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Understanding postharvest practices, knowledge, and actual mycotoxin levels in maize in three agro-ecological zones in Tanzania

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Maize is a major cereal crop in Tanzania and it is grown in diverse agro-ecological zones. Like other sub-Saharan countries, postharvest losses of maize during storage in Tanzania remain significantly high, especially for smallholder farmers. Unpredictable weather and poor postharvest practice contribute to rapid deterioration of grain and mold contamination, and subsequent production of mycotoxins. The purpose of this study was to assess awareness and knowledge regarding mycotoxin contamination in maize grain in three agro-ecological zones (Eastern, Central, and Northern) of Tanzania between November 2015 and February 2016. A survey using questionnaires was administered to farmers, traders, and consumers of maize. A total of 90 people (30 from each zone) were surveyed with a response rate of was 96% (87/90). In addition, several samples of maize were collected and analyzed for aflatoxin, fumonisin, and zearalenone contamination to validate the awareness and knowledge of mycotoxin contamination of maize. The result shows a high level of postharvest losses of maize mainly through insect infestation. Moreover, over 80% of the farmers, traders, and consumers of maize were unaware of mycotoxins contamination. All maize samples collected contained detected levels of mycotoxins. The maximum concentration of aflatoxins, fumonisin, and zearalenone in maize samples was 19.20 ppb,, 7.60 ppm, and 189.90 ppb respectively. Education intervention is necessary to decrease the disconnect observed between actual mycotoxin contamination and the awareness and knowledge of farmers, traders, and consumers of maize in Tanzania. Enhancing awareness and knowledge provide the opportunity to educate on post-harvest practices that reduce postharvest losses and mycotoxin of maize in Tanzania.

Key words: Corn, postharvest, mycotoxins, Africa, Tanzania, food safety.

INTRODUCTION

Maize (*Zea mays*, L.) is the major and most cultivated cereal crop in Sub-Saharan Africa (SSA) with over 70 million metric tons grown on more than 34 million hectares in 2014/2015 (Macauley, 2015; FAOSTAT, 2016). It is the third most important cereal crop in the world and serves an important food source for over one billion people (IITA, 2009). It accounts for over half and one-fifth of the calories and protein consumed in East and West Africa, respectively (Macauley, 2015). In Tanzania, maize is considered the major staple food for a large proportion of (~ 75%) the population, and is grown in diverse agro-ecological zones (Suleiman and Rosentrater, 2015). Maize contributes ~ 36% of the total daily calorie intake, with an estimated annual per capita consumption of about 128 kg (Smale et al., 2011; BEFS, 2013). This is equivalent to around 400 g per person per day, with average annual national consumption of three million metric tons (Kimanya et al., 2008; Peter et al., 2013).

Unfortunately, despite its importance as the main staple and commercial crop, many smallholder farmers in SSA, including Tanzania have continued to experience problem post-harvest losses (PHL) of maize during storage. These losses are mainly due to storage insect pests, lack of proper storage structures, and poor handling practices (Demissie et al., 2008). The most significant PHL pests to maize in storage are maize weevil (*Sitophilus zeamais*), larger grain borer (*Prostephanus truncates*), Angoumois grain moth (*Sitotroga cereallella*: Olivier) and rodents (Abass et al., 2014; Kaminski and Christiaensen, 2014; Affognon et al., 2015). The estimated PHL of maize in SSA ranged 10 and 40% (APHLIS, 2015) and can be as high as 50% for maize stored in a traditional storage structure (Rugumamu, 2004). According to Abdoulaye et al. (2016) the current PHL of maize in Tanzania is around 7.5%. The postharvest losses of maize and other cereal grains has a significant impact on the food security and the economy of the smallholder farmers (Jones et al., 2015). In SSA, smallholder farmers are more affected by PHL than middle and larger scale farmers. A survey conducted by the World Bank in Tanzania between November and December 2008 shows PHL for smallholder farmers is almost twice (11%) compared to large scale farmers (6%), which corresponds to 19.9 and U$10.8 per ton respectively (AGRA, 2013). According to Rosegrant et al. (2015) PHL of cereal grain not only pose a threat to the sustainable food security, but also to the nutritional status of the population, especially to the women and children under five in developing countries. Postharvest losses also increase food price by removing a portion of the maize from the supply chain and as well as loss of revenue from producers and traders (Mhlanga et al., 2010; Tefera, 2012). Therefore, reducing PHL will have a significant impact on smallholder farmers by increasing their incomes, food security, reduces malnutrition (Arends-Kuenning et al., 2015), and counteracts the issues of poverty and hunger in developing countries (De-Schutter, 2016).

