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Aflatoxins B_1 contamination levels in maize and awareness of aflatoxins among main maize stakeholders in Chemba and Kondoa Districts, Tanzania

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Maize (*Zea mays*) is the staple food for the majority of people in Tanzania which plays a key role in subsistence and a cash crop among actors of the maize value chain. Environmental factors such as soil contamination by fungi, water stress, warm and humid conditions are among several factors contributing to fungal growth and aflatoxins contamination in maize, leading to significant economic loss, reduced household income, health problems to humans and animals and interferes with food security to communities. Structured questionnaires were used to collect information on awareness associated with aflatoxin contamination in maize from 160 smallholder farmers, 160 consumers and 60 traders in Kondoa and Chemba districts in Dodoma Region. A total of 90 maize samples (40 from smallholder farmers, 30 from consumers and 20 from traders) were analyzed for AFB1 using immuno-affinity high-performance liquid chromatography (HPLC) type Agilent Technologies 1200 serial. Data were statistically analyzed to assess awareness levels among maize main stakeholder and to check the current levels of aflatoxins B_1 contamination in the study community. AFB_1 was detected in five samples. About 3.3% of the contaminated maize had AFB_1 levels above TBS acceptable levels (5 μg/kg). The highest mean concentration of AFB1 was in maize samples taken from traders with a mean of 9.88±5.904 μg/kg. The majority 56% of smallholder farmers and 52% of traders were aware of aflatoxins contamination and associated health effects on animals and humans. However, 74% of consumers were unaware of aflatoxins contamination in maize. The levels of contamination are low in the sample taken along maize value chain. An effective and broad awareness programme for community especially consumers on good management for prevention of aflatoxins contamination is necessary, as maize is the most consumed grain in the study area.

Key words: Aflatoxins contamination, smallholder farmers, consumers.

INTRODUCTION

Agriculture accounts for 26.7% of Tanzania's GDP and provides employment for majority of the nation's population (FAO, 2020). The safety of food is a pervasive concern of general public health and government authorities' worldwide (Logrieco et al., 2018). However, fungi producing a poison that contaminates foods crops are often found on the most important staple crops. Increasing awareness of its occurrence and contamination is important to all stakeholders due to adverse effects on human and animal health (Wild et al., 2012). Fungi are capable of producing hundreds of secondary metabolites but only a relative few are regulated (Ostry et al., 2017). These metabolites include the widely regulated mycotoxins such as aflatoxin, fumonisins, trichothecenes (particularly deoxynivalenol), ochratoxins and zearalenone. Other mycotoxins that are less regulated include the ergot alkaloids, patulin and the T-2 and HT-2 toxins (Logrieco et al., 2018). The three main genera of fungi that produce mycotoxins and toxigenic are *Aspergillus*, *Fusarium*, and *Penicillium*, that attack various food commodities. *Aspergillus* spp. is fungi that produce a group of toxins known as aflatoxin (Guchi, 2015). Specifically, *A. flavus* is the major aflatoxin producing species, which predominately contaminates maize (Samson et al., 2014; Iqbal et al., 2015; Seetha et al., 2017). Aflatoxins B_1 (AFB_1), the most potent of the aflatoxin is classified as a human carcinogen (Adekoya et al., 2017) and has been associated with child growth impairment, suppressed immune function, and death due to acute poisoning known as aflatoxicosis (Salano et al., 2016; Shirima et al., 2015). In 2016, death resulting from acute aflatoxicosis has also been reported in Tanzania and there were 68 cases of acute aflatoxicosis and 20 related deaths in central Tanzania (Manyara and Dodoma) (Kamala et al., 2018). In Tanzania, maize is the most important staple crop for the majority of the population and a major component of feed for livestock (URT, 2016). Smallholder farmers produce over 85% of the total national cultivation of maize, and production is growing at an average annual rate of 6.44% in 2020 (URT, 2020); it also serve as a source of 30% of dietary calories to millions of population (FAOSTAT, 2020). The majority of smallholder farmers produce maize as food and cash crop while consumers prefer white dent corn with a negligible amount of yellow corn grown in Tanzania (Mtaki, 2019). Thus, maize is important and therefore deserves adequate and effective monitoring in its production chain (Nyirenda et al., 2021).

