantitative cross-sectional survey was carried out from February to March 2025 in five purposively selected wards (Chamwino, Chilonwa, Msanga, Majeleko, and Buigiri) where aflatoxin intervention programs had been implemented. Data were collected using a semi-structured questionnaire to assess farmers' knowledge, attitudes, and practices. The cross-sectional design was appropriate because it provided a timely snapshot of farmers' post-intervention adoption of aflatoxin mitigation practices.

Sampling and sample size

The number of maize farmers in the district was obtained from the Agriculture Extension Offices. The total number of maize farmers across all wards was 1195. Yamane's formula (Eq. 1) was used to calculate sample size (n) as shown below:

$$\text{Yamane's formula } (n = N / (1 + N(e)^2)) \quad (\text{Eq. 1})$$

Whereby N, the total number of maize farmers in all wards = 1195,

(e), The margin of error at a confidence level of 95% = 0.05.

Calculate from the formula

$$\text{Sample size } (n) = 1195 / (1 + 1195 (0.05)^2) = 300$$

Thus, a total of 300 maize farmers participated in this survey (Fig. 2). About sixty (60) respondents from each ward, were randomly selected to participate in this study. In this study, villages were not considered as separate sampling units. Maize farmers were selected directly from ward-level lists obtained from the Ward Agriculture Extension Offices. The random selection was carried out using Microsoft Excel by generating random numbers within the farmer lists obtained from the Ward Agriculture Extension Offices.

Data collection

Data was collected through direct interviews with respondents using a semi-structured questionnaire. The questionnaires included three sections: social-demographic information; awareness of specific projects, programs, interventions, and campaigns; and Knowledge, Attitude, and Practices (KAP) concerning aflatoxin contamination and mitigation. The questionnaire was in English but translated to Swahili during the interview. Social-demographic information covered the age of the respondents, gender, level of education, farmers' experience with maize farming, type of farming, and the size of the farms. Pre-testing of the questionnaire was done by 10 maize farmers from Chamwino ward, who were not included in the study. Necessary modifications were made to enhance proper contents, wording and sequencing before commencing the actual data collection.

Before the interviewing, an initial assessment concerning their awareness of specific projects, programs, and campaigns related to aflatoxin was conducted. These questions, which are presented in **Appendix 1**, were used for preliminary assessment. Among 300 farmers, only 221 farmers responded affirmatively and demonstrated awareness of aflatoxins and relevant initiatives, projects, campaigns and programs were directed to the second section of the questionnaire. In this section, data regarding their awareness of specific projects, programs, and campaigns were collected. This included gathering information on various initiatives projects and programs that focused on aflatoxin contamination and mitigation strategies. The final section of the questionnaire focused on assessing farmers' KAP regarding aflatoxin contamination and its mitigation. The questions used to assess knowledge and attitudes are presented in **Appendices 2 and 3**. Data were recorded instantly in the field using KoboToolbox.

Ethical considerations were observed throughout the study. Participation in the study was entirely voluntary, and farmers were informed of their right to withdraw at any time without any consequences. Informed consent was obtained from all participants before the interviews. Respondents were assured

that their information would remain strictly confidential.

Data analysis

Data was analyzed by using IBM Statistical Package for Social Sciences (SPSS) version 27 software. Descriptive and inferential statistics were computed. Farmers' knowledge of aflatoxin contamination and mitigation was assessed by summing responses from relevant survey questions to obtain a composite knowledge score for each participant. The raw knowledge score was then converted to a percentage scale using the formula (**Eq. 2**):

$$\text{Knowledge Score (\%)} = (\text{Knowledge Score} / \text{Maximum Possible Score}) \times 100 \quad (\text{Eq. 2})$$

Farmers' attitudes were measured using Likert-scale questions scored from 1 (strongly disagree) to 5 (strongly agree) (**Eq. 3**). The total attitude score was computed as the sum of all responses across the attitude questions. Similarly, practices were assessed using Likert-scale questions scored from 1 (never) to 3 (always), and the total practice score was obtained by summing across the practice-related questions as shown below. Scores were added together and converted into percentages.

$$\text{Attitude/Practice Score} = \sum_{i=1}^n X_i \quad (\text{Eq. 3})$$

where X_i represents the score for each attitude or practice question, and n is the total number of attitude or practice questions.

For all three domains (knowledge, attitude, and practices), the resulting scores were categorized into three levels; Poor (0-49.9%), Medium (50-74.9%), and Good (75-100%) based on thresholds commonly used in KAP studies (Hossen et al., 2020). Additionally, associations between KAP levels and farmers' socio-demographic as well as farming-related characteristics were analyzed using the Chi-square test of independence, with statistical significance set at $p < 0.05$.

Ethical consideration

Ethical clearance for this study was granted by Sokoine University of Agriculture on behalf of the Tanzania Commission for Science and Technology

(COSTECH), under reference number SUA/ADM/R.1/8/1365. In addition, research authorization letters were secured from the relevant local authorities before data collection. Verbal consent was obtained from all participants after a clear explanation of the study objectives, procedures, and assurances of confidentiality. Participants were also informed of their right to withdraw from the study at any point without facing any negative consequences.

Results and Discussion

Maize farmers' social-demographic characteristics

A total of 300 maize farmers were interviewed, with equal representation from the five wards of Buigiri, Chamwino, Chilonwa, Majeleko, and Msanga. Gender distribution was nearly balanced (51% female and 49% male). Most respondents were aged 31–45 years (41%), followed by those aged 46–60 years (28.7%), while only 10% were above 60 years. Regarding education, 44% had completed primary school, 30% had secondary education, 4.3% had higher education, and 21.7% had no formal schooling. Farming experience varied considerably, with 11.4% having less than five years of experience and the majority (74.2%) having more than ten years. Over half of the farmers (56.7%) practiced subsistence farming, 12.7% were involved in commercial production, and more than a quarter engaged in both (Table 1). Most farmers cultivated 2–5 acres of land (60.4%), while only 4.8% farmed more than 10 acres (Table 1).

Awareness of programs against socio-demographic characteristics

The study initially involved 300 maize farmers, out of whom 221 (73.7%) were aware of aflatoxin-related projects, programs, campaigns, and initiatives and had received training on aflatoxin contamination and mitigation, while 79 (26.3%) were not aware. The analysis considered both who were aware and those who were not aware as shown in Table 2. The Chi-square test was used to determine whether there were significant associations between farmers' socio-demographic characteristics and their level of awareness (Yes/No). The p-values presented in the table represent the statistical significance of these associations.

Table 1. Social-demographic characteristics of the interviewed maize farmers.

Characteristics	Frequency (percentage)
Gender	
Female	153 (51.0%)
Male	147 (49.0%)
Age categories	
15-30	61 (20.3%)
31-45	123 (41.0%)
46-60	86 (28.7%)
Above 60	30 (10.0%)
Education level	
No formal education	65 (21.7%)
Primary	132 (44.0%)
Secondary	90 (30.0%)
Higher education	13 (4.3%)
Years of experience in maize farming	
Less than 5	34 (11.4%)
6-10	43 (14.4%)
Above 10	221 (74.2%)
Type of farming	
Both	92 (30.7%)
Commercial	38 (12.7%)
Subsistence	170 (56.6%)
Size of Farm (in acres)	
<= 1	45 (15.4%)
2-5	177 (60.4%)
6-10	57 (19.5%)
Above 10	14 (4.8%)
Awareness of aflatoxin projects, programs, or initiatives	
Yes	221 (73.7%)
No	79 (26.3%)

Results showed no significant difference in awareness between female (75.8%) and male (71.4%) respondents ($p = 0.388$). However, significant differences were observed across age categories ($p = 0.002$). Farmers aged 31–45 years demonstrated the highest awareness (80.5%), followed by those aged 46–60 years (74.4%) and 15–30 years (72.1%), whereas farmers above 60 years showed the lowest awareness (46.7%). Education level also showed a significant association with awareness ($p < 0.001$). Respondents with secondary education had the highest awareness (81.1%), followed by those with primary education (79.5%). Awareness was lower among farmers with no formal education (46.2%), and all respondents with higher education reported being aware (100%). Farming experience was also significantly associated with awareness ($p = 0.002$), with farmers who had 5–10 years of experience having the highest awareness (86.7%), followed by those with more than 10 years (73.3%), whereas farmers with less than 5 years of experience showed the lowest awareness (55.9%).

Moreover, awareness varied significantly with the type of farming: both commercial and subsistence farmers had different levels of awareness of programs, with commercial farmers showing higher awareness (78.9%) compared to subsistence

farmers (65.3%), as indicated by a p-value of 0.001. However, when considering the size of the farm, no significant difference was found in awareness levels across different farm sizes, as reflected by a non-significant p-value of 0.178 (**Table 2**).