Furthermore, the poor postharvest practices can lead to rapid deterioration of grain quality, dry matter losses and mold growth (Tangi and Pussemier, 2006; Magan and Aldred, 2007). Mold growth in grain is associated with the production of toxic metabolic by-products or mycotoxins (Hell et al., 2004; Magan et al., 2003). Besides the postharvest losses, mycotoxin contamination is another huge burden on smallholder farmers in SSA (Merck, 2006). It attracts much attention because of its significant impact on the economy and its potential hazard to human health, animal productivity, and trade (Wu, 2004; Wagacha and Muthomi, 2008; Darwish et al., 2014). Mycotoxins are a major problem in SSA countries where climatic conditions, agronomic and storage practices are favorable for insect infestation, fungal growth and toxin production (Fandohan et al., 2004; Kumar et al., 2008). They are described as 'silent killers' since they are hard to detect and some are extremely toxic to both humans and animals (Haladi, 2014; Alimi and Workneh, 2015) due to damage they cause by damaging the immune system (Mboya and Bogale, 2012). The most important groups of mycotoxins that often occur in agricultural products such as maize grain and of public concerns are aflatoxins, zearalenone, deoxynivalenol (vomitoxin), fumonisins, and ochratoxin (Owaga et al., 2011; Kimanya et al., 2014). However, in SSA, the most prevalent classes of mycotoxins are aflatoxins and fumonisins (Lewis et al., 2005; Kimanya et al., 2008).

Aflatoxins are secondary metabolites primarily produced by spoilage fungi *Aspergillus flavus* and *Aspergillus parasiticus* (Williams et al., 2004; Marin et al., 2013). Aflatoxin contamination is a major contributor to PHL of maize, especially when stored above 12% moisture content (Hell et al., 2010). Most of the maize grain in SSA is poorly handled and stored in local traditional structures (Rugumamu, 2004). Storing maize in these structures exposes them to the environment which leads to insect infestation and invasion by storage fungi (Hell et al., 2000), subsequently increasing the risk of aflatoxin contamination (Borgemeister et al., 1998).

Another important class of mycotoxins is fumonisins, which are produced by several *Fusarium* species (Bennett and Klich, 2003), notably by *Fusarium verticillioides* (Bruns, 2003). Fumonisins have been related to several fatal diseases in animals such as leukoencephalomalacia in horses, donkeys, and rabbits, pulmonary edema and hydrothorax in swine, hepatotoxic and apoptosis in sheep. They also promote tumors in several animals such as rats and mice (Hussein and Brasel, 2001; Bennett and Klich, 2003; Fandohan et al., 2004). In humans, fumonisins have been linked to carcinogenic effects such as oesophageal cancer in

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different regions of the world such as South Africa, China, Italy and Iran (Bennett and Klich, 2003; Fandohan et al., 2004) and impaired growth in young children (Shirima et al., 2014; Kimanya et al., 2008).

Zearalenone (ZEA) is another type of mycotoxin produced by *Fusarium* species, primarily by *Fusarium graminearum* (Doko et al., 1996). Like other types of mycotoxins zearalenone has been associated with a number of detrimental effects to animals. There affects include hyperestrogenisms, increased incidence of pseudopregnancy, infertility, change in libido, abnormal lactation, feminization, virginal prolapse, vulval edema and others in pigs (Kuiper-Goodman et al., 1987; Peraica et al., 1999; Zinedine et al., 2007). In the dairy cows, zearalenone has been associated with milk reduction (Suleiman and Rosentrater, 2015). In humans, the primary symptoms of zearalenone include nausea, vomiting, and diarrhea (Lombard, 2014). It has also been linked with pubertal changes of young children in Puerto Rico (Kuiper-Goodman et al., 1987).

Previously published literature, while extensive in terms of occurrences and impacts, however, has not yet addressed the issue of awareness, on the consumer level, the farmer level, or the trader level. Because maize is such an important foodstuff in many African countries, this type of information could be vital in terms of developing food safety training and education programs, which could thus help reduce mycotoxin risk in the food supply chain. Therefore, the objective of this study was to assess the postharvest practices, awareness and knowledge of mycotoxins contamination in maize grain in three agro-ecological zones (Eastern, Central, and Northern) of Tanzania.

