STAKEHOLDERS' AWARENESS IN THE CONTEXT OF PREVALENCE OF AFLATOXIN IN MAIZE (*Zea Mays* L.) ALONG THE MAIZE VALUE CHAIN ACTORS IN URBAN AND PERI-URBAN AREAS OF MOROGORO MUNICIPALITY, TANZANIA: A CROSS-SECTIONAL STUDY

Kija Steven Magembe
Institute of Adult Education, Morogoro-Campus, **TANZANIA**
E-mail: stevenkmagembe2001@gmail.com

ABSTRACT

The purpose of this study was to assess the level of awareness and knowledge on the prevalence of aflatoxins among stakeholders along the maize value chain actors in urban and peri-urban areas of Morogoro Municipality, Tanzania. A cross-sectional study design with mixed methods of sampling was employed whereby data were collected from a total of 164 respondents between August and September 2020. The study used a quantitative approach. Semi-structured questionnaires, in-depth interviews were used to obtain the data. Descriptive, inferential, methods were used for data analysis. Purposive and stratified sampling techniques were used in this study. The population under this study included; processors, farmers, retailers, and consumers. The study did not do any laboratory testing. Quantitative data were collected and analyzed using Statistical Package for Social Science (SPSS) version 20. The Chi-Square test of association was carried out to determine whether there was a significant association between categorical variables. The findings showed that there was no significant difference ($p > 0.05$) in responses among stakeholders in knowledge and awareness of aflatoxin. There was also no difference ($p >0.05$) in response to the occurrence of aflatoxin, factors influencing aflatoxin contamination, dangers of aflatoxin contamination, and awareness of aflatoxin effects on humans and animals. However, stakeholders differed in terms of the solution to aflatoxin contamination in maize ($p <0.05$). Although aflatoxins were prevalent in the study area, the majority of respondents (63.42%) didn't know about the importance of proper storage. It was also found that molds are prevalent in all stages of the maize value chains. Some actors receive already affected maize. In some cases, the maize was affected during storage due to the type of storage practices. It is necessary to make concerted campaigns to create awareness among farmers, processors, retailers, and consumers about aflatoxin contamination in the maize value chain. The study further suggests that an adoption of pre-and post-harvest technologies together with awareness creation is still required to reduce aflatoxin contamination in the country.

Keywords: Aflatoxin, prevalence, awareness, knowledge, value chain actors, Tanzania.

1.0 INTRODUCTION

Aflatoxins (AFs) are the best-known and most widely studied mycotoxins. They were first isolated in the early 1960s when 100,000 turkey poultry died after consuming aflatoxin-contaminated peanut meal in the UK (the so-called Turkey X disease); this event was followed by proliferation in research on fungal toxins contaminating food and feeds. AFs were found to be the most potent naturally formed carcinogen, and researchers started their investigation on factors that influence this production (CAST, 1989). Aflatoxins are one of the highly toxic mycotoxins to humans and livestock (WHO, 2018). Aflatoxin contamination in African foods and food commodities has exhibited a serious threat to human and animal health over the past few decades (Chauhan, 2017). Aflatoxin contamination of foods including Maize is a major hazard to human health and has been associated with liver failure, stunted growth in children, hepatocellular carcinoma (HCC), and death (Khlangwiset et al 2011). It has been estimated that more than 5 billion people in developing countries worldwide are at risk of chronic exposure to aflatoxins through contaminated foods (Strosnider et al 2006)· Aflatoxins are produced in food crops such as peanuts when they are poorly dried and stored (Fung, 2004). Aflatoxins can be produced at both the pre-and post-harvest stages (Waliyar et al., 2008).

A recent review suggests that about 60 to 80% of the global food crops are contaminated with mycotoxins (Eskola et al., 2020). This estimation pushed back the widely cited 25% estimation attributed to the Food and Agricultural Organization (FAO) of the United Nations. Nonetheless, these figures are surprising because a large proportion of the world's population is faced with the risks associated with exposure to aflatoxins causing significant economic losses (Wu, 2015); interfering with food security; significant decline in agricultural trade between developed and developing countries (WHO, 2018). In many developing countries, levels of aflatoxins awareness are extremely low or non-existent altogether. Despite the increase in aflatoxin levels, there is limited published information on the awareness in the context of the prevalence of aflatoxins by players in the maize value chain in urban and peri-urban areas of Morogoro Municipality. Relatively little information on the prevalence of aflatoxin across the maize value chain in Tanzania is available (Abt Associates, 2012). The maize value chain in Tanzania (as in many parts of Africa) is often a long and fragmented supply chain with many actors. In addition, maize is often mixed with other commodities in the production of food and feed. These conditions create many opportunities for aflatoxin contamination during maize production, handling, processing, and storage. Therefore, this study aimed to assess stakeholders' awareness in the context of the prevalence of aflatoxins in the maize value chain in urban and peri-urban areas of Morogoro Municipality using a cross-sectional design. Specifically, the study sought to:

1. Assess the level of awareness and knowledge among stakeholders along the maize value chain in urban and peri-urban areas of Morogoro Municipality.
2. Assess the association between socio-demographic characteristics and knowledge about aflatoxin contamination in maize.
3. Determine the prevalence of aflatoxin along the maize value chain in urban and peri-urban areas of Morogoro Municipality.
4. Find out the strategies that are used by the stakeholders to avoid molds in the maize value chain in urban and peri-urban areas of Morogoro Municipality.

