ISSN: 2456-8643

ASSESSMENT OF FARMER'S AWARENESS IN HARVESTING AND POSTHARVEST HANDLING PRACTICES FOR MANAGEMENT OF AFLATOXINS ON MAIZE IN MOROGORO REGION

Christina Zakayo Wuiya[1*], Valerian. C. K. Silayo[1], Frida Nyamete[1] and Ramadhani Omari Majubwa[2]

[1]Department of Food and Agro-processing Sokoine University of Agriculture, P. O. Box 3005, Chuo Kikuu, MOROGORO, TANZANIA

[2]Department of Crop Science and Horticulture Sokoine University of Agriculture, P. O. Box 3005, Chuo Kikuu, MOROGORO, TANZANIA

https://doi.org/10.35410/IJAEB.2022.5762

ABSTRACT

Aflatoxins are toxins produced by certain strains of Aspergillus flavus that are found in several crops. This toxin is produced by Aspergillus flavus in food and feeds results in adverse health effects for humans and animals, as well as economic barriers to farmers and countries. This study aimed to assess the awareness of farmers in harvesting and postharvest handling practices for the management of Aflatoxin in maize. The assessment was conducted using questionnaire to capture data on bio-data information, farmer's awareness on aflatoxin contamination, harvesting time, post-harvesting practices, and storage facilities. Statistical analyses were performed using Statistical Package for Social Science (SPSS) version 25. The result shows that 65.63% of farmers in Kilosa and 67.28% of farmers in Gairo districts were aware of aflatoxin contamination. The study revealed that, during harvesting time, 92% of farmers at Kilosa and 98% of farmers in Gairo district harvest maize when completely dry. In drying practice, the use of canvas had higher usage compared to other practices where 42.70% of farmers in Kilosa and 16.70% of farmers in the Gairo district were using canvas. Additionally, it was observed that the majority of farmers in both districts store their maize by using storage bags/sacks that favor the rise of insect/pest contamination. The study suggests that there is a need for establishing an educational campaign for maize farmers on the effect of aflatoxin contamination to improve their awareness. The knowledge should base on harvesting, drying practices, and modern storage facilities that can reduce aflatoxin contamination.

Keywords: Aflatoxin, awareness, demographic factor, harvest, post-harvest.

1. INTRODUCTION

Aflatoxin is among the toxins that result from fungal metabolism, which occurs naturally (Ayo et al., 2018). This toxin is produced by molds known as *Aspergillus flavus* and *Aspergillus parasiticus*, which grow in soil, decaying vegetation, hay, and grains (Timothy et al.,2020). In June 2016, the outbreak of an unknown disease was reported to affect clusters of families in different villages in the Dodoma and Manyara regions of the central part of Tanzania (Kamala, 2018). The disease, which was associated with aflatoxin contamination, affected subsistent farmers who produced and consumed maize as their major staple food. Aflatoxin poses a health hazard to both animals and humans through transfer into the animal products food chain (Atherstone et al., 2016). Various studies have reported the illness impacts of aflatoxin in humans. These effects include immune suppression, liver cancer, digestive disorders, fertility impairment, and central nervous system interference (Chen et al., 2021).

Aflatoxin affects many staple crops including cereals and legumes, nuts, and spices. Maize and groundnuts are highly susceptible to aflatoxin contamination despite being consumed at high rates (Boni et al., 2021). Globally, it is estimated that the region lying between 40°N and 40°S latitudes is generally at risk of aflatoxin contamination of their farm produce (Ayo et al., 2018). Aflatoxin is an odorless, colorless, flavorless toxin and for this reason is not easy for farmers to detect its presence in crops or grains (Massomo, 2020). Aflatoxin contamination occurs at different stages of the maize value chain including production, harvesting, postharvest handling, processing, storage, and distribution (Nji et al., 2022). Also, weather conditions like rainfall, high temperature, and high humidity have been regarded as predisposing factors to aflatoxin contamination.

This paper assessed the awareness of farmers on harvesting and postharvest handling practices through the use of a questionnaire to gather information on how farmers can reduce the level of aflatoxin contamination in maize. The collected data will help in the establishment of farmers' awareness of harvesting and postharvest handling practices used in the management of aflatoxin in maize.

2. METHODOLOGY

2.1 Study area

The study was conducted in two districts in the Morogoro region: Kilosa district (located between latitude 6° and 42´ South, and between longitude 36° and 48´ East) and Gairo district (located between latitude 6° and 91´ South, and between longitude 36° and 08´ East) shown in Figure 1. These locations were purposefully selected due to their different agroecological zones and previous reports that depicted a high level of aflatoxin contamination in maize (Kamala et al., 2015). The selected districts are characterized by temperatures above 27°C and atmospheric humidity above 62%, which make them the main predisposing factors to aflatoxin contamination (Bhatnagar et al., 2004).