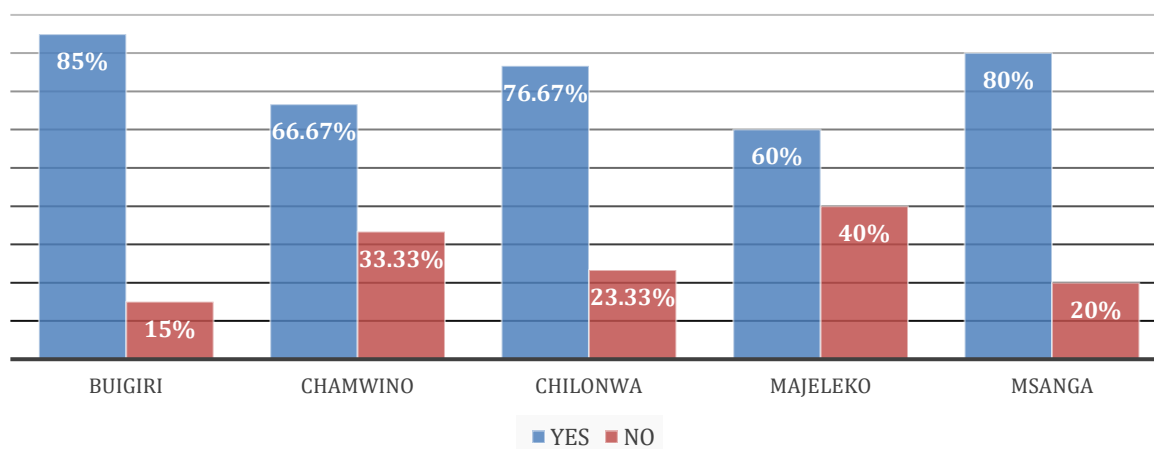


Figure 3. Awareness of aflatoxin mitigation programs among farmers in Buigiri, Msanga, Chilonwa, Chamwino, and Majeleko.

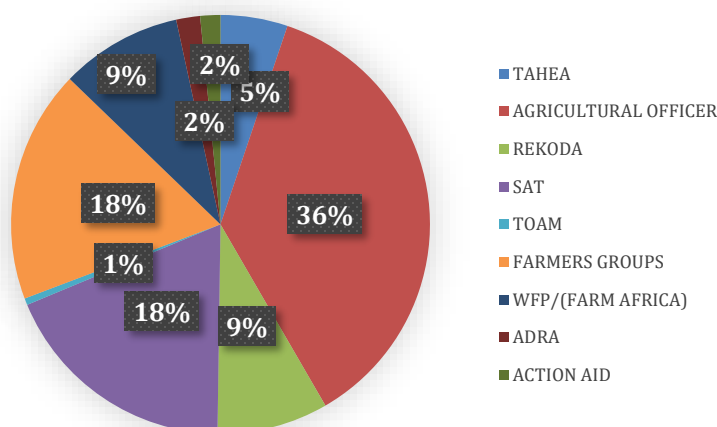


Figure 4. Projects, programs, campaigns, and initiatives done in Chamwino, Dodoma.

Awareness of programs, projects and campaigns across the wards

The results revealed varying levels of awareness across the five wards surveyed, as illustrated in **Figure 3**, where percentage values are clearly indicated on the chart. In Buigiri, 51 of the 60 farmers (85%) reported being aware of the programs, whereas 9 (15%) were not aware. Similar patterns were observed in Msanga and Chilonwa, where 46 farmers (76.67%) reported awareness and

14 (23.33%) lacked awareness. In Chamwino, 40 farmers (66.67%) were aware of the programs, compared to 20 (33.33%) who were unaware. Majeleko had the lowest awareness level, with 36 farmers (60%) aware and 14 (40%) unaware. These variations may be influenced by differences in access to programs, the frequency of extension officer visits, and the presence or activity level of NGOs and community sensitization initiatives across the wards.

Projects, programs, campaigns and initiatives done in Chamwino, Dodoma

The study revealed varying levels of engagement with different initiatives, programs, and projects across the district. The Agricultural Extension Officers (AEOs) program was the most frequently reported intervention, cited by 63.3% of respondents. Other initiatives included Sustainable Agriculture Tanzania (SAT) (32.1%), the World Food

Programme (WFP) (16.3%), and Research Community and Organizational Development Associates (RECODA) (14.9%). The Tanzania Home Economics Association (TAHEA) and ActionAid were mentioned by 9.0% and 3.2% of farmers, respectively, while the Adventist Development and Relief Agency (ADRA) (2.7%) and the Tanzania Organic Agriculture Movement (TOAM) (0.9%) were the least frequently reported (**Fig. 4**).

Table 2. Awareness of programs, projects and campaigns against socio-demographic characteristics.

Variables	No	Yes	Total	p-value
N	79 (26.3%)	221 (73.7%)	300 (100.0%)	
Gender				
Female	37 (24.2%)	116 (75.8%)	153 (100.0%)	0.388
Male	42 (28.6%)	105 (71.4%)	147 (100.0%)	
Age categories				
15-30	17 (27.9%)	44 (72.1%)	61 (100.0%)	0.002
31-45	24 (19.5%)	99 (80.5%)	123 (100.0%)	
46-60	22 (25.6%)	64 (74.4%)	86 (100.0%)	
Above 60	16 (53.3%)	14 (46.7%)	30 (100.0%)	
Education level				
No formal education	35 (53.8%)	30 (46.2%)	65 (100.0%)	<0.001
Primary	27 (20.5%)	105 (79.5%)	132 (100.0%)	
Secondary	17 (18.9%)	73 (81.1%)	90 (100.0%)	
Higher education		13 (100.0%)	13 (100.0%)	
Years of experience in maize farming				
Less than 5	15 (44.1%)	19 (55.9%)	34 (100.0%)	0.002
5-10	6 (13.3%)	39 (86.67%)	45 (100.0%)	
Above 10	59 (26.7%)	162 (73.3%)	221 (100.0%)	
Type of farming				
Both	12 (13.0%)	80 (87.0%)	92 (100.0%)	0.001
Commercial	8 (21.1%)	30 (78.9%)	38 (100.0%)	
Subsistence	59 (34.7%)	111 (65.3%)	170 (100.0%)	
Size of Farm (in acres)				
<= 1	17 (37.8%)	28 (62.2%)	45 (100.0%)	0.178
2-5	43 (24.3%)	134 (75.7%)	177 (100.0%)	
6-10	11 (19.3%)	46 (80.7%)	57 (100.0%)	
Above 10	7(33.3%)	14(66.67%)	21(100.0%)	

Peer-to-peer learning was also evident, with 31.2% of farmers participating in organized groups, an approach that enhances knowledge exchange and collective response to aflatoxin contamination. These groups included “Wamama 90” in Chamwino; “Imani” and “Tumaini VISL” in Msanga; “Mkombozi” and “Jipemoyo” in Majeleko; and “Mshikamano” in

Chilonwa. Notably, no farmer groups were identified in Buigiri. This absence may be linked to limited mobilization efforts by AEOs, lower participation in community-based initiatives, or less established structures for forming farmer groups compared to the other wards. These factors may have reduced

opportunities for collective learning and engagement with programs in Buigiri ward.

A high level of awareness regarding aflatoxin contamination was observed in this study, with percentage values clearly shown on the chart in Figure 5. Most respondents (88.2%) were able to identify crops commonly contaminated by aflatoxins,

and 91.4% understood the conditions that favor their development. Additionally, 95% of farmers reported that aflatoxin contamination had occurred in their maize. However, awareness of specific health risks was limited, as most responses mentioned only liver cancer or death. Despite this, 92.8% of farmers were aware of methods for preventing or controlling aflatoxin contamination in maize (**Fig. 5**).

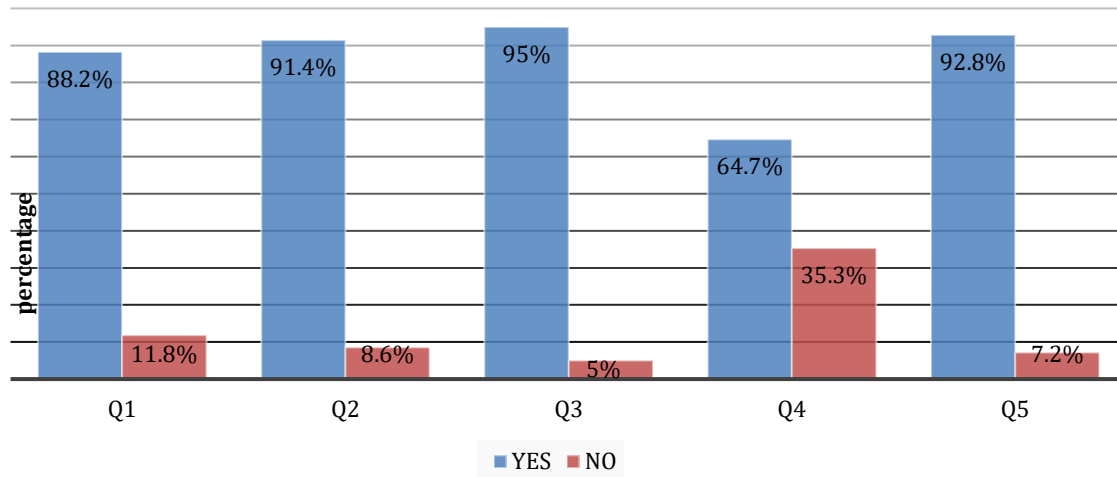


Figure 5. Farmers' knowledge towards Aflatoxin contamination and mitigation **Q1)** crops that are most affected by aflatoxins **(Q2)** Conditions favorable for aflatoxin contamination **(Q3)** Experienced aflatoxin contamination **(Q4)** Health risks associated with aflatoxins **(Q5)** methods for preventing or controlling aflatoxin contamination.