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); interfered 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. Awareness has been found to vary with various socioeconomic characteristics. For instance, in Tanzania, studies have shown that education level has a positive effect on aflatoxins awareness (Ngoma et al., 2017; Magembe et al., 2017). In Kenya, women were found more informed of the danger of fungal toxins and cautious to moldy feeds than men (Kiama et al., 2016). Furthermore, in Vietnam, young farmers (at age of 21–29) were more informed of aflatoxins in crops than the older groups (Lee et al., 2017). The field of study particularly life sciences had a positive impact on aflatoxins awareness in Ghana (Ayo et al., 2018) while individuals in other occupations are more informed of aflatoxins than farmers in Ethiopia (Ephrem et al., 2014). Detection and quantification of aflatoxins levels in human food are important to compare levels of contamination with the recommended maximum residue limit (MRL), so that appropriate remedial action and preventive practices of aflatoxins contamination during handling and storage of foods can be implemented (Udomkun et al., 2017). Aflatoxins contamination in maize can only be accurately quantified with laboratory testing along maize value chains, and hence significantly reduce risks of aflatoxins exposure (Hoffmann et al., 2018). Therefore, the study aimed at assessing awareness of aflatoxins among stakeholders and determining the current levels of aflatoxin in maize stored among stakeholders in Chemba and Kondoa districts of Dodoma region.

MATERIALS AND METHODS

Study design, sampling procedure and sample collection

A cross-sectional descriptive study was carried out between smallholder maize farmers (have less than 5 acres), traders (Village Agents, wholesaler) and consumers (different professions, (farmers, teachers, students, house wife and entrepreneurs) in collecting field data in Kondoa and Chemba districts, whereby two wards in each district were selected. Then two villages were selected in each ward to make a total of eight villages. A simple random sampling was used to select 40 samples from smallholder farmers, 30 samples from consumers and 20 samples from traders making a total of 90 samples. Face to face interview was among selected 20 smallholder farmers, 20 consumers from each village, making a total of 160 smallholder farmers and 160 consumers' respondents. On the other hand, 60 traders including market sellers were randomly selected from the study area. A total of 90 maize samples were purchased and collected randomly from three different stakeholders (smallholder farmers, 40 samples; consumers, 30 samples; and traders, 20 samples) in the study area. The larger number of maize sample collected is due to availability of the samples from stakeholders. All samples were coded and transported in an ice box together with their original packaging prior to laboratory analysis at Tanzania Bureau of standards (TBS) in Dar es Salaam.