METHODS

Study design, setting, and period

This study was conducted in Morogoro Municipality Tanzania among maize value chain actors from July to August 2020 (Fig. 1), whose population is about 471,409 people growing at 4.1% per year (URT, 2022). Morogoro Municipality is located in the Eastern part of Tanzania about 190 kilometres west of Dar es Salaam. It is situated at the bottom of the Uluguru Mountains and covers 260 square kilometers (100 miles). The Municipal lies between longitude 37˚34'52" east of the Greenwich Meridian and 37˚45'25" and between latitude 6˚38'56"S and 6˚55'8" south of the equator (Mutiba, 2009). It is bordered to the East and South by Morogoro Rural District and to the North and West by Mvomero District. Administratively it is divided into 29 wards and 295 sub-wards (Muhanga, 2017). This study used a cross-sectional design that involved collecting data once at a point (Neuman, 2014). This design according to Bailey (1998) and Babbie (1990 is useful for descriptive purposes as well as for the determination of the relationship between and among variables at a particular point in time. It is also economical in terms of time and financial resources (Babbie and Mouton, 2005; Kothari, 2004).The rationale behind this study in Morogoro Municipality is due to the non-existence of studies on stakeholders' awareness in the context of the prevalence of aflatoxins in the maize value chain in urban and peri-urban areas of Morogoro Municipality using a cross-sectional design.

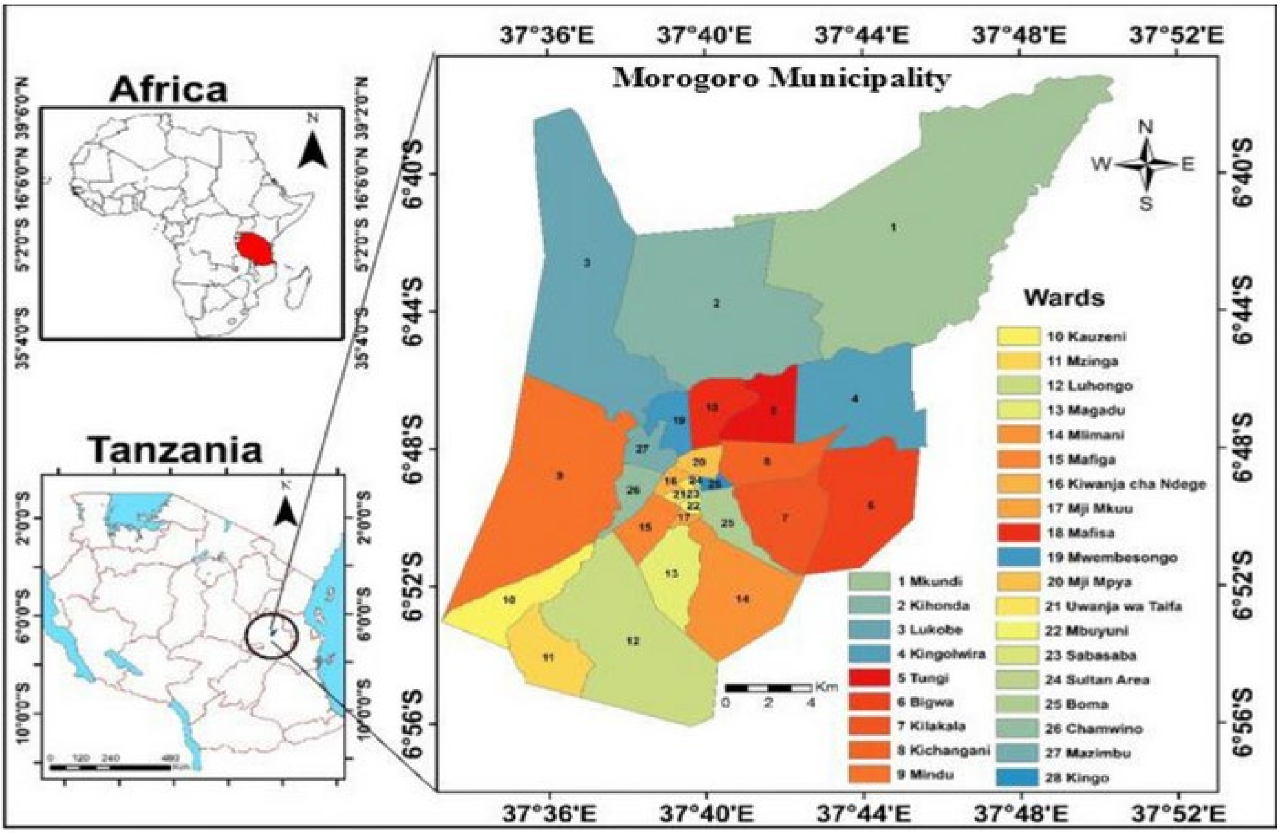

Figure 1: Location of Morogoro Municipality in Tanzania.