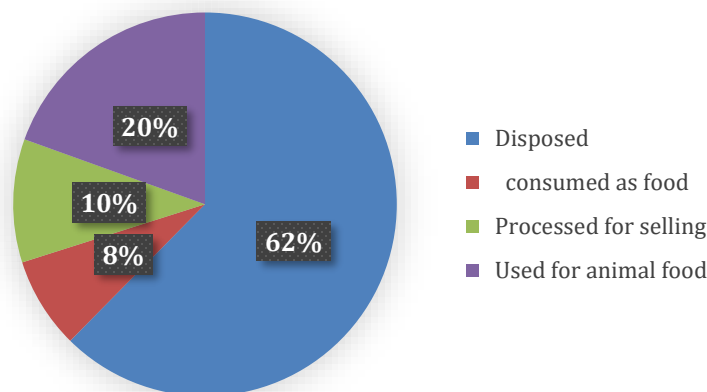


Figure 6. Farmers' actions on contaminated maize in Chamwino.

Table 3. Frequency and percentage distribution of Farmers' attitudes towards aflatoxin contamination and mitigation (n=221).

Variables	SD	D	N	A	SA	DK
Q1	30 (13.6%)	116 (52.5%)	9 (4.1%)	35 (15.8%)	31 (14.0%)	-
Q2	5 (2.3%)	20 (9.0%)	100 (45.2%)	23 (10.4%)	73 (33.0%)	-
Q3	-	-	9 (4.1%)	93 (42.1%)	117 (52.9%)	2 (0.9%)
Q4	-	-	19 (8.6%)	88 (39.8%)	110 (49.8%)	4 (1.8%)
Q5	-	-	29 (13.1%)	108 (48.9%)	76 (34.4%)	-
Q6	1 (0.5%)	2 (0.9%)	13 (5.9%)	120 (54.3%)	83 (37.6%)	2 (0.9%)
Q7	-	1 (0.5%)	11 (5.0%)	140 (63.3%)	69 (31.2%)	-
Q8	-	24 (10.9%)	1 (0.5%)	103 (46.6%)	92 (41.6%)	1 (0.5%)
Q9	-	3 (1.4%)	10 (4.5%)	114 (51.6%)	94 (42.5%)	-
Q10	3 (1.4%)	52 (23.5%)	13 (5.9%)	94 (42.5%)	59 (26.7%)	-
Q11	1 (0.5%)	76 (34.4%)	27 (12.2%)	85 (38.5%)	30 (13.6%)	-
Q12	-	6 (2.7%)	13 (5.9%)	117 (52.9%)	85 (38.5%)	-
Q13	1 (0.5%)	5 (2.3%)	20 (9.0%)	120 (54.3%)	60 (27.1%)	-
Q14	-	5 (2.3%)	8 (3.6%)	132 (59.7%)	76 (34.4%)	-
Q15	38 (17.2%)	44 (19.9%)	42 (19.0%)	57 (25.8%)	20 (9.0%)	20 (9.0%)
Q16	-	5 (2.3%)	5 (2.3%)	124 (56.1%)	85 (38.5%)	2 (0.9%)
Q17	1 (0.5%)	4 (1.8%)	12 (5.4%)	130 (58.8%)	60 (27.1%)	14 (6.3%)
Q18	-	10 (4.5%)	36 (16.3%)	107 (48.4%)	58 (26.2%)	10 (4.5%)
Q19	-	4 (1.8%)	5 (2.3%)	113 (51.1%)	97 (43.9%)	2 (0.9%)
Q20	2 (0.9%)	5 (2.3%)	14 (6.3%)	91 (41.2%)	109 (49.3%)	-
Q21	-	22 (10.0%)	46 (20.8%)	100 (45.2%)	53 (24.0%)	-
Q22	-	3 (1.4%)	25 (11.3%)	144 (65.2%)	45 (20.4%)	4 (1.8%)
Q23	7 (3.2%)	20 (9.0%)	39 (17.6%)	118 (53.4%)	28 (12.7%)	9 (4.1%)
Q24	-	4 (1.8%)	7 (3.2%)	93 (42.1%)	115 (52.0%)	2 (0.9%)
Q25	-	3 (1.4%)	4 (1.8%)	109 (49.3%)	105 (47.5%)	-
Q26	-	3 (1.4%)	10 (4.5%)	132 (59.7%)	76 (34.4%)	-

Note: SD: Strongly disagree, D: disagree, N: Neutral, A: Agree, SA: Strongly agree, DK: Don't know. Q1: Awareness campaigns have been effective. Q2: Knowledge about mycotoxins has improved. Q3: Mycotoxins threaten maize quality. Q4: Mycotoxins pose a risk to production. Q5: Farmers are willing to adopt new techniques. Q6: Cleanliness is essential to prevent contamination. Q7: Training information is trusted. Q8: Proper storage reduces aflatoxin levels. Q9: Monitoring moisture prevents aflatoxin growth. Q10: Training improved farming techniques. Q11: Farmers can identify aflatoxin signs. Q12: Programs influenced storage practices. Q13: Community discussions changed perspectives. Q14: Drying maize combats aflatoxins. Q15: Awareness campaigns reached enough farmers. Q16: Drying on bare ground is risky. Q17: Farmers are responsible for crop safety. Q18: Fumigation of storage facilities is essential. Q19: Educating the community on dangers is important. Q20: Financial support is needed for mitigation. Q21: Post-training support is sufficient. Q22: Proper transport prevents contamination. Q23: Markets are becoming more aware. Q24: Awareness improves health and economic outcomes. Q25: Continuous education is essential. Q26: Community workshops improved understanding.

In terms of actions taken on spoiled maize, the predominant response was disposal (62%) which indicates an understanding that contaminated products should not be consumed or sold, followed by using it for animal feed (20%), processing for sale (10%), and (8%) consume them as food (**Fig. 6**). Farmers reported disposing of spoiled maize by burying it, while others reported burning it along with other unwanted materials or farm waste.

Farmers' attitude towards Aflatoxin contamination and mitigation

Out of 221 farmers, a considerable proportion of farmers (52.9%) agreed that aflatoxin contamination poses a significant threat to maize quality and safety. About 54.3% acknowledged the importance of hygiene during planting, harvesting, and storage to prevent mycotoxin contamination. About 46.6% recognized that proper storage methods could

significantly reduce aflatoxin levels. A notable percentage of farmers expressed confidence in their ability to identify signs of aflatoxin contamination. Majority of farmers acknowledged that drying maize on bare ground posed a risk to the overall safety of their crops. Nearly half of the respondents (48.4%) recognized the importance of fumigating maize storage facilities before and after storing maize. More than half of the respondents (65.2%) acknowledged the importance of effective methods for transporting harvested maize in preventing contamination. Furthermore, a substantial majority (59.7%) acknowledged the importance of drying maize as a crucial practice in combating aflatoxin contamination (**Table 3**).

Practices of maize farmers towards aflatoxin mitigation

The study found that 84% of farmers inspect maize for mold before harvesting or milling, follow proper harvesting and storage methods, and moderately use pesticides. Majority of the farmers (78.7%) sort spoiled maize after harvesting. Sun drying was reported by 65% of farmers to mitigate aflatoxin contamination. Most farmers participate in pest eradication, record farming activities, consult AEOs, and seek advice from agricultural officers. About seventy-eight percent of the farmers disseminate information about mycotoxin hazards, but 55.2% never report aflatoxin occurrences (**Table 4**). Around 70.1% of farmers actively sought updated knowledge on aflatoxins, while 73.8% adhered to standard operating procedures learned from aflatoxin-related programs and projects (**Table 4**).

The study showed that 76% of Chamwino maize farmers consistently practice field cleaning during harvesting and processing, and participate in seminars to raise awareness about aflatoxin contamination. However, practices like insecticide use and dropping maize cobs on the ground show varying levels of adoption (**Table 4**). About 86% of farmers reported storing maize in dry areas, using traditional facilities like granaries and cribs, and ensure timely harvesting. The study also revealed that 80.5% of maize farmers consistently maintain clean processing equipment, demonstrating a strong awareness of hygiene's role in preventing aflatoxin contamination.

Associations between social demographic characteristics and knowledge, attitude, and practices on aflatoxin mitigation among maize farmers

Association between social demographic characteristics and knowledge on aflatoxin mitigation among maize farmers

Out of 221 farmers, 55.7% had a good knowledge on aflatoxin contamination and mitigation, 23.1% had medium knowledge, and 21.3% had poor knowledge. Gender showed a notable association with knowledge scores ($p = 0.017$), with females exhibiting higher proportions of "Good" scores (63.8%) compared to males (46.7%). Age categories demonstrated a significant relationship ($p = 0.018$), with younger individuals (15-30 years) having the highest proportion of "Poor" scores (34.1%), while older age groups (46-60 years) showed better performance, with 71.9% achieving "Good" scores (**Table 5**). Education level was strongly associated with knowledge ($p = 0.004$), as higher education correlated with the highest proportion of "Good" scores (92.3%), while those with no formal education had the lowest (40.0%). Farm size revealed a highly significant association ($p < 0.001$), with larger farms (6 to above 10 acres) showing markedly higher "Good" scores (82.6% and 80.0%, respectively), whereas smaller farms (≤ 1 acre) had the lowest (25.0%). Years of experience and type of farming had no show any significant association.