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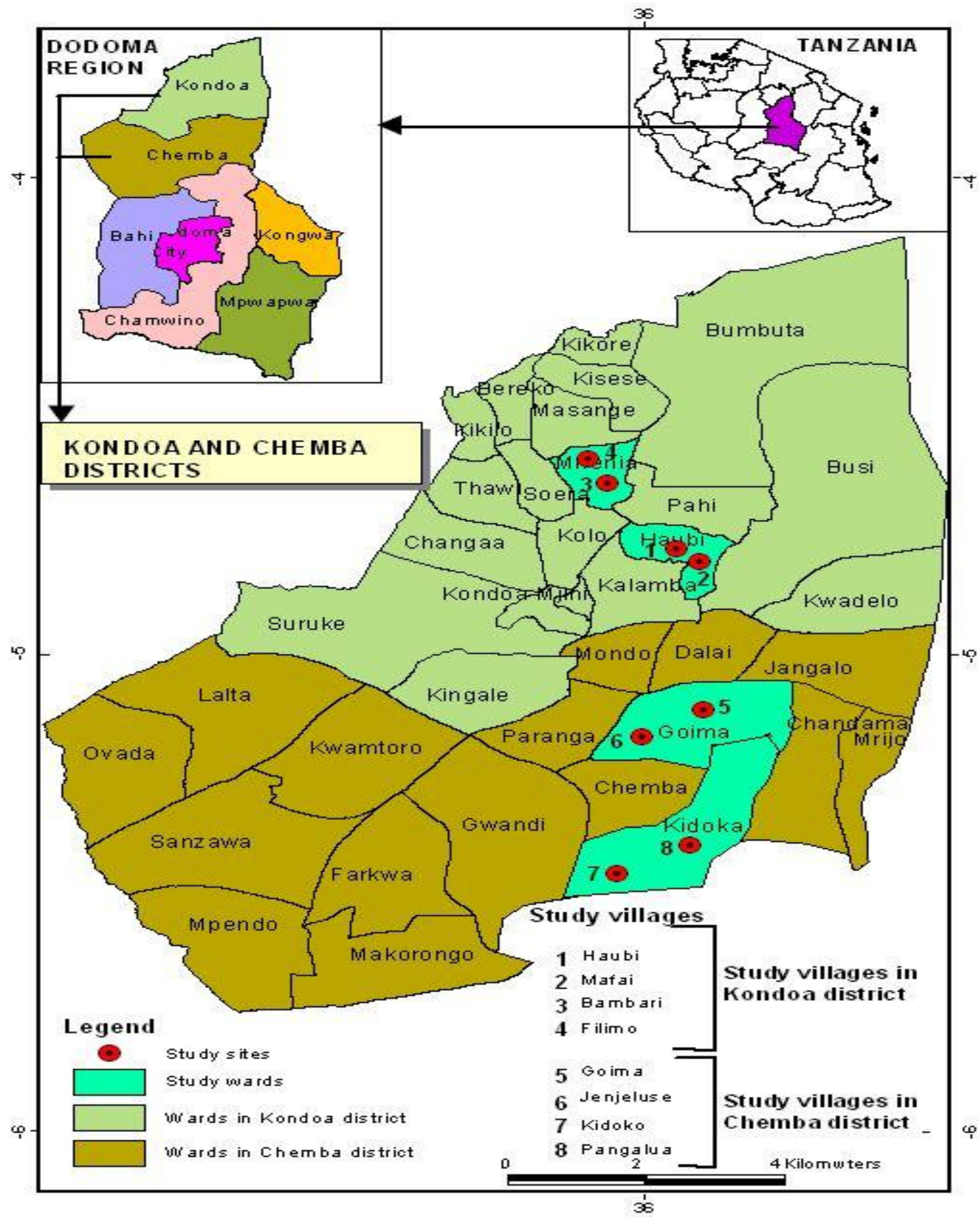

Figure 1. Map showing study sites in Kondoa and Chemba districts of Dodoma region.
Source: Authors

Study area

The study was conducted during the 2020-2021 cropping season in the semi-arid agro-ecological zone (Kondoa and Chemba districts) of Dodoma Region (Figure 1). Kondoa District lies between latitude 4° 12` to 5° 38` south and longitude 35° 6` to 36° 2` East. Chemba District lies between 5° 14` to 36° 00` south and longitude 35° 53 to 24° 00 East. Its climate is wet savannah characterized by a long dry season (DEPRP, 2012). The districts were selected due to physical attribute and multiple threats experienced annually rendering their communities at risk. The main threats affecting the districts include drought, deforestation, soil degradation and hunger conditions which impose a pattern of risk evasion in traditional agriculture (URT, 2017). Furthermore, the reported epidemic of aflatoxicosis in 2016 (Kamala et al., 2018) and the presence of the conditions conducive to the formation of aflatoxins production is another issue (Ngoma, 2019).

Sample size estimation

Since the exact population of maize main stakeholders (smallholder farmers, traders and consumers) was unknown, the sample size was estimated using the Kothari equation (Kothari and Garg, 2014):

$n = z^2P (1-P) / e^2$

Where; n = sample size, Z = Standard variant at a given confidence level, for this study a 95% confidence level = 1.96, P = Standard deviation that will show how much the results will vary from each other and the mean number for this study (0.5) was used and e = acceptable error (the precision/ estimation error) set at 5% (0.05) for this study. Thus, the sample size of the study for assessment of awareness among stakeholders was:

$n = 1.96^2 \times 0.5 (1 - 0.5)/0.05^2$

n = 384 for respondents for interview

And for samples used in determining the aflatoxins contaminations, maximum allowable error of 0.05% was used thus, the sample size of maize for analysis was:

$n = 1.96^2 \times 0.05 (1 - 0.05)/0.045^2$

n = 90 for maize sample for aflatoxin analysis

Data collection tools

The household survey was conducted using a pretested structured questionnaire. Face-to-face interviews were conducted with randomly selected stakeholders (smallholder farmers, traders and consumers). The data of the study was collected using quantitative methods.