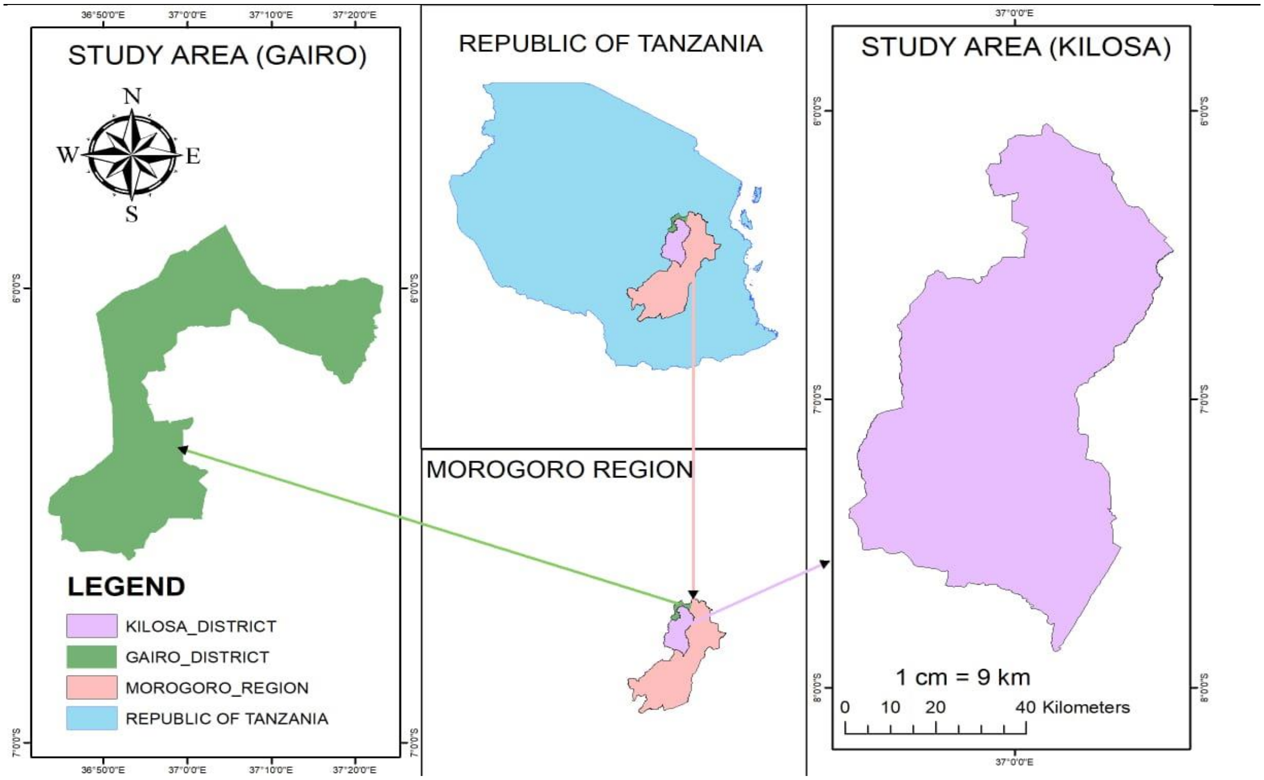

Figure 1: Morogoro region map showing Kilosa and Gairo Districts where the assessment on awareness of aflatoxin was conducted among the respondent farmers.

2.2 Survey and data collection

Data collection was done by the TANPAC project in Kilosa and Gairo Districts in 2020 (*TANIPAC project baseline survey* Report, 2020). These data were used for the assessment of awareness and contribution of smallholder farmers to practicing post-harvest techniques that reduce the level of aflatoxin in maize. Data were collected from the households and youths through the household interview using an electronic questionnaire mounted on the Kobo Collect Application and saved on the Kobo Toolbox platform. Other data collection tools were the key informants' checklist and FGD guide, as well as the document review guide. Household and youths data were checked for errors and submitted on the online server on daily basis. The raw data collected by *TANIPAC project baseline survey* Report (2020) were analyzed using Statistical Package for Social Sciences (SPSS v.25).