Research Approach, Design, and Population

The study adopted a mixed-method research approach. The study involved a descriptive cross-sectional study under which, the design was considered to be capable of providing some baseline information that could be used for future studies in the country. Moreover, a cross-sectional study usually takes the form of a survey where data are collected from several individuals about their opinions, beliefs, attitudes, or behaviors about a given topic. A cross-sectional survey was conducted from July to August 2020. The target population was the maize value chain including farmers (n=58), traders (retailers and wholesalers) (n=36), processors (n=18), and consumers (n=52).

Sampling Procedures

In the drawing, the sample of 164 maize value chain actors, from Morogoro municipality, the respondents was stratified by location. Morogoro municipality has one division and 29 wards which were grouped into two strata. The wards were those within urban and those in peri-urban (strata) features. Two wards were randomly selected from each stratum. Two urban wards with a high proportion of maize value chain actors (Kingo and Sabasaba) and two peri-urban wards (Kihonda and Mkundi). In the random selection of the two wards from urban and peri-urban, the names of the wards were written on pieces of paper then the papers were folded and shaken in a container. Consequently, the sampling approach showed a stratified

ISSN 2056-5879

sampling strategy. This approach assumed that the environments of the different wards when mixed for urban and peri-urban would provide a common atmosphere that would be representative of the urban and peri-urban areas.

Sample Size Determination.

A purposive sampling technique was employed in this study to select the participants. Purposive sampling is a kind of sampling that selects appropriate participants with useful information (Kelly et al., 2010-[19]; Robinson, 2014. According to the Small and Medium Enterprise Offices of the Municipality, there were about 238 maize value chain actors (stakeholders) in Morogoro Municipality (personal communication). The sample size was determined according to Yamane (1967) at a 95% confidence interval. Yamane (1967) provides a simplified formula to calculate sample sizes.

$$n = \frac{N}{1 + N(e)^2}$$

Where,
n = required sample size
e = margin of error (e.g., 0.05 for 5%)
N=Population size. If N= 238, and e=0.05, Therefore the sample size of the study is calculated as follows:
$n = 238/ (1+238(0.05)^2$
n =149
An additional 10% allowance (non-response) for incomplete questionnaires and refusal to participate in the study was considered. Thus, 149 + 14.9 = 164 was the sample size.

Data collection procedure and aflatoxin awareness surveys

Data were collected using questionnaires and face-to-face interviews. Aflatoxin awareness, predisposing practices during handling and/or processing, and existing strategies for aflatoxin contaminations were investigated through focus group discussions (FGDs) with the processors, retailers, consumers, and farmers. Some of the farmers and processors were engaged at their sites of operations to get clear information.

Statistical Data Analysis

Quantitative data was analyzed after cleaning and coding using IBM Statistical Package for Social Science (SPSS version 20). The data set was used to generate descriptive statistics (means, standard deviation, and frequencies), while inferential statistics such as the chi-square test was used to test association and relationship between and among variables. The chi-square test for the level of significance was set at 5%.

Ethical considerations

The respondents were informed about the study and were given the option to participate or not participate in the study. Confidentiality of the information obtained from respondents and anonymity of respondents were maintained.

RESULTS

The socio-demographic characteristics of the studied respondents are shown in Table 1. Nearly two-thirds (73.2%) were males. The majority of the study respondents were aged between 36-45 years (36.6%) and 18–35 years (24.4%). More than 40% of respondents had a secondary level of education. The monthly income of a large proportion of the participants (63.4%) ranged from 100,000–500,000 Tzs. Besides, 53.7% were urban residents whereby

Table 1: Socio-demographic characteristics of the respondents (n = 164).