MATERIALS AND METHODS

Study area

This study was conducted in three districts in Tanzania: Babati (located below the equator between latitude 3° and 4´ south, and between longitude 35° and 36° east), Chamwino (located below the equator between latitude 7° and 5´ south, and between longitude 36° and 13° east) and Kilosa (locate between latitude 6° and 42´ South, and between longitude 367° and 48´ East) for the Manyara, Dodoma, and Morogoro regions respectively (Figure 1). These locations were purposefully selected due to different agro-ecological zones and previous reports of high postharvest losses and mycotoxins contamination of maize, sorghum and other cereal grains in these areas (TFDA, 2012; APHLIS, 2015; Kamala et al., 2015). Agro-ecological zones selected were different in terms of rainfall pattern, growing seasons,temperature, production practices and socioeconomic status.

Assessment of postharvest practices and awareness of mycotoxin contamination

The study was conducted to attempt to seek answers to the key questions about postharvest losses, awareness, and knowledge of mycotoxin. What are the main causes of postharvest losses of maize? At what level do you discard your maize grain? How long do you store your maize grain? In the maize value chain where does the major losses occur? Any knowledge or awareness of mycotoxin contamination (Table 1).

A structured questionnaire was developed and used to collect the data. After written informed consent was obtained from the university's Institutional Review Board (IRB 15-528 Suleiman), the study was conducted in three districts (Kilosa, Chamwino and Babati) of Tanzania between November 2015 and February 2016. A total of 90 participants (30 farmers, 30 traders and 30 consumers) participated in the study with a response rate of 96% (87/90). The survey was pre-tested with farmers, traders, and consumers of maize in Morogoro municipality December 2014 (n = 10) in an ad-hoc fashion. Based upon feedback from the pre-test, the survey was revised into its final format. Upon completion, the survey was administered in all three regions in Tanzania. Farmers, traders and consumers of maize were chosen because they are main stakeholders in maize production process. In each region, a random selection of individuals from each category was contacted regarding their willingness to participate in the survey. The questions were written in English and was then translated to Swahili to make it easy for the participants to understand. For those participants that were unable to read, the investigator read each question and the participants responded verbally. Each participant was given an honorarium of $2 USD for their participating in the study.

Maize sample collection from the three regions

Moreover, maize samples for mycotoxins analysis were sampled according to the procedures described by Kimanya et al. (2008) and Kamala et al. (2015). Briefly, about 1 kg of stored maize (not freshly harvested) was drawn randomly from the farmers and traders (who participated in the survey) for mycotoxin analysis. A total of 30 samples (10 per district) from all regions were collected and stored in airtight plastic bags at 4°C until analyzed for aflatoxin, fumonisin, and zearalenone. The samples of maize were collected to analyze various mycotoxins and to supplement the survey on awareness and knowledge of mycotoxins of maize in Tanzania.

Sample preparation and mycotoxin determination

Insects on the participating farms were assessed previously (Suleiman et al., 2016), and thus are not reported here.

The aflatoxin, fumonisin, and zearalenone content of maize samples from the farms was analyzed using Reveal Q$^+$ kits (Neogen® Corporation, Lansing, MI, USA) as per manufacturer's instructions. Briefly, the 1 kg of maize samples collected from farmers and traders were mixed well and about 500 g was ground using a high-speed universal grinder (Great Wall Instruments Co., Ltd, Huang Cheng, Mainland, China), thoroughly mixed and stored in Ziploc® slider (6.8 µm) one-quarter polyethylene freezer bags (SC Johnson, Racine, WI 53403) stored at 4ºC until analyzed. Then, 10 g of a well-homogenized ground sample was weighed using an electronic balance (Contech® Instruments Ltd, Model CA-224, 301, Punit Indl. Premises, Turbhe, Navi Mumbai - 400705, India).

Mycotoxin extractions were performed by adding 50 mL of 65% ethanol to the sub-samples followed by handshaking for three minutes. The mixture was allowed to settle for about two minutes, then the supernatant was drawn by uses of a three-mL syringe (BD Luer-Lok™, 1 Becton Drive, Franklin Lakes, NJ 07417, USA) passed through a sterile syringe filter of 0.45 microns (Corning Incorporated, Corning, NY 14831), collected in a clean test tube, and labeled appropriately. Five hundred microliter of sample diluent was added to the red dilution cup (provided in the kits) and 100 µL of the filtrate was added to the red dilution cup and mixed up and