2.3 Assessment and contribution of smallholder farmers on harvesting and post-harvest techniques in aflatoxin contamination

This study was conducted to seek information on the following key questions about awareness of postharvest practices in aflatoxin contamination: How do farmers harvest their maize against aflatoxin contamination? How do farmers dry and sort their maize against aflatoxin contamination and also which methods do they use during maize storage to prevent aflatoxin contamination? Any knowledge or awareness of aflatoxin contamination.

The questionnaires were developed and used to collect the data among farmers in Kilosa and Gairo districts. A sampling of the heads of households and youths was done using a mix of methods of Snowball sampling and random movements at the village level, with the help of sub-village leaders. The total sample size of household heads used in the Kilosa district was 248. Among these, 76 respondents (31%) were the control group (those who were not interviewed) and 172 respondents (69%) were in the intervention/treatment group (interviewed villagers). Also, the total number of households sampled in the Gairo District was 225, 20% of which were the control group and 80% of the interviewed group. Open Data Kit (ODK Collector) was used in data collection.

2.4 Data analysis

Statistical analyses were performed using Statistical Package for Social Science (SPSS) version 25 to obtain frequency and percentage for the selected variables.

3. RESULTS

3.1 Assessment of farmers' awareness of harvesting and postharvest handling practices for management of aflatoxin on maize

3.1.1 Demographic information of farmers in Kilosa and Gairo districts on awareness of aflatoxin contamination.

Farmer's responses to the survey from the two districts (Kilosa and Gairo) are presented in Table 1, in which it is shown there were 35% females and 65% males in Kilosa while in Gairo there were 22% females and 78% males who participated in the survey. This implies that males appear more in the household surveys compared to females almost twice as much in Kilosa and three times in Gairo. In the case of awareness of aflatoxin in the Gairo district results show that among the female farmers 81.63% were aware and 18.37% were not aware of aflatoxin contamination. Also among the male farmers in the Gairo district, 72.73% were aware while 27.27% were not aware of aflatoxin contamination. In the Kilosa district results show that among the 35% of female farmers, 17.4% of them were aware while 82.56% were not aware of aflatoxin contamination. In the case of males, results show that 34.57% of them were aware of aflatoxin contamination while 65.43% have not heard about it.

In the Kilosa district, 53% of the farmers who participated in the study were in the age range of 41-60, of which 27.48% of farmers were aware and 72.52% of farmers were not aware of aflatoxin contamination. Also, in the Gairo district, 56% of the farmers were between the age of 41-60 years, of which 84% were aware and 16% were not aware of aflatoxin contamination. Farmers aged above 60 years were 18%, of which 35.65% of farmers were aware while 64.44% of farmers were not aware of aflatoxin contamination in the Kilosa district. In the Gairo district farmers with the age above 60 years were 1% less than those in the Kilosa district in which all of them were not aware of aflatoxin contamination. Concerning education, the majority of the farmers in Gairo (80%) and Kilosa (79%) had primary education. Among those farmers with primary education, 82.78% in the Gairo district were aware of aflatoxin contamination while 17.22% were not aware. In the Kilosa district, 28.06% of farmers were aware of aflatoxin contamination while 71.94% were not aware.

Vol. 07, No. 05; 2022

ISSN: 2456-8643

Pearson product-moment correlation analysis was conducted to identify the relationship between demographic variables with farmers' awareness of aflatoxin contamination in maize. The result in Table 3 shows that demographic factors such as sex, age, education level, and occupation had a significant relationship with farmers' awareness of aflatoxin at 5% and 1% levels of significance.

Table 1:Demographic information of farmers in Kilosa and Gairo districts on awareness of aflatoxin contamination.

		Kilosa n=248 **Proportion Percentage (%),** **[Percentage of awareness of aflatoxin (Yes, No)]**	**Gairo n=225** **Proportion Percentage (%),** **[Percentage of awareness of aflatoxin (Yes, No)]**
Sex	Female	35[(17.4,82.56)]	22,[(81.63,18.37)]
	Male	65[(34.57,65.43)]	78[(72.73,27.27)]
Age group	18-25	2[(20,80)]	3[(50,50)]
	26-40	27[26.87,73.13)]	32[66.20,33.80)]
	41-60	53[(27.48,72.52)]	56[(84,16)]
	Above 60	18[(35.65,64.44)]	1[(0,100)]
Education level	Not attended	15[(19.4,80.56)]	18[(41.46,58.54)]
	Primary	79[(28.06,71.94)]	80[(82.78,17.22)]
	Secondary-Form Four	5[(41.67,58.33)]	2[(50,50)
	Secondary-Form Six	1[(100,0)]	0.0
	College (Certificate and or Diploma)	1[(100,0)]	1[(100,0)]
Occupation	Business	1[(0,100)]	0.0
	Farmer (Livestock, farming, fishing)	99[(28.98,71.02)]	91[(74.67,25.3)]