Aflatoxins analysis

Chemicals and standards, HPLC conditions and column and other materials

HPLC grade chemicals, acetonitrile, methanol and glacial acetic acid were from Fisher Chemical, UK. Aflatoxins standards (2.02 µg/kg for AFB_1 and AFG_1, 0.505 µg/kg for AFB_2, and AFG_2) solution were of chromatography grade obtained from Biopure, Romer Labs Diagnostics GmbH-Tulin Austria, Distilled water was produced with a Milli-Q Integral 15 water purification system - France and Immunoaffinity columns (AflaTest from Romer Labs GmbH, Technopark 5and 3430 Tulin, Austria).

HPLC conditions

HPLC with a fluorescence detector (FLD) (Model Agilent ChemStation technology, series 1200, 5301 Stevens Creek Blvd, Santa Clara, CA 95051, USA). The HPLC system was equipped with a G1322A degasser, and a G1311A Quat pump. Chromatography separation was achieved by Zorbax 20 Rbax RX C18 column 5 µL (250 × 4.6 mm) (Agilent, USA) and maintained at 30°C and a flow rate of 1.2 ml/min. The analytical separation of aflatoxins (AFB1, AFB2, AFG1 and AFG2) was performed using the mobile phase contained water: methanol: acetonitrile (60:30:10, v/v) for both standard solution and sample extracts. After separation, AFG1 and AFB1 were derivatized to allow their detection with a fluorescence detector at an emission wavelength of 465 nm and an excitation wavelength of 360 nm.

Extraction of samples

Maize grain was ground separately to obtain a homogenous flour mixture and then sub-divided to obtain representative sub-samples for analysis. Each ground maize sample (Maize flour) or quality control samples were placed into amber colored Erlenmeyer flask and weighed using the calibrated analytical balance to 25 ± 0.1g (Shimadzu electronic balance, ATX224 type). By using a measuring cylinder, 100 ml of methanol: water (70:30 v/v) as extraction solvent was added to the 250 ml amber colored Erlenmeyer flask containing the sample. The flask was placed on the gyratory shaker (Stuart® Orbital Shaker SSL1, Cole-Parmer LLC, and USA) at 250rpm/30 min, then using a filter paper Whatman No. 1, the extract was filtered into a 250 ml flask.

Dilution stage

Four (4) ml of extract sample was transferred to 15 ml amber colored volumetric flask, followed by the addition of 8 ml of distilled water. Then, the mixture was vortexed (Talboys® Hvy Dty Vortex, USA) for 1 minute to get a homogeneous mixture.

Clean-up of aflatoxins

The diluted extract was loaded and allowed to pass through Solid Phase Extraction (SPE) immunoaffinity columns and the sample loaded columns were rinsed twice with 10 ml of HPLC grade water.

Elution stage

The adsorbed aflatoxins were eluted with 1 ml of HPLC grade methanol and the eluent was collected in HPLC vials. Finally, the pressure was slightly applied on top of the column to remove any remaining liquid. Three hundred microliter of the eluate was mixed with 0.6 ml of water and 0.1 ml of acetonitrile and the mixture was vortexed for 30 seconds ready for HPLC injection.

Determination of the limit of detection (LOD) and limit of quantification (LOQ) of the HPLC method

The LOD and LOQ were established by analyzing successive lowest dilutions (0.1 µg/kg) of the standard solution in the matrix. These LOD and LOQ values were related to the signal to noise ratio considering the concentration generated at 3 and 10 times, respectively of the lowest calibration point. The limits of detection (LOD) and quantification (LOQ) of the HPLC method for AFB1, AFB2, AFG1 and AFG2 were 0.1 and 0.5 µg/kg, respectively. The precision of the method was determined by running the lowest standard of 0.1 ng/mL ten times for three days and precision was determined by calculating their relative standard deviation. The measurement uncertainty, expressed as relative standard deviation (RSD) was 1.402% and this is within the acceptable range of < 2.4%, ISO 16050:2003.