Association between social demographic characteristics and attitude on aflatoxin mitigation among maize farmers

Among the 221 farmers, a large majority (84.2%) exhibited good attitude scores, 15.4% had medium, and only 0.5% demonstrated a poor attitude towards aflatoxin contamination and mitigation. Although a slightly higher proportion of females (88.8%) exhibited good attitudes compared to males (79.0%), the difference was not statistically significant ($p = 0.106$). Age was significantly associated with attitude scores ($p = 0.007$), with participants aged 31-45 and 46-60 showing the highest proportion of good attitudes (83.8% and 87.5%, respectively), while those above 60 had the lowest (64.3%). Education level also demonstrated a statistically significant relationship with attitude scores ($p = 0.004$). Farmers with secondary education and higher education had the highest proportions of good attitudes (94.5% and 92.3%, respectively), while those with no formal education had the lowest (66.7%). No significant association was found between attitude scores and years of experience in maize farming ($p = 0.902$), type of farming ($p = 0.133$), or farm size ($p = 0.660$), though the overall trend still showed relatively high proportions of good attitudes across these groups (**Table 5**).

Table 4. Frequency and percentage distribution of Farmers' practices towards aflatoxin mitigation (n=221).

Variables	Never	Sometimes	Always
Use of pesticides	111 (50.2%)	24 (10.9%)	86 (38.9%)
Implementation of pest management strategies	49 (22.2%)	73 (33.0%)	99 (44.8%)
Keeping records of farming activities and expenditures	39 (17.6%)	79 (35.7%)	103 (46.6%)
Seminar participation	114 (51.6%)	33 (14.9%)	74 (33.5%)
Seeking advice from agricultural officers	21 (9.5%)	90 (40.7%)	110 (49.8%)
Seeking new information about new ways to reduce aflatoxin contamination in maize?	9 (4.1%)	57 (25.8%)	155 (70.1%)
Adhere to the guidelines provided by agricultural extension officers regarding aflatoxins?	4 (1.8%)	54 (24.4%)	163 (73.8%)
Harvesting on time	9 (4.1%)	47 (21.3%)	165 (74.7%)
Field cleaning during harvesting and processing	2 (0.9%)	51 (23.1%)	168 (76.0%)
Family members participation in field cleaning	20 (9.0%)	58 (26.2%)	143 (64.7%)
Sorting of spoiled maize crops after harvesting	5 (2.3%)	42 (19.0%)	174 (78.7%)
Inspection of maize	0(0.0%)	39 (17.6%)	182 (82.4%)
Keep the harvested maize grain from the soil	111 (50.2%)	67 (30.3%)	43 (19.5%)
Traditional drying methods	12 (5.4%)	40 (18.1%)	169 (76.5%)
Proper storage of maize (In dry areas)	3 (1.4%)	28 (12.7%)	190 (86.0%)
Use of traditional storage facilities	116 (52.5%)	56 (25.3%)	49 (22.2%)
Cleaning and drying of any machinery/equipment used for processing or storing of maize	7 (3.2%)	36 (16.3%)	178 (80.5%)
Transport your produce in a manner that is safe and protected from contamination?	8 (3.6%)	40 (18.1%)	173 (78.3%)
Report incidents of aflatoxin contamination to agricultural institutions or offices?	122 (55.2%)	60 (27.1%)	39 (17.6%)

Association between social demographic characteristics and practices on aflatoxin mitigation among maize farmers

Of 221 farmers, 71.0% demonstrated good agricultural practices, while 29.0% were categorized as having medium-level practices. Although a higher proportion of females (75.9%) had good practice scores compared to males (65.7%), the difference was not statistically significant ($p = 0.097$). Similarly, age was not significantly associated with practice scores ($p = 0.083$), although participants aged above 60 showed a relatively lower proportion of good practices (42.9%). Education level showed a statistically significant association with practice scores ($p < 0.001$), with participants having higher education reporting the highest proportion of good practices (92.3%). In contrast, those with no formal education had the lowest (33.3%). Other variables, such as years of experience in maize farming ($p = 0.326$) and farm size ($p = 0.858$), were not significantly associated with practice levels (**Table 5**). However, the type of farming was significantly associated with practice scores ($p = 0.023$); subsistence farmers were more likely to have good practices (79.3%) compared to those practicing both types (63.7%) or commercial farming alone (60.0%).

Discussion

Knowledge of maize farmers aflatoxin towards contamination and mitigation

The findings of this study revealed that maize farmers in Chamwino District attained a relatively high level of knowledge regarding aflatoxin contamination and mitigation, with the majority (88.2%) able to identify contaminated crops, the environmental conditions that promoted fungal growth and methods for preventing or controlling aflatoxin contamination in maize. This suggests that intervention programs including awareness campaigns, projects, training sessions, and agricultural extension efforts, had a positive impact. The findings of this study are in line with the findings of the study by Kortei et al. (2023) in Ghana, who reported that the majority of the respondents were aware of the methods of controlling and preventing fungi on foods. These results contrast with the findings of Mabruki et al. (2022), who reported that 67.3% of the respondents in Morogoro and Makambako did not know the conditions that

favor the growth of aflatoxin-producing fungi, highlighting the uneven reach or effectiveness of interventions across regions. Similarly, Onesmo et al. (2024) found that while most dairy farmers in Kondoa had heard of aflatoxins, only slightly more than half understood the key contamination factors.

Additionally, the majority of farmers in this study (95.0%) reported encountering aflatoxin contamination in maize. In terms of actions taken on spoiled maize, the predominant response was disposal (62%), indicating an understanding that contaminated products should not be consumed or sold. This was followed by use as animal feed (20%), processing for sale (10%), and consumption as food (8%). These findings are comparable to those of Kimario et al. (2022), who found that 14.4% of smallholder farmers in Chamwino, Dodoma, used contaminated grains as livestock or poultry feed, while others used them as food (61.1%) or for sale (5.6%). Importantly, the 20% of farmers feeding contaminated maize to livestock in Chamwino provides direct evidence of a critical risk pathway, as aflatoxins particularly aflatoxin B1, are metabolized by animals into aflatoxin M1, which is excreted in milk, meat, and eggs (Min et al., 2021). This transfer is well documented in toxicological studies and poses health risks to consumers, underscoring the need for stronger farmer education on safe handling and disposal practices. Similarly, Anitha et al. (2019) reported in Malawi that many farmers were unwilling to discard contaminated grade-outs, as these accounted for 10–20% of their profit. The fact that some farmers in Chamwino still use spoiled maize for animal feed, processing for sale, or consumption highlights the need for continued education on safe disposal and handling practices to minimize health risks associated with aflatoxin contamination. Many farmers and consumers may not fully understand that feeding contaminated maize to livestock can result in toxin bioaccumulation in animal products, posing health risks to both animals and humans (Umar et al., 2025).

Despite the observed awareness among maize farmers in Chamwino about aflatoxin contamination, this study found limited understanding of the full range of health risks associated with aflatoxin exposure. Most respondents only mentioned liver

cancer or death. This finding aligns with Waryoba (2025), who reported that farmers in Shinyanga and Morogoro were generally unaware of specific health effects of aflatoxin. Similarly, Toma (2019) in Ethiopia found that farmers mainly associated aflatoxin with abdominal diseases, liver disease, and cancer, while Fundikira et al. (2021) reported that 96.7% of spice retailers in Dar es Salaam were unaware of aflatoxin contamination and its health impacts. Collectively, these findings suggest that while awareness campaigns have improved general knowledge of aflatoxin risks, they often fail to communicate specific health consequences effectively. The limited knowledge of health consequences may be attributed to the emphasis of existing awareness campaigns, which often focus on general messages about “danger” or “cancer risk” rather than providing detailed, practical information on the broader health impacts of aflatoxin. Additionally, inadequate involvement of health professionals during sensitization activities and limited access to health-related educational materials may further contribute to these knowledge gaps. Strengthening collaboration between agricultural extension officers and healthcare providers, integrating aflatoxin education into routine community health outreach, and developing targeted health-focused communication materials could improve farmers’ understanding of the specific health risks associated with aflatoxin exposure.

Attitudes of maize farmers towards aflatoxin contamination and mitigation

The post-intervention programs implemented in Chamwino District have significantly shaped farmers’ attitudes toward aflatoxin contamination and its mitigation. A large majority (95%) of respondents recognized that mycotoxin contamination poses a serious threat to the quality, safety, and productivity of maize. This finding indicates that farmers in Chamwino were not only aware of the presence of aflatoxins but also understood their broader effects on food security and livelihoods. These results contrast those of Gichohi-Wainaina et al. (2021) in Malawi, where more than half of the households did not perceive aflatoxin contamination as a controllable problem. The difference may be attributed to the greater scope and intensity of awareness interventions in

Chamwino, which successfully influenced farmers' attitudes.