Source: *TANIPAC project baseline survey*

ISSN: 2456-8643

Table 2: Relationship between the selected demographic variables with farmer's awareness of aflatoxin contamination using Pearson product-moment correlation

Variables	Correlation coefficient (r)	
	Kilosa district	**Gairo district**
Sex	0.00*	0.01*
Age	0.02**	0.03**
Education level	0.04**	0.05**
Occupation	0.01*	0.00**

****correlation is significant at 1% level, *Correlation at 5% level**

3.1.2 Proportional farmers' awareness of aflatoxin in maize in Gairo and Kilosa districts

In this study farmers' awareness of aflatoxin is described in Table 3. The results show that 65.63% of the farmers in Kilosa are aware of aflatoxin, which is nearly the same as those of Gairo (67.28%). Again, 34.38% of farmers in Kilosa and 32.72% of farmers in the Gairo districts were not aware of aflatoxin contamination.

Table 3: Proportional farmers' awareness of aflatoxin in maize in Gairo and Kilosa districts

Awareness of Aflatoxin	Kilosa (n=256)	Gairo (n=256)
	Percentage (%)	**Percentage (%)**
Yes	65.63	67.28
No	34.38	32.72
Chi-square	0.154	0.087

Also, results show how the sources of information are being utilized among farmers in both districts. Almost 37.0% of farmers in Kilosa and 46.9% of farmers in Gairo receive information through radio. Friends as a source of information are the next media in which farmers received information whereby Kilosa accounts for 13.7%, less than Gairo which is 24.0% (Table 4).

Table 4: Proportion source of information to the farmers' awareness of aflatoxin in maize in Gairo and Kilosa districts

Source of information	Kilosa (n=73) Percentage (%)	Gairo (n=262) Percentage (%)	Chi-square	P-value
Radio	37.0	46.9	77.126	0.000***
Extension officer	23.3	9.9	0.424	0.316^{ns}
Village Meetings	17.8	10.7	1.323	0.179^{ns}
Friends	13.7	24.0	3.990	0.035**
Newspaper	4.1	6.1	6.533	0.010***
Television	2.7	2.3	0.922	0.651^{ns}
Others (Specify)	1.4	0.0	2.264	0.132^{ns}

Source: *TANIPAC project baseline survey* Where by P<0.01 ***, p<0.05 **, p<0.1 *, $^{ns=}$not significant

From the Chi-Square Test, the results show that there were significant differences (P<0.01) between the source of information and the level of awareness of aflatoxin (radio and newspaper). For the case of television, extension officers, and village no significant difference showed. (Table 4).

3.1.3: Harvesting practices that influence the rate of Aflatoxin contamination

3.1.3.1 Harvesting Time

Farmers harvest maize in three periods, which are green maize, before completely dry, and fully dry. The results show that majority of farmers in Kilosa and Gairo harvest maize when they are completely dry. For Kilosa, 92% of farmers harvest when completely dry while 98% of farmers in Gairo harvest maize when completely dry. Also, results show that in both districts maize is not harvested at the green stage (Table 5). The criteria for a general indication of percentage moisture content of maize on the wet-weight basis is 18-20% for green maize, 12-13% before completion of in-field drying, and less than 12% when fully dry.

Table 5: Farmer's awareness of aflatoxin during maize harvesting time in Kilosa and Gairo districts

Demographic factors		Kilosa n=248 (Percentage of farmers that harvest their maize b4 dry, green maize, complete dry)	Gairo (Percentage of farmers that harvest their maize b4 dry, green maize, complete dry)	Statistical value	
				Chi-square	P-value
Sex	Female	10.5,0,92	2,0,98	**3.2**	**0.072**
	Male	14.8,0,85.9	3.4,0.6,96.0	14.4	0.001
Age group	18-25	20,0,80	0,0,100	1.320	0.251
	26-40	22.39,0,77.61	2.82,0,97.18	12.224	0.000
	41-60	9.92,0,90.08	3.2,0.80,96.00	5.644	0.059
	Above 60	8.89,0,91.11	4.35,0,95.65	0.461	0.497
Education level	Not attended	8.33,0,91.67	2.44,0,97.56	1.352	0.245
	Primary	14.80,0,85.20	14.80,0,85.20	15.568	0.000
	Secondary-Form Four	0,0,100	0,0,100	-	-
	Secondary-Form Six	0,0,100	0,0,100	-	-
	College (Certificate and or Diploma)	50,0,50	0,0,0	-	-
Occupation	Business	100,0,0	0,0,0	-	-
	Farmer (Livestock, farming, fishing)	12.2,0,87.8	3.1,0.4,96.4	14.482	0.001