Data analysis

Statistical Package for Social Sciences (IBM SPSS® Version 20, Minnesota and USA) was used to analyze the obtained data. The analysis involved descriptive statistics to describe the sample population, socio-demographic of respondents and awareness of aflatoxins contamination of maize. The chi-square test was used for testing the association between study independent variables and dependent variable (aflatoxins contamination). Laboratory analysis data was entered and processed using Excel sheets and analyzed using R software (version 4.1.0, 2021) whereby Friedman’s test was used to test for significant differences between the combination

Table 1. Socio-demographic characteristics of interviewed respondents (n=380).

Variable	Descriptions	(%) respondents		
		Farmers (n= 160)	Consumer (n = 160)	Traders (n = 60)
Districts	Kondoa	50	50	58
	Chemba	50	50	42
Gender	Male	55	59	89
	Female	45	41	13
Age categories	20 - 35	20	48	32
	36 - 45	26	19	46
	46 - 55	28	24	18
	55 < above	25	9	3
Education level	Informal education	6	9	0
	Primary education	88	67	70
	Secondary education	5	19	30
	Tertiary education	0	4	0
	University level	0	6	0
Marital status	Married	97	88	88
	Single	3	12	12

Source: (Author survey, 2021).

of the type of stakeholder and districts in aflatoxins concentration from the maize grain samples. A probability value less than 0.05 was considered significant and the mean separation test was done using the Turkey HSD test.

RESULTS

Recovery of aflatoxins B_1 contamination

The recovery of aflatoxin B_1 were greater than 70% (94.025, 93.09 and 92.2%) with an average of 93.11%, indicating the suitability and good performance of the HPLC, extraction protocol and quantification (Beyene et al., 2019)

Social - demographic characteristics of respondents

Results in Table 1 show the socioeconomic characteristics of the respondents. Over 90% were married giving an indication of the importance of the marriage in the study area. About 75% of all stakeholders that is smallholder farmers, traders and consumers completed at least primary school education indicating a measure of literacy.

Stakeholders' level of awareness on aflatoxins in maize contaminations

The overall score (Figure 2) indicate that more smallholder farmers and traders and a few consumers are aware of the occurrence, cause and effect of aflatoxins contamination in maize in Kondoa and Chemba districts.

Aflatoxins contamination in maize samples

The mean values of aflatoxins AFB_1 and total aflatoxins in farmer, traders and consumer maize samples ranged from 0.00±0.000 to 9.88±5.904 as shown in Table 2. The highest mean value for total aflatoxins was in traders' maize samples. However, there was a significant difference between the means at $p<0.05$.

A higher number of samples were taken from smallholders farmers due to the availability of samples that is normally stored for sale at a higher price later. Mean ± SEM across the column with different statistical letters indicates statistical difference according to the Turkey HSD test.

Incidence of aflatoxins B_1 contamination in maize grain samples that exceeding EU and TBS regulatory limits

Few samples were contaminated with AFB_1 (Figure 3), Samples from Filimo and Mafai wards did not detect to AFB_1 and total aflatoxins. Also Jengeluse and Goima wards didn't detect for aflatoxins B_1 contaminations.

Table 2. Mean aflatoxins concentration (μg/kg) in maize grains samples collected from different stakeholders in Kondoa and Chemba Districts (Mean ± SEM).

Stakeholder	District	Sample (N)	Aflatoxins B1 Mean ±SEM (μg/kg)	Total aflatoxins Mean SEM (μg/kg)
Consumer	Chemba	15	0.00±0.000[b]	0.00±0.000[b]
	Kondoa	15	0.00±0.000[b]	0.00±0.000[b]
Smallholder Farmer	Chemba	20	0.04±0.029[b]	0.04±0.029[b]
	Kondoa	20	0.00±0.000[b]	0.00±0.000[b]
Trader	Chemba	10	0.00±0.000[b]	0.00±0.000[b]
	Kondoa	10	9.88±5.904[a]	12.42±7.652[a]