Most farmers also demonstrated strong awareness of the importance of hygiene and moisture control in preventing aflatoxin contamination. The majority (91.9%) of the maize farmers in this study identified cleanliness during planting, harvesting, and storage as crucial to minimizing contamination risk. Similar findings were reported by Kobia (2022) in Kenya, where most farmers cleaned their storage facilities before and after harvest. In this study, 94.1% of

farmers believed that regular monitoring of moisture levels could prevent aflatoxin growth, and many practiced sun drying to control moisture. These findings are consistent with Wekesa (2022), who reported that 83.2% of respondents were aware of the risks linked to inadequate drying. However, maize farmers in Chamwino were unfamiliar with the use of moisture meters and instead relied on traditional methods such as chewing grains to estimate dryness, as also noted by Kimario et al. (2022).

Table 5. Association between social demographic characteristics and farmers' knowledge, attitude, and practice on aflatoxin contamination and mitigation (n = 221).

Variable	Category	Knowledge			Attitude			Practice		p-value		
		Poor n (%)	Medium n (%)	Good n (%)	Poor n (%)	Medium n (%)	Good n (%)	Medium n (%)	Good n (%)	Knowledge	Attitude	Practice
Gender	N	47 (21.3%)	51 (23.1%)	123 (55.7%)	1 (0.5%)	34 (15.4%)	186 (84.2%)	64 (29.0%)	157 (71.0%)	0.017	0.106	0.097
	Female	17 (14.7%)	25 (21.6%)	74 (63.8%)	0 (0.0%)	13 (11.2%)	103 (88.8%)	28 (24.1%)	88 (75.9%)			
	Male	30 (28.6%)	26 (24.8%)	49 (46.7%)	1 (1.0%)	21 (20.0%)	83 (79.0%)	36 (34.3%)	69 (65.7%)			
Age categories	15–30	15 (34.1%)	10 (22.7%)	19 (43.2%)	0 (0.0%)	6 (13.6%)	38 (86.4%)	14 (31.8%)	30 (68.2%)	0.018	0.007	0.083
	31–45	19 (19.2%)	26 (26.3%)	54 (54.5%)	0 (0.0%)	16 (16.2%)	83 (83.8%)	24 (24.2%)	75 (75.8%)			
	46–60	10 (15.6%)	8 (12.5%)	46 (71.9%)	0 (0.0%)	8 (12.5%)	56 (87.5%)	18 (28.1%)	46 (71.9%)			
	Above 60	3 (21.4%)	7 (50.0%)	4 (28.6%)	1 (7.1%)	4 (28.6%)	9 (64.3%)	8 (57.1%)	6 (42.9%)			
Education level	No formal education	9 (30.0%)	9 (30.0%)	12 (40.0%)	1 (3.3%)	9 (30.0%)	20 (66.7%)	20 (66.7%)	10 (33.3%)	0.004	0.004	<0.001
	Primary	26 (24.8%)	30 (28.6%)	49 (46.7%)	0 (0.0%)	20 (19.0%)	85 (81.0%)	23 (21.9%)	82 (78.1%)			
	Secondary	11 (15.1%)	12 (16.4%)	50 (68.5%)	4 (5.5%)	0 (0.0%)	69 (94.5%)	20 (27.4%)	53 (72.6%)			
	Higher education	1 (7.7%)	0 (0.0%)	12 (92.3%)	1 (7.7%)	0 (0.0%)	12 (92.3%)	1 (7.7%)	12 (92.3%)			
Years of Experience	<5	8 (42.1%)	3 (15.8%)	8 (42.1%)	0 (0.0%)	4 (21.1%)	15 (78.9%)	5 (26.3%)	14 (73.7%)	0.313	0.902	0.326
	5–10	7 (17.9%)	9 (23.1%)	23 (59.0%)	0 (0.0%)	5 (12.8%)	34 (87.2%)	15 (38.5%)	24 (61.5%)			
	>10	32 (19.8%)	38 (23.5%)	92 (56.8%)	1 (0.6%)	24 (14.8%)	137 (84.6%)	43 (26.5%)	119 (73.5%)			
Type of farming	Both	17 (21.2%)	21 (26.2%)	42 (52.5%)	0 (0.0%)	13 (16.2%)	67 (83.8%)	29 (36.2%)	51 (63.7%)	0.399	0.133	0.023
	Commercial	3 (10.0%)	6 (20.0%)	21 (70.0%)	1 (3.3%)	3 (10.0%)	26 (86.7%)	12 (40.0%)	18 (60.0%)			
	Subsistence	27 (24.3%)	24 (21.6%)	60 (54.1%)	0 (0.0%)	18 (16.2%)	93 (83.8%)	23 (20.7%)	88 (79.3%)			
Farm size (acres)	<=1	8 (28.6%)	13 (46.4%)	7 (25.0%)	3 (10.7%)	0 (0.0%)	25 (89.3%)	9 (32.1%)	19 (67.9%)	p<0.001	0.66	0.858
	2–5	37 (27.6%)	28 (20.9%)	69 (51.5%)	1 (0.7%)	25 (18.7%)	108 (80.6%)	40 (29.9%)	94 (70.1%)			
	6–10	1 (2.2%)	7 (15.2%)	38 (82.6%)	4 (8.7%)	0 (0.0%)	42 (91.3%)	12 (26.1%)	34 (73.9%)			
	Above 10	1 (10.0%)	1 (10.0%)	8 (80.0%)	1 (10.0%)	0 (0.0%)	9 (90.0%)	2 (20.0%)	8 (80.0%)			

Furthermore, 94.6% of respondents agreed that drying maize on bare ground compromises its safety. This shows that farmers understood one of the most common and risky post-harvest practices contributing to aflatoxin contamination. Such awareness reflects the success of local intervention programs in communicating the dangers of improper drying and encouraging the adoption of safer techniques. In many rural areas, maize continues to be dried on bare soil due to limited infrastructure or awareness, which exposes the grain to moisture, fungal spores, and soil contamination. Kyalo et al. (2023) found that maize dried on bare ground had a

higher likelihood of aflatoxin contamination than maize dried on tarpaulins. The high level of agreement in this study demonstrates a positive shift toward safer drying practices.

A majority (85.6%) of respondents also showed positive attitudes regarding the importance of proper transportation in preventing aflatoxin contamination. Farmers recognized that post-harvest safety extends beyond storage and includes all stages up to delivery to consumers or buyers. Most farmers reported using pushcarts as the main means of transportation. However, only a small

proportion acknowledged the importance of fumigating storage facilities before and after use. Although attitudes toward aflatoxin prevention were generally positive, knowledge about fumigation and storage management remained limited. This may result from high fumigation costs, inadequate access to fumigation services, or insufficient training on chemical and structural management. As noted by Akullo et al. (2025), practices that require financial resources or technical expertise such as fumigation or storage modification are less frequently adopted despite increased awareness.

The study also found that just over half of the farmers felt confident in identifying signs of aflatoxin contamination in maize, while many were uncertain and a few lacked confidences altogether. This indicates that, although awareness programs improved general knowledge, farmers still struggled to accurately identify contaminated maize. Aflatoxin contamination is difficult to detect visually because fungal growth and discoloration do not always correspond to toxin presence (Abrehame et al., 2023; Mishra et al., 2021; Wang et al., 2022). This may explain the uncertainty among farmers regarding visual identification. A similar trend was observed by Mabruki et al. (2022) in Morogoro and Makambako, where among 75 respondents who attempted to identify fungal growth, only 27 (36%) did so correctly. These findings highlight the need for practical demonstrations during training and the introduction of affordable testing methods, as visual inspection alone is unreliable.

Finally, 94.1% of respondents agreed that continuous education and training are essential for improving attitudes toward aflatoxin management. Farmers recommended annual refresher courses to stay informed and motivated. This reflects a shared understanding that consistent capacity building is key to sustaining behavioral change and reducing aflatoxin risks over time.

Practices of maize farmers aflatoxin towards contamination and mitigation

Majority of maize farmers in Chamwino, Dodoma adopted good practices aimed at mitigating aflatoxin contamination. Most respondents reported consistent engagement in practices such as inspecting maize after harvest, properly storing

grains in dry areas, sorting out spoiled maize, and cleaning equipment used for processing and storage. This aligns with the findings of Lesuuda et al. (2021) in Kerio Valley, Kenya, who reported that households practicing regular post-harvest inspection and sorting of sorghum grains were better able to minimize fungal contamination and reduce mycotoxin exposure. Their study highlighted that visual inspection and rejection of discolored or damaged grains were among the most effective low-cost strategies for aflatoxin prevention. This was also observed in Chamwino. The results are in line with the study of Anitha et al. (2019), who reported that after targeted training on pre- and post-harvest management, Malawian farmers demonstrated improvements, especially in grading and storage practices for groundnut, maize, and sorghum. These results suggest that the post-intervention programs were largely successful in shaping farmers' behavior towards low-cost, preventive measures.