Variables	Frequency	Percentage (%)
Gender		
Female	44	26.8
Male	120	73.2
Age(in Years)		
18-35 Years	40	24.4
36-45 years	60	36.6
46-55 years	34	20.7
56-65 years	18	11.0
> 65 years	12	7.3
Educational level		
Higher secondary and above	36	22.0
Secondary level	68	41.5
Primary school	46	28.0
None	14	8.5
Household income/Month		0.0
< 100, 000-500,000 Tanzanian Shillings (TZS)	60	36.6
>500,000 TZS	104	63.4
Residence		
Urban	88	53.7
Peri-urban	76	46.3

Income range 2,313.94 TZS =1 USD based on the exchange rate in August 2020
Source: Field Survey, 2020

Differences in the level of awareness and knowledge among stakeholders along the maize value chain in urban and peri-urban areas of Morogoro Municipality

Findings on the difference in the level of awareness and knowledge among stakeholders along the maize value chain in urban and peri-urban areas are summarized in Table 2. There was no significant difference (p=0.617) in responses among stakeholders in knowledge and awareness of aflatoxin. Similarly, there was no significant difference (p=0.521) in responses among stakeholders regarding knowledge and awareness of the dangers of aflatoxin contamination and the solution to aflatoxin contamination (p=0.410). There was a significant difference (p=0.012) in response to the occurrence of aflatoxin, factors influencing aflatoxin contamination (p=0.0067), and effects of aflatoxin on humans and animals (p=0.0145).

Table 2: Maize value chain actors' awareness of aflatoxins contamination in maize in Urban and Peri-urban areas of Morogoro Municipality (n=164)

Knowledge parameter	Response	Farmers (n=58)	Processors (n=18)	Retailers (n=36)	Consumers (n=52)	p-value
Awareness of aflatoxin	Yes	10(17.24%)	5(27.78%)	8(22.22%)	14(26.92%)	χ2=1.79, df=3, p= 0.617
	No	48(82.76%)	13(72.22%)	28(77.78%)	38(73.0%8)	
Occurrence of aflatoxin	Yes	7(12.07%)	3(16.67%)	12(33.33%)	19(36.54%)	χ2=10.86 df=3,p=0.012
	No	51(87.93%)	15(83.33%)	24(66.67%)	33(63.46%)	
Factors influencing aflatoxin contamination	Rodents/insects/molds	12(20.69%)	1(5.56%)	3(8.33%)	4(7.69%)	χ2=31.89 df=15, p=0.0067
	Poor harvesting	5(8.62%)	3(16.67	2(5.56%)	4(7.69%)	
	Poor storage	10(17.24%)	2(11.11%)	5(13.89%)	10(19.23%)	
	High Temperature.	5(8.62%)	7(38.89%)	4(11.11%)	4(7.69%)	
	Drought/ flood,	6(10.34%)	2(11.11%)	8(22.22%)	18(34.62%)	
	High moisture content	20(34.48%)	3(16.67%)	14(38.89%)	12(23.08%)	
Dangers of aflatoxin contamination	ill-health	9(15.52%)	5(27.78%)	6(16.67%)	8(15.38%)	χ2=8.13 df=9, p=0.521
	reduced animal productivity	22(37.93%)	4(22.22%)	20(55.56%)	22(42.31%)	
	Cancer	12(20.69%)	3(16.67%)	3(8.33%)	10(19.23%)	
	Economic loss	15(25.86%)	6(33.33%)	7(19.44%)	12(23.08%)	
Awareness of aflatoxin effects to human and animals	Yes	3(5.17%)	4(22.22%)	9(25%)	14(26.92%)	χ2=10.54 df=3 p=0.0145
	No	55(94.83%)	14(77.78%)	27(75%)	38(73.08%)	
Solution to aflatoxin contamination	Drying	5(8.62%)	2(11.11%)	5(13.89%)	12(23.08%)	χ2=15.59 df=15, p=0.410
	Sorting	6(10.34%)	3(16.67%)	8(22.22%)	6(11.54%)	
	Pesticide use	8(13.79%)	3(16.67%)	4(11.11%)	5(9.62%)	
	Proper storage	7(12.07%)	2(11.11%)	3(8.33%)	9(17.31%)	
	Surveillance and awareness creation	14(24.14%)	5(27.78%)	9(25.00%)	15(28.85%)	
	Do not know	18(31.03%)	3(16.67%)	7(19.44%)	5(9.62%)	

Values are presented as the number of respondents
Source: Field Survey, 2020

Association between socio-demographic characteristics and knowledge about aflatoxin contamination in maize

The association between socio-demographic characteristics and knowledge about aflatoxin is shown in Table 3. There was no statistically significant ($p>0.05$) association between sex and awareness of aflatoxin contamination in maize. There was a highly significant ($p<0.001$) association between education level and awareness of aflatoxin contamination in maize. Similarly, there was no statistically significant association between age and awareness of aflatoxin contamination in maize ($p>0.05$). Similarly, there is a statistically significant ($p<0.05$) association between household income and awareness of aflatoxin contamination in maize. Also, there is no statistically significant ($p>0.05$) association between residence and awareness of aflatoxin contamination in maize. Generally, education level and household income show significant associations with awareness of aflatoxin contamination in maize, while sex, age, and residence do not show significant associations. Education level and household income show significant associations with knowledge of aflatoxin contamination in maize, while sex, age, and residence do not show significant associations.