Source: Authors

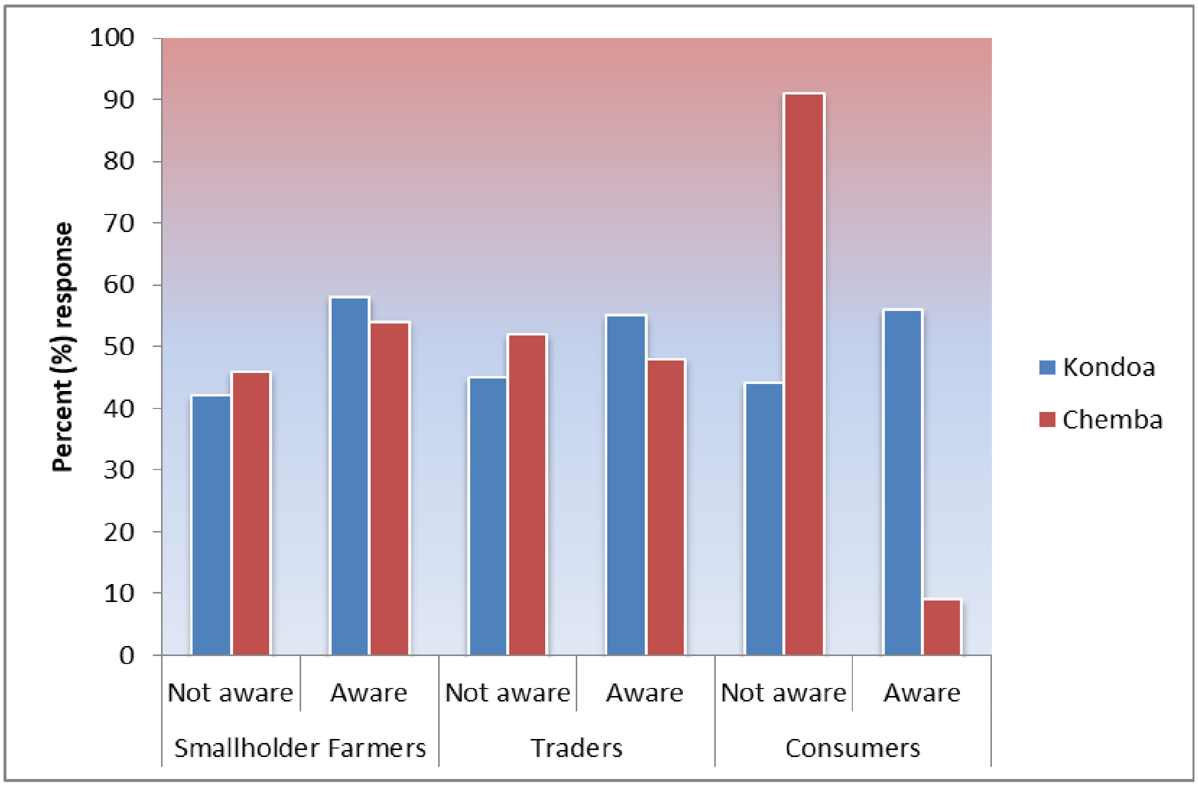

Figure 2. Respondents' overall score on awareness of aflatoxins contamination in maize.
Source: Authors

DISCUSSION

Social - demographic characteristics of respondents

Generally, the study found that the number of males who participated in the study exceeded that of female. The male participants were 61% (Smallholder farmers 55%, Traders 89% and Consumer 59%) (Table.1) while the female participants were 39%, this implied that male respondents were dominating the main supply chain. In the study area traditional farming activities are dominated by women because it's a tedious work. Women in nature are tolerant as being seen in the way of taking care of the family hence, traditional believed that farming activities are women work. Lack of permanent market to sell maize was the reasons for men to engage in trading activities. Male respondents were dominating in trading activities, a trend found mostly in many developing countries actively engaged in trading activities and in providing information. A similar trend was observed by Toma (2019) in Ethiopia