Source: *TANIPAC project baseline survey*

3.1.3.2 Maize harvesting practices in Gairo and Kilosa districts

Harvesting is the essential key factor in reducing aflatoxin contamination. During maize harvesting, farmers in Gairo and Kilosa districts practice three main methods: harvesting by the use of bags, plastic containers, and dropping maize cobs directly on the ground. Results show that 89% of farmers in Kilosa and 81% in Gairo districts harvest maize by dropping the cobs down. On another hand, 4% of farmers in Kilosa and 7% in Gairo harvest maize by using bags. Therefore, the majority of farmers normally harvest their maize by dropping the cobs on the ground (Table 6).

Table 6: Maize harvesting practices used by farmers at Gairo and Kilosa.

Harvesting practices	Kilosa (n=46) Percentage (%)	Gairo (n=44) Percentage (%)
Harvest maize using bags	4	7
Harvesting maize using a plastic container	7	11
Harvesting maize by dropping down to the soil	89	81

3.1.4 Post-harvest practices for reducing aflatoxin in maize

3.1.4.1 Maize sorting and drying practices in Kilosa and Gairo districts

Drying and sorting are the key factors to consider as principle post-harvest practices in controlling aflatoxin contamination. Results show that farmers in Gairo and Kilosa districts dry their maize on canvas, on the ground/soil, on concrete, and on the rooftop. The use of canvas is higher compared to other practices by 42.70% in Kilosa and 16.70% in the Gairo district. On the other hand, drying of maize on the ground/soil had higher usage by Gairo farmers at 30.47% and 1.07% of farmers in the Kilosa district. Other practices like drying on the rooftop and concrete slab had the least usage (Table 7).

The results also show that farmers in Gairo and Kilosa districts, sort their maize by color, cob size, damage, and grain size. Sorting by color in the Gairo district was 28.22%, which is higher than in the Kilosa district (21.35%). On the other hand, sorting based on cob size is rarely done as it has shown fewer responses by farmers in Gairo (0.45%) and Kilosa (1.78%) districts (Table 8).

Table 7: Maize sorting and drying practices in Kilosa and Gairo districts

Post harvesting practices		Kilosa (n=562)	Gairo (N=443)	Chi-square	P-value
Drying criteria	On rooftop	0.36	0.45	0.010	0.922ns
	On the concrete/slab	0.00	1.35	6.698	0.011**
	On the ground/soil	1.07	30.47	192.480	0.000***
	Use the canvas	42.70	16.70	117.541	0.000***
Sorting criteria	Cob size	1.78	0.45	7.164	0.008***
	Color	21.35	28.22	16.388	0.000***
	Damage	12.46	4.51	7.133	0.009***
	Grain size	3.02	0.45	13.009	0.000***
	Other	17.26	17.38	0.245	0.537ns

Source: *TANIPAC project baseline survey*

Where by P<0.01 ***,p<0.05 ** , p<0.1 * , ns=not significant

ISSN: 2456-8643

From Chi-square (Pearson value) statistical analysis, Table 8 above shows there were highly significant differences (p<0.01) between post-harvest practices (On the ground/soil, use of the canvas, cob size, color, damage, and grain size) on aflatoxin level. Finally, results show no significant difference shown in the use of rooftops and other practices.

3.1.4.2 Maize Storage Facilities

Maize storage facilities vary across distinctive farmers in Kilosa and Gairo districts. Results show that 38.3% of farmers in Kilosa and 32.3% of farmers in Gairo use hermetic storage bags referred to as modern methods (PICS, Agro-Z, and Grain Pro) rather than traditional methods. Storage bags/sacks are the only traditional methods used by farmers in both districts, with Gairo showing a high tendency (57.6%) compared to Kilosa (52.6%) (Table 8).