Table 3: Chi-square (χ2) test results between gender, education level, age variables, and knowledge of aflatoxin

Variable	Gender		Educational level		Age		Income		Residence	
	Sig(2-tailed)	χ2	Sig(2-tailed)	χ2	Sig(2-tailed)	χ2	Sig (2-tailed)	χ2	Sig(2-tailed)	χ2
1.I am aware of aflatoxin in maize	0.58	0.300	0.00016	20.15	0.23	5.60	0.0036	8.47	0.130	2.280
2.Aflatoxin can be present in maize	0.930	0.007	9.28×10^{-13}	59.07	0.600	2.74	3.40×10^{-9}	34.94	0.370	0.800
3.Aflatoxin contamination can reduce the price of crops	0.922	0.917	0.450	7.815	0.000	72.391	0.000	28.896	0.000	28.896
4.Maize that are discoloured produce aflatoxins	0.301	1.068	6.7×10^{-5}	21.96	0.231	5.600	0.388	0.744	1.000	0.000
5.Poor storage conditions promote mold growth	0.583	0.302	0.000362	18.74	0.204	5.94	0.0036	8.466	0.639	0.221
6.Broken bruised crops increase a chance of contamination	0.489	0.480	0.0001	21.04	0.231	5.60	0.0036	8.470	1.000	0.000
7.Aflatoxins cause cancer in humans	0.690	0.159	0.000092	21.28	0.168	6.456	0.0009	11.012	0.978	0.001
8. Consumption of contaminated food can cause health effects on human	0.306	1.047	0.509	2.317	0.00026	21.469	3.38×10^{-8}	30.475	0.205	1.607

3.2 Respondent's knowledge of aflatoxins contamination in maize

Table 4 shows the results of respondents' knowledge of aflatoxin contamination in Maize. The majority of respondents (63.42%) don't know about the importance of proper storage. A notable percentage (28.05%) is not sure, and a smaller percentage (8.54%) does not know. A similar pattern, with 64.63% not knowing the causes of aflatoxin buildup, 28.66% not sure, and only 6.71% knowing the causes. A majority understand the risk associated with high moisture content (57.93% know). However, a significant proportion (34.15%) is not sure. More than half (57.32%) know that aflatoxin-infected maize will be discolored. Over half (55.49%) are aware of the risks associated with consuming contaminated maize. The majority (60.98%) know about proper transportation practices. Most respondents (64.02%) understand the importance of removing damaged or moldy maize. A high percentage (66.46%) recognizes the link between poor storage conditions and aflatoxin presence. A high percentage (66.46%) recognizes the link between poor storage conditions and aflatoxin presence. A significant portion (63.42%) is aware of the adverse health implications. Again, a majority (64.63%) knows that maize products like roasted maize or maize flour can contain aflatoxin. The overall mean score across all statements is 1.471, showing that stakeholders had little knowledge about aflatoxin contamination in the maize value chain.

Table 4: Stakeholders' knowledge on aflatoxins contamination (n=164)

Statements	**Responses % (n)**			**Mean**	**SD**
	Do not know	Not sure	Know		
1.Storage of processed maize should be cleaned, dried, weather proof, free from infestation and sealed to prevent water, rodents or insects from reaching maize	63.42(104)	28.05(46)	8.54(14)	1.451	0.649
2. Do you know the causes of aflatoxin build up in maize?	64.63(106)	28.66(47)	6.71(11)	1.421	0.617
3. Maize with high moisture content allows infection with aflatoxigenic mold	57.93(95)	34.15(56)	7.93(13)	1.500	0.641
4. Maize infected with aflatoxin will always be discolored	57.32(94)	30.49(50)	12.20(20)	1.549	0.703
5. Do you know the risks that are involved when you consume contaminated maize	55.49(91)	31.71(52)	12.81(21)	1.573	0.710
6.Transportation of processed maize should be loaded and unloaded properly to protect from damage	60.98(100)	31.10(51)	7.93(13)	1.470	0.640
7.Special precautions must be taken to remove maize that show any sign of damage or moulds growth	64.02(105)	29.27(48)	6.71(11)	1.427	0.617
8.Poor storage conditions will promote the presence of aflatoxin in foods	66.46(109)	26.22(43)	7.32(12)	1.409	0.625
9.Do you know that, intake of maize with aflatoxin have adverse health implications	63.42(104)	28.66(47)	7.93(13)	1.445	0.639
10. Do you know that, maize products like ''roasted maize'' maize flour can contain aflatoxin?	64.63(106)	29.27(48)	6.10(10)	1.415	0.606
Overall mean score (n=164)				**1.471**	**0.651**

Note: 1= Do not know, 2= Not sure and 3= Know

3.3 Prevalence of aflatoxin in Maize Value Chains

Mycotoxin contamination can occur at various stages of the food chain, including pre-harvest, harvest, drying, and storage. Inadequate agricultural practices, poor handling, and improper storage conditions contribute to fungal growth and mycotoxin contamination

(Marin et al., 2013). Once produced, mycotoxins permeate the entire fungal colony, including hyphae, mycelium, spores, and the surrounding substrate.