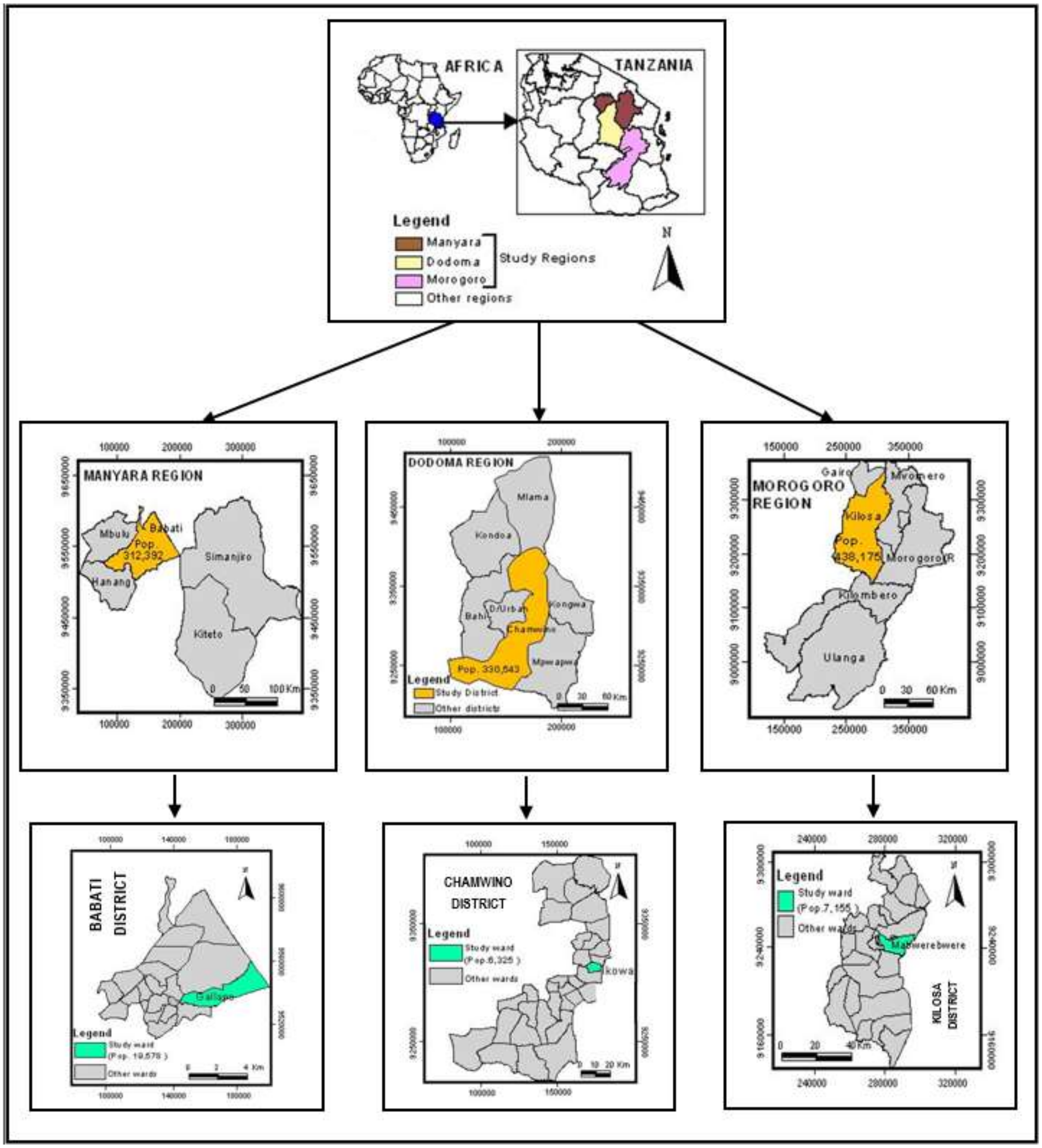

Figure 1. Map of Tanzania showing study regions, districts and wards sampled.

down five times. Then, 100 µL of the filtered dilute extract solution was pipetted and transferred onto the white sample cup (provided in the kits), and the Reveal Q^+ strips were inserted for either aflatoxin, fumonisin or zearalenone, and then incubated for six minutes. After the incubation, the developed strips were removed and inserted into a Reveal AccuScan Pro 2.0 Reader System (620 Lesher Place, Neogen® Corporation, Lansing, MI 48912 USA) to determine aflatoxin, fumonisin or zearalenone content of the sample. The Reveal Q^+ assay is quantitative for total aflatoxins, fumonisin, and zearalenone with a range of detection of 2-150 ppb, 0.3-6 ppm and 50-1200 ppb for aflatoxin, fumonisin, and zearalenone, respectively. All maize samples were analyzed in duplicate.

Statistical analysis

Collected data were coded and entered into Microsoft Excel 2016 then analyzed. Descriptive statistics were performed to assess relevant variables, and included response rates for the survey questions, as well as means and standard deviations for each mycotoxin (aflatoxin, fumonisin, and zearalenone) for each district.

Table 1. Types of information collected in the study.