Table 8: Proportion of farmers using modern and traditional storage facilities on the level of aflatoxin in maize in Kilosa and Gairo districts

Methods	Storage practices	Gairo n=229 Percentage (%)	Kilosa n=253 Percentage (%)	Total N=482	Chi-square	P-value
Modern	Hermetic storage bag(PICS, Agro-Z, Grain Pro)	32.3	38.3	35	98.622	0.000***
	Warehouse/Grain Banks	0.0	1.6	0.83	0.384	0.723^{ns}
	Metal/Plastic Silos	1.7	0.4	1	2.131	0.157^{ns}
	Concrete structures	0.0	0.4	0.2	0.909	0.524^{ns}
Traditional	Ground/Drying floors	4.4	0.8	2.5	5.634	0.012**
	Storage bags/Sacks	57.6	52.6	55	87.483	0.000***
	Traditional Granaries/Vihenge	1.7	0.8	1.2	0.032	0.969^{ns}
	Storage cribs/Kichanja	0.9	3.6	2.3	3.717	0.089*
	Rooftops	0.4	0.4	0.4	0.005	0.726^{ns}
	Aerial storage	0.0	0.4	0.2	0.909	0.524^{ns}
	Recycled vegetable oil containers	0.4	0.0	0.2	1.105	0.476^{ns}
Others		0.4	0.8	0.6		

Source: *TANIPAC project baseline survey* whereby P<0.01 ***, p<0.05 **, p<0.1 *, ^{ns} not significant

Table 8 above shows that there were highly significant differences (p<0.01) between the traditional storage and modern storage facilities (storage bags and hermetic storage bags) and for ground/drying floors (p<0.05). Also, no significant difference was shown in warehouse/Grain Banks, metal/Plastic Silos, concrete structures, rooftops, aerial storage, and recycled vegetable oil containers.

4. DISCUSSION

4.1 Demographic information of farmers in Kilosa and Gairo districts on awareness of aflatoxin contamination.

The study found that farmers who participated in this study were male farmers rather than female farmers. But in the case of farmers' awareness of aflatoxin contamination female farmers are more aware than male farmers. This result is comparable to the findings by Jolly et al. (2009) found a high proportion of male farmers in Ghana rather than female farmers their results report that females farmer are more aware of aflatoxin contamination than male farmers. Most of the farmers in the Gairo and Kilosa districts who participated in this surveying had primary education. The National Bureau of Statistics (NBS) in Tanzania reported that over 80% of the population in the Tanzania mainland attained primary education (NBS, 2013). Education level appears to be directly related to aflatoxin contamination awareness. Overall aflatoxin contamination in the Kilosa district was significantly lower compared to Gairo. In addition, the survey conducted by Dosman et al. (2001) found that people who are more educated are more aware of the risks associated with food safety, such as aflatoxin contamination, compared to the less educated people.

4.2 Harvesting time

Harvesting time is among the key factors to consider in reducing aflatoxin contamination. As extended or delaying field harvesting of maize could result in serious crop losses during storage, timely harvesting is recommended to combat aflatoxin problems (Kaaya et al., 2006). An increase in aflatoxin of up to seven times was observed when maize harvesting was delayed for a month in Uganda (Kaaya et al., 2006). Another report noted that aflatoxin in maize increased 4- to 7-fold after a 3-4 weeks delay in harvesting after maturity (Demissie, 2018). Physiological maturity varies with varieties and location; it is approximately 100 to 120 days after planting for yellow maize and 90 to 100 days after planting for white maize (Philippine National Standards, 2008), and 80-120 days for some varieties in the Southern highlands of Tanzania (Ashley, 2021). Harvesting of maize at physiological maturity is recommended in low-risk regions (Mejía, 2013). Hence the fields with a higher risk of aflatoxin formation should be treated differently from those fields with a lower risk. If the maize will not be harvested at the recommended moisture (13-14%) fungal pathogens will rapidly develop and potentially produce aflatoxin (Bruns, 2003; Dovenyi-Nagy et al., 2020; Monda et al., 2020; Udoh et al., 2000). This study reveals that the majority of the farmers harvest their maize when completely dry, with a 14% moisture level, a temperature of 28°C, and 70% relative humidity. Hence this study follows the recommendation of Bhatnagar et al., 2004 that the grain should be harvested when completely dry with recommended moisture level above14%, temperature above 27°C, and atmospheric humidity levels above 62% to prevent the growth of Aspergillus flavus. Early or late harvest of crops causes a rise in moisture, temperature, and insect/pest damage, which are the main factors causing aflatoxin contamination(Xu et al., 2022)