This study revealed that most farmers practiced timely harvesting and maintained clean fields, often involving family members to support these activities. Timely harvesting prevents crops from prolonged exposure to high humidity and pests in the field, thereby reducing contamination risk. Field cleaning, meanwhile, minimizes the chances of cross-contamination during processing and storage. The high adoption of these practices in Chamwino suggests that the intervention programs succeeded in instilling preventive measures that farmers could integrate into their routine activities without a significant financial burden. These results are consistent with the findings of Udomkun et al. (2018), who emphasized that timely harvesting and post-harvest hygiene were critical in reducing aflatoxin risk in Congo. Similarly, Ayo et al. (2018), in a study of livestock farmers in Tanzania, noted that cleaning of equipment and facilities significantly reduced contamination risks, demonstrating that hygiene-based practices are universally effective across agricultural systems.

However, some critical gaps remain as a considerable proportion of maize farmers in Chamwino had never participated in seminars, while many did not report aflatoxin contamination cases to agricultural institutions. This aligns with the results of the study by Nyangi et al. (2024), who reported

that 57.5% of farmers in Mbarali, Sumbawanga, and Mbozi never reported any cases of aflatoxin contamination to the agriculture extension officers. Similarly, the use of fungicides, pesticides, and improved storage facilities was relatively limited, with many farmers continuing to depend on traditional methods such as the use of granaries “vihenge” and storage cribs “vichanja”. These findings highlight the influence of economic barriers, similar to those reported by Kamala et al. (2016), who found that farmers still prefer traditional storage options (granaries, cribs) over improved alternatives due to economic constraints. Another study by Bisheko and Rejikumar (2023) reported that the key barriers to the adoption of improved postharvest technologies were high cost, local unavailability, and limited knowledge and awareness about these technologies.

In conclusion, the findings from Chamwino show that post-intervention programs have been effective in raising awareness and encouraging farmers to adopt simple, low-cost practices that help protect household maize from aflatoxin contamination. However, challenges such as high costs, limited access to inputs, and weak reporting systems continue to prevent farmers from using more resource-demanding methods like fumigation and improved storage. To overcome these barriers, there is a need for a combined approach that strengthens farmer education while also providing policy support, affordable storage and processing technologies, and stronger agricultural extension services.

Association between farmers' demographic characteristics and knowledge, attitudes and practices regarding aflatoxin contamination and mitigation

Association of farmers' demographic characteristics with knowledge regarding aflatoxin contamination and mitigation

The findings of this study showed that knowledge concerning aflatoxin contamination and mitigation was significantly associated with age, education level, and farm size. Gender, however, was not significantly associated with knowledge ($p = 0.388$). Although female farmers appeared slightly more knowledgeable—63.8% demonstrated good knowledge compared to 46.7% of males, the

difference was not statistically significant. This contrasts with reports by Cheruiyot et al. (2024), who found women to have higher aflatoxin knowledge due to their central role in post-harvest handling. In the Chamwino context, the lack of statistically meaningful gender differences suggests that men and women received similar levels of exposure to aflatoxin-related information through community programs and extension services.

Age was significantly associated with knowledge ($p = 0.018$). Among the youngest farmers (15–30 years), only 19 (43.2%) had good knowledge, compared to 54 (54.5%) in the 31–45 age group and 46 (71.9%) among farmers aged 46–60 (**Table 5**). Even though knowledge declined in those above 60 years (4 farmers, 28.6% with good knowledge), the clear trend indicates that middle-aged and older farmers were more knowledgeable. This pattern likely reflects accumulated farming experience and exposure to agricultural training, consistent with findings by Bila et al. (2025) in Mozambique. Education level also showed a strong association with knowledge ($p = 0.004$). Only 12 farmers with no formal education (40.0%) demonstrated good knowledge, compared to 49 (46.7%) among those with primary education. Knowledge levels increased substantially among secondary-educated farmers, with 50 (68.5%) demonstrating good knowledge, and were highest among respondents with higher education, 12 (92.3%) of whom showed good knowledge. This gradient confirms the positive influence of formal education on the ability to understand aflatoxin contamination and mitigation strategies.

Farm size was another significant determinant of knowledge ($p < 0.001$). Only 7 farmers with ≤ 1 acre (25.0%) had good knowledge, compared to 69 (51.5%) among those cultivating 2–5 acres. Knowledge scores were highest among farmers with larger farms: 38 farmers (82.6%) in the 6–10-acre category and 8 farmers (80.0%) with farms above 10 acres demonstrated good knowledge. These differences likely reflect greater access to extension services, training opportunities, and improved post-harvest technologies among larger-scale farmers. This pattern is consistent with Gachara et al. (2022), who reported higher awareness of aflatoxin risks among large-scale farmers compared to

smallholders. By contrast, years of farming experience and farming type were not significantly associated with knowledge ($p = 0.313$ and $p = 0.399$, respectively). For example, knowledge remained relatively similar across experience groups, with 8 farmers (42.1%) with <5 years of experience and 92 farmers (56.8%) with >10 years showing good knowledge. Similarly, farmers engaged in subsistence, commercial, or mixed farming exhibited comparable knowledge levels. These patterns suggest that farming experience or production orientation alone does not guarantee higher knowledge unless supported by structured training or exposure to aflatoxin mitigation programs. This aligns with findings by Njeru et al. (2019), who also observed that farming experience was not a significant predictor of aflatoxin knowledge.

Association of farmers' demographic characteristics with attitudes towards aflatoxin contamination and mitigation

The findings of this study showed that farmers' attitudes toward aflatoxin contamination and mitigation were significantly associated with age ($p = 0.007$) and education level ($p = 0.004$). Among the youngest farmers (15–30 years), only 38 respondents (86.4%) demonstrated a positive attitude (good), compared with 83 farmers (83.8%) in the 31–45 age group and 56 farmers (87.5%) among those aged 46–60. In contrast, farmers above 60 years demonstrated considerably weaker attitudes, with only 9 respondents (64.3%) showing good attitudes and 4 (28.6%) showing medium attitudes (Table 5). These results indicate that middle-aged farmers and to some extent those in the 46–60 range had more favorable attitudes, likely due to greater involvement in farming decisions and higher exposure to interventions. This pattern aligns with Cheruiyot et al. (2024), who reported lower responsiveness among older farmers compared to middle-aged groups.

Education level was also strongly linked to attitudes. Only 20 farmers with no formal education (66.7%) exhibited good attitudes, compared with 85 farmers with primary education (81.0%). Attitudes improved substantially among those with secondary education, where 69 farmers (94.5%) demonstrated good attitudes, and were highest among respondents with higher education, where 12 farmers (92.3%) showed

good attitudes. These results reinforce findings by Sewunet et al. (2024) that higher education enhances openness to health- and safety-related practices. Gender was not significantly associated with attitudes ($p = 0.106$). Both women (88.8%) and men (79.0%) demonstrated high levels of positive attitudes, suggesting that program interventions, community sensitization, and awareness campaigns reached both genders effectively.

Farm size and years of farming experience also showed no significant associations with attitudes ($p = 0.66$ and $p = 0.902$, respectively). For example, good attitudes were observed across different experience levels: 78.9% among farmers with less than 5 years of experience, 87.2% among those with 5–10 years, and 84.6% among farmers with over 10 years of experience. Similarly, attitude scores were comparable across farm size categories, with good attitudes observed in 89.3% of farmers with ≤ 1 acre, 80.6% with 2–5 acres, 91.3% with 6–10 acres, and 90.0% with more than 10 acres. These outcomes imply that community workshops, awareness campaigns, and extension messages were delivered uniformly across groups, creating consistent attitudes regardless of land size or time spent in farming. This observation aligns with Kimario et al. (2022), who reported no significant influence of farming experience or landholding size on aflatoxin awareness.

Association of farmers' demographic characteristics with practices regarding aflatoxin contamination and mitigation

The study found that education level had a significant positive influence on the adoption of good aflatoxin prevention practices ($p < 0.001$). Only 10 farmers with no formal education (33.3%) demonstrated good practices, compared to 82 farmers with primary education (78.1%). Adoption increased further among those with secondary education, with 53 farmers (72.6%) practicing appropriate mitigation measures, and was highest among respondents with higher education, where 12 farmers (92.3%) demonstrated good practices (Table 5). These results highlight the critical role of education in shaping the adoption of safe aflatoxin handling and storage practices. This finding is consistent with Kitigwa et al. (2023), who reported that smallholder dairy farmers with primary and

secondary education in Tanzania were more likely to adhere to recommended post-harvest and storage practices.

Farming type was also significantly associated with practice levels ($p = 0.023$). Subsistence farmers demonstrated the highest proportion of good practices, with 88 farmers (79.3%) applying recommended aflatoxin mitigation measures, compared with 51 farmers (63.7%) engaged in both subsistence and commercial farming and 18 farmers (60.0%) practicing commercial farming exclusively. Subsistence farmers may be more cautious because their households rely directly on the harvested maize for consumption, making them more vigilant in preventing contamination. These results support findings by Mutegi et al. (2018), who reported that farmers producing primarily for home use were more likely to adopt aflatoxin control practices to ensure food safety.