In this study, the researcher did not use any scientific methods for analyzing the presence of aflatoxins along the maize value chain but used primary information from the respondents. The presence of molds was used as a synonym for aflatoxin, and respondents were asked if they had noticed or experienced molds with their maize. From Figure 1, we can see that more than half of the stakeholders receive moldy maize. In the value chain, from the sample of retailers, farmers, consumers, and processors 67.5 %, were confirmed to have received maize with molds from sellers (Figure 1). The observed limited knowledge and awareness may result in a high prevalence of aflatoxin contamination in maize. This indicates that molds may be passed along the value chain from stakeholder to stakeholder and the contamination may increase due to the length of the storage or the type of storage facilities. Storage facilities are considered a contributing factor to the accumulation and contamination of molds and aflatoxins (Desai et al., 1999; Magembe et al 2016).

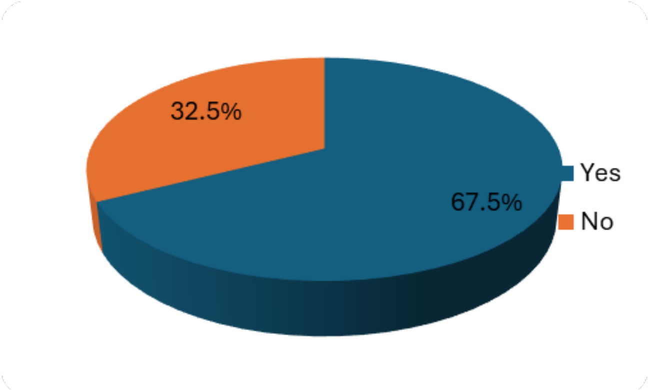

Figure 1: Frequency of stakeholders who have received moldy maize

3.4 Strategies used by the stakeholders to avoid molds in maize

Strategies that were used by stakeholders in the study area are shown in Figure 2. Physical sorting after shelling is rarely done by most of the farmers in the study area (10.7%) which increases aflatoxin infestation during storage. 31.3% of respondents supported the use of chemicals as a method to avoid aflatoxin contamination in maize (Figure 2). Other significant methods supported included: early harvesting of completely matured maize (24.1%), use of clean and dry containers for collection and carrying harvested crops (6.3%), control of moisture in the store(5.4%), drying maize properly(9.8%) and insect management (12.5%). Information on modern technologies e.g., the new biocontrol product called Aflasafe being recommended to fight aflatoxin contamination was lacking in this study. This confirms the reports that nearly all farmers in Tanzania are not aware of biocontrols recommended to protect maize from the harmful effects of aflatoxin. Even though a lot of research has been conducted on technologies that can minimize aflatoxin contamination, especially in maize in Tanzania, most of the research findings are not disseminated to the farmers and other stakeholders. This underlies the need for the Government through the Ministry of Agriculture and Food Security (MoAFS) to conduct more sensitizations for the farmers on biocontrol technologies.

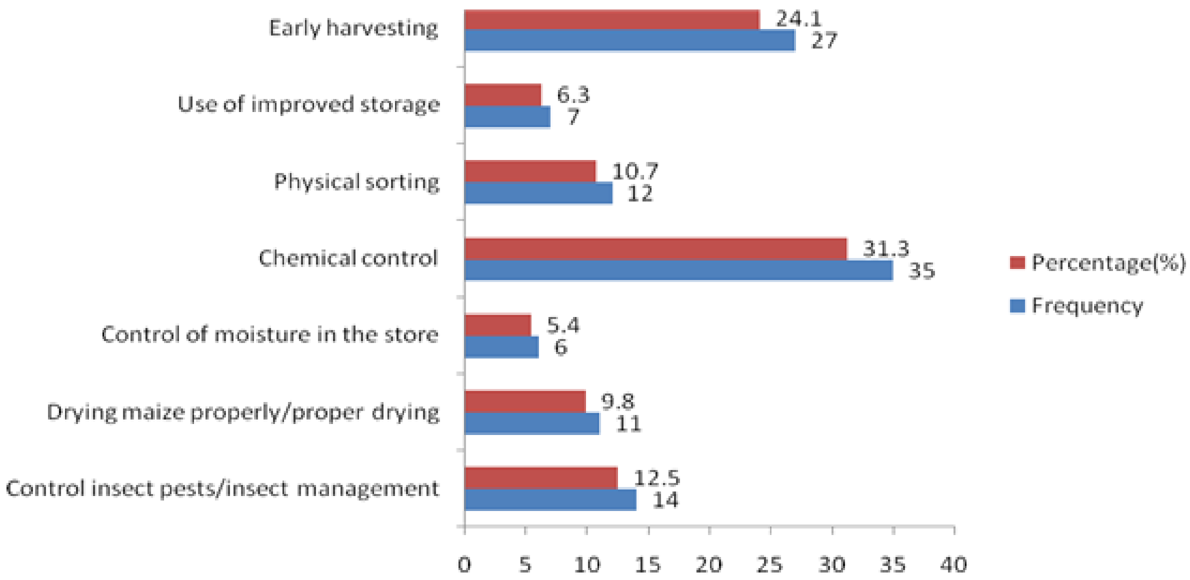

Figure 2: **Strategies used by the stakeholders to avoid molds in the maize value chain**
**Questions were asked from only those farmers, retailers, and processors who responded positively to the question*