Type of information	Specific data collected in the questionnaire
General information	Biodata (gender, age, education level) Name of district Source of income (daily activity)
Postharvest practices	Total area cultivated (ha) Amount of maize harvested (last season) Sorting criteria after harvest Storage structures, practices and losses Main cause of losses (postharvest losses) of maize
Mycotoxin contamination	Knowledge on moldy maize How moldy maize is handled (discard, sell, as food/feed) Have you heard the word "mycotoxin" before? Awareness of mycotoxin (aflatoxin) contamination Effects of mycotoxin contamination on humans and animals

RESULTS

Assessment of postharvest practices and awareness of mycotoxin contamination

The assessment of postharvest practices and awareness of mycotoxins contamination in three agro-ecological zones of Tanzania were divided into three main categories: Farmers, traders, and consumers.

Farmers

The farmer responses to the survey from the three agro-ecological zones are presented in Table 2. The results show women constituted 80% of the farmers interviewed in Kilosa and Chamwino districts and 40% in Babati. Seventy percent of the farmers have at least a primary education. The mean age of all farmers was 25 ± 6.4 years (Table 2). The survey found 70, 70 and 40% of the farmers in Kilosa, Chamwino, and Babati respectively cultivated an average of five to ten hectare for maize production. All respondents (farmers) across all zones experience postharvest losses of maize, mainly due to weather conditions and insect infestation. The result shows most of the farmers sort their maize prior to storage. Also, the study found damaged maize was used as feed and discarded when totally moldy. In addition, the result shows that postharvest losses were mainly (over 60%) occurring during storage as shown in Table 2. Most of the farmers (over 80%) said they do not have any knowledge or they never heard about mycotoxin contamination before.

Traders

A descriptive summary of Trader's is shown in Table 3. As expected, most of the traders were male: 100% in Kilosa, 88.9% in Chamwino, and 100% in Babati. The majority of the traders have at least a primary education: 70, 77.8 and 60% for Kilosa, Chamwino, and Babati respectively. The mean age of traders was 27 ± 4.6 years. The study also found most of the traders store their maize in the living house without proper storage structures (Table 3). Likewise, the result shows insect infestation is the main cause of maize losses during storage: 100, 88.9 and 90% for Kilosa, Chamwino, and Babati, respectively.

Chemical insecticides were used by over 75% of traders to control insects in storage. Mixed results were obtained when traders asked when they discard their maize, 70 and 66.7% in Kilosa and Chamwino discard their maize only it when it shows signs of mold contamination, but 70% of the traders in Babati discard maize when is totally moldy. Furthermore, over 50% of the traders surveyed used damage maize for animal feed. Also, the result shows over 87% of the losses occur in the storage. In addition, a nearly two-thirds of the participants had no knowledge of mycotoxins contamination (Figure 2).

Consumers

Table 4 shows a descriptive summary of the responses of consumers. The results show most of the consumers of maize (that responded to our survey) were female: Chamwino (60%) and Babati (90%). However, males were the majority of respondents in Kilosa accounting for 70% of responses. The average age of the consumers responding to the survey in all districts was 25 ± 4.2 years. It was observed that the majority of these respondents had primary educations, except in Chamwino (Table 4). The main quality criteria used by

Table 2. Farmer's responses on postharvest practices and mycotoxin awareness in three agro-ecological zones (%) (n = 30 for each district).

Post-harvest practice and mycotoxins awareness	Parameter	Percent respondents (%)		
		Kilosa	Chamwino	Babati
Biodata				
Gender	Male	20	20	60
	Female	80	80	40
Education level	None	10	10	0
	Primary (grade 8)	60	50	100
	Secondary	30	40	0
Age group	18-25 years	30	25	0
	25-40 years	20	35	40
	Over 40 years	50	40	60
Total production area	Below 5 ha	30	30	60
	5-10 ha	70	70	40
Total yield in bags (1 bag = 100 kg)	Less than 5 bags	20	20	60
	5-10 bags	70	70	20
	Above 10 bag	10	10	20
Main cause (s) of maize losses	Pest infestation	60	60	33.3
	Poor storage	0	0	6.7
	Weather conditions	40	40	60
How long do you store your maize	Less than 3 months	0	0	3.3
	Three months	100	100	90
	Six months	0	0	6.7
	Over six months	0	0	0
Sorting practices (criteria)	Color	30	30	0
	Damage	70	70	100
Handling practices- with damage maize and level of discard	Used as food	0	0	10
	Used as feed	100	100	100
	When totally mold	100	100	86.7
	Not discarded	0	0	13.3
Knowledge of mycotoxins contamination	Yes	50	40	20
	No	50	60	80
Major causes of PHL in the value chain	Transport	30	30	20
	Drying	0	0	20
	Storage	70	70	60

consumers across all regions were maize to be free from insects and mold contamination (60, 80 and 60% for Kilosa, Chamwino, and Babati respectively). Price seemed to not be an important factor to consumers of maize in Chamwino and Babati districts, but was very important in Kilosa (70%). Also, the results indicated that consumers understand that insect infestation is the major cause of postharvest losses. Like in the other two categories (farmers and traders) most of the consumers interviewed believed that major losses of maize occurred during storage. However, most of the consumers interviewed had no knowledge of mycotoxin contamination (Figure 2).