In contrast, gender, age, farm size, and years of farming experience were not significantly associated with practices ($p > 0.05$), despite observable variations in proportions. For example, 88 female farmers (75.9%) and 69 male farmers (65.7%) demonstrated good practices, and good practice proportions ranged from 30 farmers (68.2%) in the 15–30 age group to 46 farmers (71.9%) in the 46–60 age group. Similarly, good practices were observed across all farm sizes, including 19 farmers (67.9%) with ≤ 1 acre and 94 farmers (70.1%) with 2–5 acres. These findings suggest that while socio-demographic characteristics influence knowledge and attitudes, the actual implementation of aflatoxin mitigation practices may be more heavily shaped by practical constraints such as limited resources, cost of improved storage technologies, and inconsistent access to extension support. Comparable conclusions were drawn by Awuor et al. (2023) in Kenya, who found that economic limitations were the strongest predictors of poor post-harvest handling behaviors.

Limitations of the study

This study focused solely on maize farmers in Chamwino who had participated in post-intervention programs, excluding farmers of other crops and those who had not been involved in the interventions. Consequently, the research was

unable to capture potential differences in knowledge, attitudes, and practices among farmers outside these programs. Future studies should expand to include these excluded groups, as their knowledge, attitudes, and practices may be shaped by different factors. In addition, future research should consider employing a prospective cohort study, which follows the same farmers over time and enables the assessment of how exposure to interventions influences changes in knowledge, attitudes, and practices, thereby providing stronger evidence for causal relationships.

Conclusion

This study revealed that post-intervention programs had a substantial impact in enhancing farmers' knowledge, attitudes, and practices toward aflatoxin contamination and mitigation in Chamwino. Most farmers were able to identify key contamination risks, recognize environmental factors that favored fungal growth, and adopt affordable preventive measures such as timely harvesting, proper drying, sorting and cleaning of storage facilities. These findings suggest that structured awareness campaigns and training programs were effective in strengthening farmers' capacity to reduce aflatoxin risks at the community level. Nonetheless, critical gaps remain. Farmers' awareness of the full range of health effects associated with aflatoxin exposure was limited, as most only mentioned liver cancer or death. Similarly, while attitudes were generally favorable, adoption of resource-intensive measures, including fumigation and investment in improved storage facilities, remained low, largely due to financial and infrastructural constraints. These limitations suggest that knowledge alone is insufficient to ensure behavioral change where practices require significant resources.

Based on the findings, this study recommends several strategies to strengthen aflatoxin mitigation. Educational campaigns should be tailored to local literacy and culture to effectively communicate the specific health impacts of aflatoxins, including stunting and immunotoxicity. Secondly, regular, practical refresher training should be institutionalized, utilizing demonstration and farmer-to-farmer extension to sustain behavioral change. The economic barriers must be addressed by

improving access to affordable technologies and fumigation services via subsidies or public-private partnerships, alongside policies that promote cost-effective, community-level infrastructure. Finally, future research should prioritize identifying and evaluating context-specific, low-cost innovations for smallholders. Government and other stakeholders are advised to implement these recommendations which is crucial for translating knowledge into sustainable action to safeguard public health and food security.

Acknowledgments

This study was funded by Chalmers University of Technology, Sweden. We would like to thank local government leaders, Agriculture extension officers, and all the respondents and participants in this study for their kind support and cooperation during the survey.

Conflicts of interest

The authors do not have any conflict of interest.

Disclaimer

Author(s) hereby declares that NO generative AI technologies, such as large language models (ChatGPT, COPILOT, etc.) and text-to-image generators, have been used during the writing or editing of this manuscript.

References

- Abrehame, Solomon; Manoj, Valsa Remony; Hailu, Merry; Chen, Yu-Yi; Lin, Yu-Chun; & Chen, Yen-Po. (2023). Aflatoxins: Source, detection, clinical features and prevention. *Processes*, 11(1), 204. <https://doi.org/10.3390/pr11010204>
- Akullo, J. O., Okello, D. K., Mohammed, A., Muyinda, R., Amayo, R., Magumba, D., . . . Mweetwa, A. (2025). A comprehensive review of aflatoxin in groundnut and maize products in Africa: Prevalence, detection and mitigation strategies. *Journal of Food Quality*, 2025(1), 2810946. <https://doi.org/10.1155/2025/2810946>
- Anitha, S., Tsusaka, T. W., Njoroge, S. M., Kumwenda, N., Kachulu, L., Maruwo, J., . . . Masumba, J. (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. <https://doi.org/10.3390/toxins11120716>
- 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. <https://doi.org/10.3390/toxins14030167>
- Awuor, A. O., Wambura, G., Ngere, I., Hunsperger, E., Onyango, C., Bigogo, G., . . . Widdowson, M.-A. (2023). A mixed methods assessment of knowledge, attitudes and practices related to aflatoxin contamination and exposure among caregivers of children under 5 years in western Kenya. *Public Health Nutrition*, 26(12), 3013–3022. <https://doi.org/10.1017/S1368980023000150>
- Ayo, E., Matemu, A., Laswai, G., & Kimanya, M. (2018). Socioeconomic characteristics influencing level of awareness of aflatoxin contamination of feeds among livestock farmers in Meru District of Tanzania. *Scientifica*, 2018(1), 3485967. <https://doi.org/10.1155/2018/3485967>
- Benkerroum, N. (2020). Aflatoxins: Producing molds, structure, health issues and incidence in Southeast Asian and Sub-Saharan African countries. *International Journal of Environmental Research and Public Health*, 17(4), 1215. <https://doi.org/10.3390/ijerph17041215>
- Bila, J., Macuamule, C., Bombe, A., Ribeiro, M. I., Venâncio, A., Afonso, S., & Rodrigues, P. (2025). Assessment of farmers' knowledge and attitudes toward fungi and mycotoxin contamination in staple crops in southern Mozambique. *Frontiers in Sustainable Food Systems*, 9, 1622532. <https://doi.org/10.3389/fsufs.2025.1622532>
- Bisheko, M. J., & Rejikumar, G. (2023). Major barriers to adoption of improved postharvest technologies among smallholder farmers in sub-Saharan Africa and South Asia: A systematic literature review. *World Development Sustainability*, 2, 100070. <https://doi.org/10.1016/j.wds.2023.100070>
- Cheruiyot, C., Okoth, M. W., Abong', G. O., & Kariuki, S. W. (2024). Knowledge, attitudes, and food safety practices of informal market maize grain vendors and consumers in Meru County, Kenya. *International Journal of Food Science*, 2024, 6592430. <https://doi.org/10.1155/2024/6592430>
- Fundikira, S., De Saeger, S., Kimanya, M., & Mugula, J. (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. <https://doi.org/10.3920/WMJ2020.2590>
- Gachara, G., Suleiman, R., El Kadili, S., Ait Barka, E., Kilima, B., & Lahlali, R. (2022). Drivers of post-harvest aflatoxin contamination: Evidence from knowledge disparities and field surveys of maize farmers in the Rift Valley region of Kenya. *Toxins*, 14(9), 618. <https://doi.org/10.3390/toxins14090618>
- Gichohi-Wainaina, W. N., Kumwenda, N., Zulu, R., Munthali, J., & Okori, P. (2021). Aflatoxin contamination: Knowledge disparities among agriculture extension officers, frontline health workers and small holder farming households in Malawi. *Food Control*, 121, 107672. <https://doi.org/10.1016/j.foodcont.2020.107672>