4.0 DISCUSSIONS
The current study revealed low levels of knowledge on aflatoxins among maize value chain stakeholders. This finding is similar to that by Kang'ethe and Lang'at (2009) who reported that that 67% of urban farmers do not know the existence of aflatoxins in grains. Also, in Uganda, the majority of farmers, traders, and consumers are not aware of the aflatoxin contamination in foods (Kaaya. and Warren, 2005). However, these results contradict the finding of another study from Malawi where the level of awareness was higher, 65% (ICRISAT and NASFAM, 2009), and Lower Eastern Kenya where the level of awareness was 59% (Daniel *et al*., 2011; Marechera and Ndwiga, 2014). The higher level of awareness in Malawi and Kenya was attributed to the high literacy levels of the communities and the many outbreaks experienced in the countries. Also in Malawi, 80% of the farmers had experienced aflatoxin problems in their households (Monyo *et al*., 2010). A survey of maize growers in Vietnam indicates that awareness of aflatoxins in farmers is generally low and varies between zero to 23.3% in six provinces (Lee et al., 2017; Nguyen et al., 2018). Strosnider et al. (2006) indicated that education and awareness are crucial factors in alleviating the problems of aflatoxin in developing countries. Community education and national awareness programs are required to increase aflatoxin awareness. Support for this notion comes from the reports published in some African countries where both national and international organizations have been working on aflatoxin mitigation and increasing awareness. Since aflatoxins are invisible, and can only be detected by laboratories, it is important to increase knowledge with awareness campaigns.

Studies have been conducted to determine the relationship between awareness, social demographics, and economic characteristics on fungal contaminations in maize, groundnuts, and animal feeds. The findings indicated that almost all (97%) of the respondents were not aware of the mold growth in stored maize and groundnuts. Also, there was a significant association between awareness and socio-demographic and economic characteristics and mycotoxin contaminations (Magembe et al., 2016; Ngoma et al., 2017; Ayo et al., 2018). In Kenya, women were found more informed of the danger of fungal toxins and cautious about moldy feeds than men (Kiama et al., 2016). Furthermore, in Vietnam, young farmers (at the age of 21– 29 years) were more informed about aflatoxins in crops than the older groups (Lee et al., 2017).

For aflatoxin prevention and control strategies, respondents mentioned physical sorting after shelling, use of chemicals as a method to avoid aflatoxin, early harvesting, use of clean and dry containers, control of moisture, drying maize properly, and insect management. This corroborates the finding of Marechera and Ndwiga (2014) who reported the low use of modern postharvest aflatoxin control technologies in Eastern Kenya. Considering the cost associated with control methods, most farmers indicated that the use of resistant varieties and the control of pests and diseases are the most expensive. This was followed by cleaning crops before storage, seed treatment with chemical fungicide, and using anti-microbial agents. Midega, Murage, Pittchar, and Khan (2016) reported that the low use of chemical applications is due to a lack of information on appropriate and effective products as well as the inability to afford these chemicals. Kumar and Popat (2010) noted that farmers were indifferent to aflatoxin contamination due to many factors such as their perceptions of aflatoxins as an economic constraint, low levels of awareness and knowledge, and market restrictions. Implementation of advanced agricultural technologies, good agricultural practices (GAPs), good manufacturing practices (GMPs), and good storage practices (GSPs) can mitigate mycotoxin contamination (Kamle et al., 2019). The novel processing techniques involving a microwave, UV, pulsed light, electrolyzed water, cold plasma, ozone, electron beam and gamma (γ) irradiation treatment have the potential for AFs management and preserving and maintaining the quality of agricultural and food products (Jalili et al., 2010; Pankaj et al., 2018). The application of ozone degrades AFs by an electrophilic attack on the double-bonded carbons (C8-C9) of the furan ring resulting in the formation of primary ozonides followed by rearrangement into monozonide derivatives like aldehydes, and ketones and organic acids Jalili, 2016). Further, the detailed mechanism of ozone-degrading AFB1 has been discussed by Diao et al. (2013). The application of ozone for the degradation of AF is limited in food products due to the cost factor (Womack et al., 2014). Similarly, the mechanism behind the AF degradation by gamma rays lies in the effects of free radicals produced during the radiolysis of water and other components that attack the terminal furan ring of AFB1 resulting in byproducts of reduced biological activity (Rustom, 1997). The degradation efficiency of gamma irradiation is more effective when combined with other technologies.