Actual mycotoxin contamination of maize in three agro-ecological zones

The overall mean concentration of mycotoxin contamination (aflatoxin, fumonisin, and zearalenone) is shown in Table 5. All maize samples collected contained detectable levels of mycotoxins. The maximum

Table 3. Traders' responses on postharvest practices and mycotoxin awareness in three agro-ecological zones (%) (n= 30 for each district).

Post-harvest practice and mycotoxins awareness	Parameter	Percent respondents (%)		
		Kilosa	Chamwino	Babati
Biodata				
Gender	Male	100	88.9	100
	Female	0	11.1	0
Education level	Primary	70	77.8	60
	Secondary	30	22.2	40
Age group	Under 18 years	10	0	0
	18-25 years	0	22.2	10
	25-40 years	80	66.7	20
	Over 40 years	10	37.5	70
Maize storage	Traditional granary	0	22.2	10
	Living house without improved structure	100	77.8	30
	Living house with improved structure	0	0	40
How long do you store your maize	Less than three months	0	11.1	20
	Three months	40	66.7	10
	Six months	60	22.2	30
	Over six months	0	0	40
Insecticide application	Yes	100	77.8	50
	No	0	22.2	50
Main pest	Insects	100	88.9	90
	Rodent	0	11.1	10
Do you sell maize when damaged	Yes	70	100	90
	No	30	0	10
When do you discard your maize	Show sign mold contamination	20	0	10
	Totally moldy	70	66.7	20
	Not discarded	10	33.3	70
What do you do with damage maize	Give away	0	0	20
	Used as food	30	0	20
	Used as feed	50	55.6	60
	Mix with others and sell	20	44.4	0
Major causes of PHL	Transport	0	11.1	3.4
	Drying	0	0	24.1
	Storage	100	88.9	72.4

concentration of aflatoxins, fumonisin, and zearalenone in maize samples was 19.20 ppb, 7.60 ppm, and 189.90 ppb respectively. The highest aflatoxin concentration was observed in the Kilosa district with concentrations of 19.2 and 17.3 ppb, and the lowest concentration was detected in the Babati district with a concentration of 2.0 ppb. In addition, the highest concentration of fumonisin and zearalenone was detected in the Babati district: 7.6 ppm and 189.9 ppb, respectively. In general, 33% of all samples collected exceeded the maximum limit set by Tanzania Bureau of Standard (TBS) for total aflatoxin (10 ppb). These results underscore how critical it is that all people along the maize supply chain understand the risks and potential presence of mycotoxins in their supply of maize.

DISCUSSION

The results of this study are consistent with previous authors (Hell et al., 2000; Kimanya et al., 2008; 2010; 2014; Mboya and Bogale, 2012; TFDA, 2012; Shirima et al., 2014;