Also, harvesting maize should be completed in the shortest time possible, especially during the rainy season. Care must be taken during harvesting to prevent damage, as damage to the cobs permits the easy entrance of fungi (Sumner and Lee, 2017). Harvesting maize with the husks could reduce aflatoxin contamination (Demissie, 2018). This study result shows that most farmers harvest their maize by dropping the cobs down, and then leaving them until they finish harvesting. A similar study by Mutiga et al.(2019) shows that fungal attack occurs during harvest mainly because of dropping and drying cobs on bare ground, which tends to allow easy transfer of fungi from the soil to the storage facilities. Also, maize cobs should not be left to dry in the field on bare soil after harvesting (Massomo, 2020). Field stacking (heaping) does not provide enough aeration for the cobs and could lead to the colonization of maize by aflatoxigenic fungal strains (Manu et al., 2019). Thus, harvested products should be collected into clean baskets or onto clean sheets laid on the ground. Maize cobs should not be left in containers for more than 6 hours between harvesting and drying (Sumner and Lee, 2017).

4.3 Post-harvest practices of maize in Kilosa and Gairo district (drying and sorting practices)

4.3.1 Maize drying against aflatoxin contamination

Drying maize under natural direct sunlight helps to reduce fungal growth and aflatoxin production during postharvest storage (Hawkins et al., 2005). From the survey results, it is shown that majority of the farmers in the Gairo and Kilosa districts dry maize on bare ground. Also, some use sunlight to dry their maize by spreading it on different drying materials. Drying maize grain on bare ground/soil causes mold growth, due to moisture migration from the soil, hence the accelerated development of aflatoxin contamination in maize. The study by Kamala (2016) found that aflatoxin contamination of maize was more than three times higher for maize dried on the bare ground compared with that of maize not dried on the bare ground. Also, the findings of the current study are consistent with other studies on the association of drying maize on bare ground with aflatoxin contamination (Kaaya et al. 2006; Atukwase et al. 2009). The increase in the level and incidences of mycotoxin, particularly AFs and FBs, with the practice of drying maize on the bare ground can be a result of the possible increase in water uptake by maize from the soil, which in turn increases its water activity. Hence, the increase in water activity provides favorable conditions for fungal growth. On the other hand, direct contact of maize with soil increases the chance of uptake of fungal spores that can infect the maize. From the results of this study, it is suggested to avoid direct contact of maize with soil during drying by using drying materials such as mats or raised platforms, hence reducing contamination by the toxigenic fungi (Magan and Aldred 2007).

4.3.2 Maize sorting against aflatoxin contamination

Maize sorting criteria is the one that can help to eliminate the affected/damaged maize that can lead to insect/pest contamination. The results show that the majority of the farmers in the Gairo and Kilosa districts sort their maize based on color. Sorting helps in the reduction of the levels of aflatoxin in maize. However, as Aflatoxin is odorless, colorless, and flavorless, it has been difficult for farmers to make a detection of maize affected by aflatoxin (Massomo, 2020). Therefore, in addition to advising farmers to practice sorting laboratory testing for aflatoxin contamination should also be considered. Similar studies (Afolabi et al., 2006; Kimanya et al., 2009; Matumba et al., (2015); Kamala et al., (2015) have observed sorting to be among the ways of reducing mycotoxin contamination of maize. They also observed that aflatoxin contamination was more than three times higher for unsorted maize when compared with sorted maize.

4.4 Maize Storage Facilities

The uses of proper storage facilities and moisture management have been suggested as critical aflatoxin contamination control interventions (Walker et al., 2018). Proper conditions should be maintained by minimizing aeration or practice storage under ideal hermetic conditions. Moisture in stored maize should be kept below 13% wet basis to stop the development of aflatoxin (Shepherd, 1999). To prevent excessive moisture and humidity uptake maize grain should be packed in clean and sealed containers/hermetic bags. This study shows that 38.3% of farmers in Gairo and Kilosa practice the use of hermetic bags. When farmers use hermetic bags they will help them protect maize against aflatoxin contamination. Also, maize should be packaged into manageable weights (up to 25 kg) in clean containers or bags. The temperature of the stored maize should be checked periodically. Visual checks should also be conducted for evidence of fungal growth and to allow the separation of the infested or infected portion. Cleanliness to prevent insect infestation and disease infection should always be maintained. Through farmer surveys in Gairo and Kilosa districts, results show that a high percentage of farmers used to store their maize in storage bags/Sacks as a traditional practice. Also, a similar study in India found that farmers use jute bags for storage (Bari et al., 2012). Recent data indicated that it is better to use new jute bags; and if this is not possible the bags should be cleaned as much as possible to be freed of aflatoxigenic fungi (Wang et al., 2021). The first in first- out principle should be followed during storage as it helps to minimize the spread of aflatoxin to the maize stored in the traditional systems. To attain long-term preservation maize grain should be stored in modern facilities like hermetic bags; this tends to maintain the moisture condition during the storage period, and ultimately reduce the spread of aflatoxin contamination.