In addition to these, several synthetic and natural food additives have been studied for AF reduction in food and feed. For example, the use of citric acid in combination with moisture under high temperatures (200°C) and pressure (8N) was effective in degrading AFs in extruded sorghum (Méndez-Albores et al., 2009). On the other hand, the efficacy of sodium hydrosulfite (Na2S2O4) was enhanced with increased pressure for AF reduction in black pepper (Jalili and Jinap, 2012). Furthermore, as a part of biological control measures, Anjaiah et al. (2006) -reported that inoculation of antagonistic strains of *Pseudomonas, Bacillus*, and *Trichoderma* spp. had a significant reduction of *A. flavus* in pre-harvest crops. The non-aflatoxin-forming strains of *A. flavus* and other non-toxigenic molds are prominent biological control agents against AF contamination (Dorner et al., 2003; Udomkun et al., 2017). The application of each technique has its advantages and disadvantages. Therefore, biocontrol measures in synchrony with other physical and chemical methods along with improved packaging materials should be implemented to attain food safety and security.

5.0 CONCLUSION

The present study revealed low levels of knowledge about aflatoxins in the maize value chain by farmers, processors, retailers, and consumers since the overall mean score of 1.471 showed that stakeholders were not aware of these toxins, their occurrence, predisposing factors and dangers to both animals and humans. From a sample of 164 respondents, only 17.24 % of farmers were aware of aflatoxin, 27.7% of processors were aware of aflatoxin, 22.2% of retailers were aware of aflatoxin and 26.92% of consumers were aware of aflatoxin. The limited awareness and the high prevalence of aflatoxin contamination in the maize value chain in a study area points to a higher risk for human consumers; hence sensitization of the relevant stakeholders is necessary. In the maize value chain, from the sample of retailers, farmers, consumers, and processors, only 32.5 % confirmed to have received maize with molds from sellers. The affected maize would be passed on through selling and thus the prevalence of molds and aflatoxins along the value chain would be persistent. Other respondents said that they have experienced molding during storage. Qualitative findings revealed limited knowledge and awareness of aflatoxin and aflatoxin pathways to humans among the study participants. There is a need for urgent public health intervention.

Several strategies are used by the stakeholders to avoid molds, and this includes, proper field drying, avoiding moisture after harvest, and preventing the maize from getting in contact with the floor or the walls during storage. The majority of the respondents stated that if there were any new chemicals or strategies for preventing the occurrence and contamination of aflatoxins, they would adopt them, however at the same time, the remaining percentage insisted on not adopting them, especially chemicals as they said, they might be toxic and cancer-causing and also add more expenses than it would bring profits.

5.1 RECOMMENDATIONS

Based on the findings of this study, the following recommendations are proposed:

1. The majority of farmers, traders, processors, and consumers in the study are not currently aware of the aflatoxin contamination of food. There is, therefore, a need to disseminate information to these people, using simplified methods, about the dangers and management aspects of aflatoxins, and the susceptible produce. Farmers should have good storage conditions and farming practices.
2. Creating global awareness of the aflatoxin issue in the maize value is strongly needed. Awareness messages should have specific content adapted to the different categories of stakeholders, from the farmers to the consumers. The messages should be formulated in a way that they do not create a global panic but, while informing the stakeholders about the importance of their health the message conveys practical advice for action. The vehicles and processes should be appropriate for the audience targeted.
3. There is a need to raise the level of awareness about aflatoxins throughout the country. This could be achieved through the use of various techniques like using extension agents to spread the information to farmers, processors, retailers, and consumers. Also, the mycotoxin curriculum is to be incorporated into school syllabi from primary through tertiary education. Mass media can also be used, for example, television and radio shows, and also print like newspapers, magazines, and newsletters.
4. Good agriculture practices should be observed by farmers and good hygienic and good storage practices should be followed by all actors along the maize value chain to prevent aflatoxin contamination.
5. The Government of Tanzania through the Tanzania Bureau of Standards should establish regulatory levels for aflatoxins B1 and total aflatoxins and ensure its

implementation so that maize traded in the region has aflatoxins levels conforming to the established standards to safeguard the health of consumers.

6. Based on the research findings, the key common responsibilities of the role players are that they must adhere too is the principles of risk-based food safety management, they must understand their roles and responsibilities in the food chain, and it must be communicated and understood by all the maize value chain actors, who must adhere to the reality food safety risks, prioritize and define the acceptable limits and solve all the food safety and traceability issues before the maize get consumed or exported.

Conflict of Interests

The author has not declared any conflict of interest.

Acknowledgment

The author wishes to thank the respondents for their time and cooperation in completing the questionnaires.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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