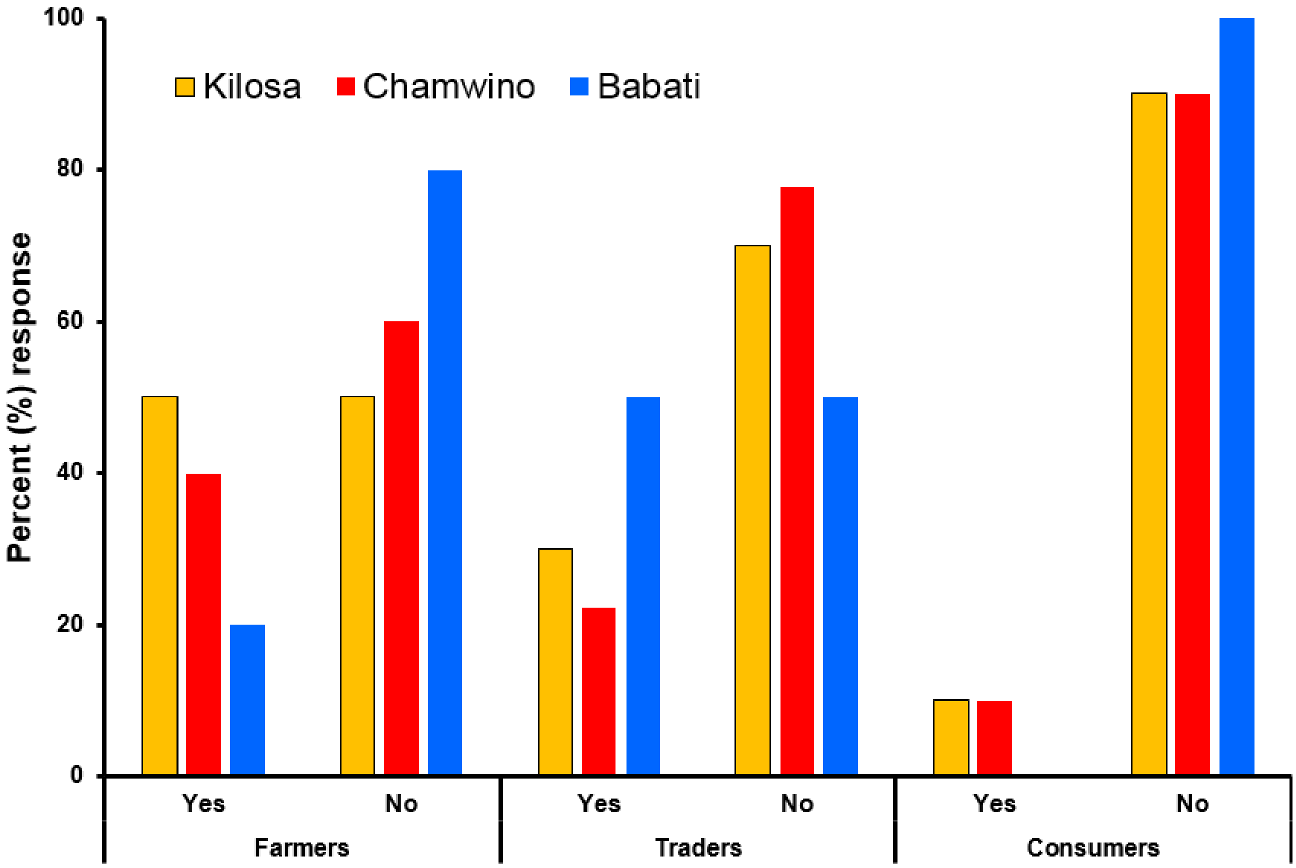

Figure 2. Mycotoxins awareness of farmers, traders and consumers in three districts.

Kamala et al., 2015; 2016) who show that postharvest practices can have a great influence on contamination of maize with mycotoxins; moreover, overcoming the lack of public awareness about mycotoxins is critical to improving food safety in Tanzania. In general, this study found most of the participants in agriculture (farming) were women rather than male. This result is comparable to the findings of Ellis et al. (2007) who reported women in Tanzania were more active in agricultural activities and account for about 52% of the farm work force. Likewise, a study conducted by the United Nations Development Program (UNDP) found women make up about 60 to 80% of the agricultural labor force in Nigeria (Ogunlela and Mukhtar, 2009), as well as in other African countries. In contrast, Jolly et al. (2009) found a high proportion of farmers in Ghana are male rather than female due to cultural differences.

In addition, Ellis and others found women in Tanzania were more engaged in trade than male (Ellis et al., 2007). However, this contrasts with the finding where over 90% of the traders surveyed were male. Most of the participants had a primary education over 50% across three categories (farmer, trader and consumer) in all agro-ecological zones. 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 seems to be directly related to mycotoxins awareness. Overall mycotoxin contamination (aflatoxin and fumonisins) in Chamwino district was significantly lower compared to Kilosa and Babati. In addition, the surveyed 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 less educated people. Also, Baker (2003) found a high correlation between education and income and food safety. The study conducted by Jolly et al. (2006) on awareness and perceptions of groundnut aflatoxin among Ghanaians found education level had a positive effect on the awareness of aflatoxin contamination and concluded that more highly educated participants to have a better knowledge of aflatoxin and are more aware of groundnut contamination compared to less educated participants. However, a survey conducted by Leong et al. (2012) in Malaysia found no significant association between aflatoxin levels with gender and education level.

Moreover, the study found a high percentage of postharvest losses of maize. One hundred percent of all participants surveyed experience PHL of maize mainly by insect infestation. The study also found main losses

Table 4. Consumer responses on postharvest practices and mycotoxin awareness in three agro-ecological zones (%) (n = 30 for each district).