- Hatibu, A. A., Akpo, E., Lukurugu, G. A., Nzunda, J., Okori, P., & Ojiewo, C. O. (2022). Upscaling groundnut seed production and delivery through long-term public-private and development organization partnerships: Experiences from Tanzania. *Agriculture*, 13(1), 79. <https://doi.org/10.3390/agriculture13010079>
- Hossen, M. T., Ferdous, M. J., Hasan, M. M., Lina, N. N., Das, A. K., Barman, S. K., . . . Roy, R. K. (2020). Food safety knowledge, attitudes and practices of street food vendors in Jashore region, Bangladesh. *Food Science & Technology*, 41, 226–239. <https://doi.org/10.1590/fst.13320>
- 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. <https://doi.org/10.1080/19440049.2016.1138546>
- Kamala, A., Shirima, C., Jani, B., Bakari, M., Sillo, H., Rusibamayila, N., . . . Simba, A. (2018). Outbreak of an acute aflatoxicosis in Tanzania during 2016. *World Mycotoxin Journal*, 11(3), 311–320. <https://doi.org/10.3920/WMJ2017.2277>
- Kenei, F., Mezene Woyessa, A. M., Lema, K., & Gemmeda, M. (2023). Review on occurrence and public health significance of aflatoxin in dairy products and feed. *International Journal of Livestock Research*, 13 (6), 1–13.
- Khodaei, D., Javanmardi, F., & Khaneghah, A. M. (2021). The global overview of the occurrence of mycotoxins in cereals: A three-year survey. *Current Opinion in Food Science*, 39, 36–42. <https://doi.org/10.1016/j.cofs.2020.12.012>
- Kimario, M. E., Moshi, A. P., Ndossi, H. P., Kiwango, P. A., Shirima, G. G., & Kussaga, J. B. (2022). Smallholder farmers' storage practices and awareness on aflatoxin contamination of cereals and oilseeds in Chamwino, Dodoma, Tanzania. *Journal of Cereals and Oilseeds*, 13(1), 13–23. <https://doi.org/10.5897/JCO2020.0220>
- Kinyenje, E., Kishimba, R., Mohamed, M., Mwafulango, A., Eliakimu, E., & Kwesigabo, G. (2023). Aflatoxicosis outbreak and its associated factors in Kiteto, Chemba and Kondoa Districts, Tanzania. *PLOS Global Public Health*, 3(8), e0002191. <https://doi.org/10.1371/journal.pgph.0002191>
- Kitigwa, S., Kimaro, E., Nagagi, Y., Kussaga, J., Suleiman, R., & Matemu, A. (2023). Occurrence and associated risk factors of aflatoxin contamination in animal feeds and raw milk from three agroecological zones of Tanzania. *World Mycotoxin Journal*, 16(2), 149–164. <https://doi.org/10.3920/WMJ2022.2743>
- Kobia, J. M. (2022). Effect of hygiene status in maize storage facilities on pests, molds and aflatoxin contamination in Nakuru County, Kenya (Master's thesis, University of Nairobi). <http://erepository.uonbi.ac.ke/handle/11295/161681>
- Kortei, N. K., Badzi, S., Nanga, S., Wiafe-Kwagyan, M., Amon, D. N. K., & Odamtten, G. T. (2023). Survey of knowledge and attitudes to storage practices preempting the occurrence of filamentous fungi and mycotoxins in some Ghanaian staple foods and processed products. *Scientific Reports*, 13(1), 8710. <https://doi.org/10.1038/s41598-023-34500-0>
- Kyalo, W. M., Onono, J. O., Ombui, J. N., Gathura, P. B., Gitahi, J. N., & Ateku, P. A. (2023). Aflatoxin contamination of maize from small-scale farms practicing different artisanal control methods in Kitui, Kenya. *Journal of Food Quality*, 2023, 3501819. <https://doi.org/10.1155/2023/3501819>
- 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. <https://doi.org/10.1002/fsn3.2550>
- Mabruki, F., Makundi, I. & Temba, B. A. (2022). Knowledge, awareness and post-harvest practices predisposing stored maize to aflatoxin contamination in Morogoro Municipality and Makambako District, Tanzania. *American Journal of Public Health Research*, 10(4), 134–142. <https://doi.org/10.12691/ajphr-10-4-1>
- Martínez, J., Hernández-Rodríguez, M., Méndez-Albores, A., Téllez-Isaías, G., Mera Jiménez, E., Nicolás-Vázquez, M. I., & Miranda Ruvalcaba, R. (2023). Computational studies of aflatoxin B₁ (AFB₁): A review. *Toxins*, 15(2), 135. <https://doi.org/10.3390/toxins15020135>
- Min, L., Fink-Gremmels, J., Li, D., Tong, X., Tang, J., Nan, X., . . . Wang, G. (2021). An overview of aflatoxin B₁ biotransformation and aflatoxin M₁ secretion in lactating dairy cows. *Animal Nutrition*, 7(1), 42–48. <https://doi.org/10.1016/j.aninu.2020.11.002>
- Mishra, G., Panda, B. K., Ramirez, W. A., Jung, H., Singh, C. B., Lee, S. H., & Lee, I. (2021). Research advancements in optical imaging and spectroscopic techniques for nondestructive detection of mold infection and mycotoxins in cereal grains and nuts. *Comprehensive Reviews in Food Science and Food Safety*, 20(5), 4612–4651. <https://doi.org/10.1111/1541-4337.12801>
- Mkuki, Z., & Msuya, C. (2020). Agricultural extension officers' perceptions towards their roles: A case study of Simiyu Region, Tanzania. *Tanzania Journal of Agricultural Sciences*, 19(2), 56–66.
- Mutegi, C., Cotty, P., & Bandyopadhyay, R. (2018). Prevalence and mitigation of aflatoxins in Kenya (1960-to date). *World Mycotoxin Journal*, 11(3), 341–358. <https://doi.org/10.3920/WMJ2017.2342>
- Mutiga, S. K., Mushongi, A. A., & Kangéthe, E. K. (2019). Enhancing food safety through adoption of long-term technical advisory, financial, and storage support services in maize growing areas of East Africa. *Sustainability*, 11(10), 2827. <https://doi.org/10.3390/su11102827>
- Mutua, F. K., Grace, D., & Watts, C. (2021). Food safety investments in East Africa. Report. <https://hdl.handle.net/10568/115040>
- Njeru, N. K., Midega, C. A. O., Muthomi, J. W., Wagacha, J. M., & Khan, Z. R. (2019). Influence of socio-economic and agronomic factors on aflatoxin and fumonisin contamination of maize in western Kenya. *Food Science & Nutrition*, 7(7), 2291–2301. <https://doi.org/10.1002/fsn3.1070>

- Nyangi, C., Siyame, P., & Hussein, Z. (2024). Assessment of knowledge, attitudes, and practices in relation to mycotoxin contamination in Tanzania. *East African Journal of Health and Science*, 7(1), 205–220. <https://doi.org/10.37284/eajhs.7.1.1828>
- Onesmo, A., Frida, A. N., & Alex, N. W. (2024). Assessment of aflatoxin awareness in animal feeds and fresh milk among smallholder dairy farmers in Kondoa District, Dodoma, Tanzania. *Journal of Agriculture and Food Research*, 16, 101051. <https://doi.org/10.1016/j.jafr.2024.101051>
- Peivasteh-Roudsari, L., Pirhadi, M., Shahbazi, R., Eghbaljoo-Gharehgheshlaghi, H., Sepahi, M., Mirza Alizadeh, A., . . . Jazaeri, S. (2022). Mycotoxins: Impact on health and strategies for prevention and detoxification in the food chain. *Food Reviews International*, 38(Suppl 1), 193–224. <https://doi.org/10.1080/87559129.2020.1858858>
- Ramani, A., Hazra, T., Das, A., Manik, S., Tarafdar, A., Dey, S., & Singh, U. (2025). Comprehensive review on the occurrence of aflatoxin M₁ in milk, prevalent health issues associated with it, and innovative strategies for mitigation of aflatoxin M₁ in processed milk. *Food Safety & Health*, (Early View). <https://doi.org/10.1002/fsh3.70047>
- Salazar-López, N. J., Ovando-Martínez, M., & Domínguez-Avila, J. A. (2020). Cereal/grain by-products. In R. Campos-Vega, B. Dave Oomah, Haydé Azeneth Vergara-Castañeda, (Eds.), *Food wastes and by-products: nutraceutical and health potential* (pp.1-34). USA: John Wiley & Sons Ltd. <https://doi.org/10.1002/9781119534167>
- 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. <https://doi.org/10.1155/2024/5568286>
- Tanzania Meteorological Authority. (2019). *Statement on the status of Tanzania climate in 2019*. Tanzania Meteorological Authority.
- Toma, A. (2019). Knowledge, attitude and practice of farmers towards aflatoxin in cereal crops in Wolaita Zone, Southern Ethiopia. *EC Nutrition*, 14, 247–254.
- Udomkun, P., Wossen, T., Nabahunu, N. L., Mutege, C., Vanlauwe, B., & Bandyopadhyay, R. (2018). Incidence and farmers' knowledge of aflatoxin contamination and control in Eastern Democratic Republic of the Congo. *Food Science & Nutrition*, 6(6), 1607–1620. <https://doi.org/10.1002/fsn3.735>
- Umar, A., Qanita, S., Zada, N., & Honey, S. F. (2025). From feed to food – understanding the impact of aflatoxin consumption by Pakistani livestock. *CABI One Health*, 4(1), 0021. <https://doi.org/10.1079/cabionehealth.2025.0021>
- Verma, R., Chauhan, N., Bhat, F. M., Anand, A., & Dhaliwal, Y. (2023). Role of cereals in food security. In G. A. Nayik, T. Tufail, F. M. Anjum, & M. J. Ansari (Eds.), *Cereal Grains*, (pp. 15-24). Boca Raton: CRC Press.
- Wan, J., Chen, B., & Rao, J. (2020). Occurrence and preventive strategies to control mycotoxins in cereal-based food. *Comprehensive Reviews in Food Science and Food Safety*, 19(3), 928–953. <https://doi.org/10.1111/1541-4337.12546>
- Wang, L., He, K., Wang, X., Wang, Q., Quan, H., Wang, P., & Xu, X. (2022). Recent progress in visual methods for aflatoxin detection. *Critical Reviews in Food Science and Nutrition*, 62(28), 7849–7865. <https://doi.org/10.1080/10408398.2021.1977781>
- Waryoba, F. D. (2025). Aflatoxin awareness and food security among smallholder farmers in Tanzania. Preprint. <https://doi.org/10.21203/rs.3.rs-5867493/v1>
- Wekesa, R. C. (2022). Effect of post-harvest handling knowledge and practices of small-scale maize farmers in Trans Nzoia County on mycotoxin contamination of the grains (Master's thesis, University of Nairobi). <http://erepository.uonbi.ac.ke/handle/11295/161897>