5. CONCLUSION AND RECOMMENDATION

This study summarized the current assessment of farmers' awareness of harvesting and post-harvest practices that reduces aflatoxin contamination in maize in the Gairo and Kilosa districts. Practicable harvest and post-harvest practices to reduce aflatoxin contamination of maize in the Gairo and Kilosa districts were identified. The main factors to be considered in reducing aflatoxin contamination are harvesting maize in bags, harvesting maize when completely dry and when it is dry, drying maize by using canvas and using modern storage facilities. Also, the results suggest that there is a need for educative intervention programs and established initiatives through avenues that can promote aflatoxin awareness in the country. Hence, there is an urgent need to raise awareness among the farmer about the effect of consuming maize that is affected with aflatoxin to secure our health. Awareness-raising campaigns can be carried out through appropriate media such as radio, television programs, newspapers, and drama. This is in addition to the existing system of government extension workers, health workers, and community groups in the study areas. The knowledge must be based on those harvesting practices as the farmer must know the modern practices that can reduce aflatoxin contamination during harvesting time. Also, more research studies should be on the use of maize color sorter machines and more modern storage facilities to combat aflatoxin contamination.

Acknowledgment

I thank The Almighty God for enabling me to accomplish this work. I would like to thank my supervisors, Valerian. C. K. Silayo, Frida Nyamete, and Ramadhani Omari Majubwa for their support in accomplishing this work. Much appreciation goes to the government of the United Republic of Tanzania through the TANIPAC project who initiates the prevention of aflatoxin, for funding this study. Finally, I thank the support staff of Kilosa and Gairo District Councils, the local village governments of Ulaya, Rudewa, Masanze, Madege, Kitaita, Leshata, and all households that participated in this study.

REFERENCE

Atherstone, C., Grace, D., Lindahl, J. F., Kang'ethe, E. K., and Nelson, F. 2016. Assessing the impact of aflatoxin consumption on animal health and productivity. African Journal of Food, Agriculture, Nutrition and Development, **16**(3):10949–10966.

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. 2018, **11**(3):447-458

Boni, S. B., Beed, F., Kimanya, M. E., Koyano, E., Mponda, O., Mamiro, D., Kaoneka, B., Bandyopadhyay, R., Korie, S., & Mahuku, G. 2021. Aflatoxin contamination in Tanzania: quantifying the problem in maize and groundnuts from rural households. World Mycotoxin Journal, ***14***(4): 553–564.

Chen, W. H., Lin, B. J., Lin, Y. Y., Chu, Y. S., Ubando, A. T., Show, P. L., Ong, H. C., Chang, J. S., Ho, S. H., Culaba, A. B., Pétrissans, A., & Pétrissans, M. 2021. Progress in biomass torrefaction: Principles, applications and challenges. Progress in Energy and Combustion Science, 82:100-887.

Kamala, A. 2018. Outbreak of an acute aflatoxicosis in Tanzania during 2016. World Mycotoxin Journal, *11*: 311-320.

Marechera, G., Ndwiga, J., 2014. Farmer perceptions of aflatoxin management strategies in lower Eastern Kenya. Journal of Agricultural Extension and Rural Development, **6**(12):382–392.

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

Nji, Q. N., Babalola, O. O., Ekwomadu, T. I., Nleya, N., and Mwanza, M. 2022. Six Main Contributing Factors to High Levels of Mycotoxin Contamination in African Foods. 1–26.

Timothy Omara, 1, 2, 3 Winfred Nassazi, 1, 3 Tom Omute, 4 Aburu Awath, 5, 6 Fortunate Laker, 3, 7 Raymond Kalukusu, 3, 7 Bashir Musau, 3, 7 Brenda Victoria Nakabuye, 7, 8 Sarah Kagoya, 3, 9 George Otim, 3 and Eddie Adupa1. 2020. Aflatoxins in Uganda: An Encyclopedic Review of the Etiology, Epidemiology, Detection, Quantification, Exposure Assessment, Reduction, and Control. International Journal of Microbiology,15(3):345-402.

Xu, F., Baker, R. C., Whitaker, T. B., Luo, H., Zhao, Y., Stevenson, A., Boesch, C. J., and Zhang, G. 2022. Review of good agricultural practices for smallholder maize farmers to minimize aflatoxin contamination. World Mycotoxin Journal, ***15***(2): 171–186.