Post-harvest practice and mycotoxins awareness	Parameter	Percent respondents (%)		
		Kilosa	Chamwino	Babati
Biodata				
Gender	Male	70	40	10
	Female	30	60	90
Education level	None	0	10	20
	Primary	90	20	60
	Secondary	10	30	20
	College	0	40	0
Age group	18-25 years	10	20	10
	25-40 years	40	70	40
	Over 40 years	50	10	50
Main quality criteria to buy maize	Free from insects and mold contamination	60	80	60
	Quality of maize	40	20	40
Most important parameter	Quality	70	60	70
	Price	30	40	30
Most parameter do you check before buy maize	Moisture of maize	10	10	20
	Insects contamination	60	50	40
	Mold contamination	30	40	40
Could you buy mold maize under reduced price	Yes	70	10	40
	No	30	90	60
Major causes of PHL	Insects	60	40	60
	Spillage	0	10	0
	Rodents	10	10	0
	Poor storage structure	30	40	40
Major PHL in the supply chain	Transport	30	30	0
	Drying	0	15	40
	Shelling	20	10	20
	Storage	50	45	40

Table 5. Measured mycotoxin contamination in maize grain collected from the three regions.

Parameter	Aflatoxin (ppb)	Fumonisin (ppm)	Zearalenone (ppb)
Overall mean ± S.D	4.2 ± 2.9	1.4 ± 1.3	57.8 ± 13.5
Range, all samples	2.0 - 19.2	0.3 - 7.6	50.0 - 189.9
Number of districts		3	
Number of samples		30	

occurred during storage; this result concurred with previous reports (Rugumamu, 2004; Demissie et al., 2008; FAO, 2011; Abass et al., 2014; Kaminski and Christiaensen, 2014; Affognon et al., 2015; Suleiman et al., 2016) that significant loss of maize grain in developing countries occurs during storage (15-25%). Furthermore, the results showed a noteworthy portion of the population has little or no knowledge of mycotoxin contamination. This could be the reason of high mycotoxin contamination in some regions like Kilosa and Babati. According to Gong et al. (2002), increasing awareness and knowledge about aflatoxins may reduce aflatoxin as well as other types of mycotoxin contamination of cereal grain. Moreover, reported by Nandi and Häggblom (1984) that the problem of mycotoxin contamination in agricultural commodities in developing countries is made worse by lack of public awareness of mycotoxin contamination.

In addition, the occurrences of aflatoxin and fumonisin in this study were substantially lower compared to other studies conducted by TFDA (2012), Kamala et al. (2015, 2016) and GP (2016). Overall 33% of all samples collected (30) exceeded the maximum limit set by Tanzania Bureau of Standard (TBS) for total aflatoxin (10 ppb). The recent report from TFDA shows over 14 people die because of consuming maize contaminated with aflatoxin in Dodoma, the report shows 45% of the sample collected contained aflatoxins concentration over 5 ppb of aflatoxins, the toxin ranged between 5.7 to over 200 ppb (GP, 2016). A greater variation in types and levels of mycotoxin contamination was observed across agro-ecological zones and this aligned with the results of previous studies (Kamala et al., 2015, 2016). This could be explained by postharvest practices and climatic conditions. For instance, the average mean temperature and relative humidity during the time of data collection (December 2015) were 30°C and 69% R.H in Kilosa (Morogoro), 28°C and 66% in Chamwino (Dodoma), 26°C and 64% R.H in Babati (Manyara). These conditions are favorable for the growth and development of mold growth and subsequent toxin production (Kaaya and Kyamuhangire, 2006). It has been noted by Paterson and Lima (2010) and Tran-Dinh (2013) that environmental factors and irregular weather conditions contribute to mycotoxin development and contamination in tropical countries. This study also determined the concentration of zearalenone in several maize samples. The overall result is shown in Table 5. Results of this study were within the range of the results obtained by Doko et al. (1996). However, they were substantially lower compared to those reported by Degraeve et al. (2016).

It should be noted the mycotoxin development in cereal grains is highly geographically-dependent. The results differ from other published studies due to the areas we sampled and the specific weather patterns that occurred at the time of the study.

The results of this survey have indicated the need for more education coupled with increased understanding about presence of mycotoxins in the maize.

Conclusions

This study assessed the postharvest practices and awareness of mycotoxins. The results show postharvest losses of maize are quite high and a significant portion of the population are unaware and have no knowledge of mycotoxin contamination. Mycotoxins (aflatoxins, fumonisins, and zearalenone) was detected in all samples collected. This information shows a necessity of creating a monitoring, surveillance, and intervention program on mycotoxins. Also, the necessary effort is needed to educate the general public about the risks of mycotoxin contamination and affordable techniques should be provided to reduce postharvest losses of maize in Tanzania.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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