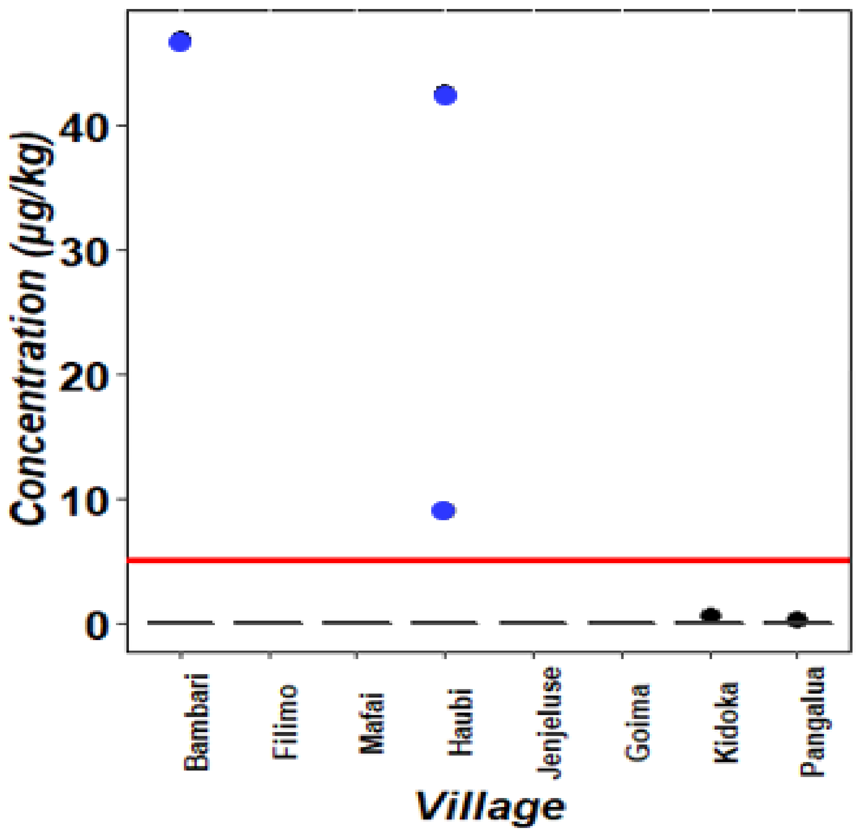

Figure 3. Incidence of aflatoxins B_1 contamination in maize grain samples that exceeding TBS regulatory limits.
Source: Authors

who found that farming activities and trades are dominated by males; the study also noted that more than half (53%) of smallholder farmers were aged above 45 years of age. On the other hand, the majority (78%) of traders in the study area were aged between 36 – 45 while, the mean duration of involvement in the maize business was 8 years; Most (67%) of consumers were in the age group between 20 to 45 years old. This finding implies that maize value chain is a demanding activity; therefore those involved ought to be physically energetic and able to supply the required labour so as to meet their responsibilities and goals. Descriptive statistics showed that the majority (88%) of smallholder farmers interviewed had primary school education, 70% of traders had attained primary school education; while 67% of consumers had attained primary school education. These findings show that farmers, traders and consumers had at least a basic primary level of education. These imply that the majority of respondents were able to follow training and instructions as they could read and write in Kiswahili. Education may help them read and understand guidelines associated with occurrence, causes, health effects and prevention of aflatoxins contaminations. These findings conform to the study by Aulakh and Regmi (2013) who suggested that smallholder farmers and traders with at least basic education are needed to reduce food losses.

Stakeholders' level of awareness on aflatoxins in maize contaminations

This study revealed that level of education was directly related to aflatoxins contamination awareness. Maize value chain is highly dominated by Smallholder farmers, whose education level was primary school (88%) and very few respondents (<10%) in this category did not hear of aflatoxins contaminations in their lifetime. Awareness of aflatoxins contamination in maize was high among smallholder farmers (58%) and traders (55%), while it was low (42%) among consumers in Kondoa District. Similarly, smallholder farmers' awareness was 54%, traders 48% and the lowest (9%) among consumers in Chemba District. The stakeholder farmers' knowledge of aflatoxin in a large amount is attributed to farmer field schools and training conducted with agricultural extension officers in the study area. Similar studies by Kamala et al. (2016) and Hell and Mutegi (2011) reported training to improve maize smallholders' farmers' awareness of fungi and aflatoxin contamination. According to Massomo (2020), the high level of awareness found in the area is attributed to the information that was communicated on contamination of food commodities, acute poisoning and deaths due to aflatoxins, during the outbreak in 2016. However, this conclusion is contrary to the studies done in Tanzania by Degraeve et al. (2016), Magembe et al. (2016) and Shabani et al. (2015) who found low level of awareness before the outbreak of the death related to aflatoxins. Traders scored higher than consumers may be due to regular training on aflatoxins contamination, seminar and workshops. Similar observations were reported by James and Zikankuba (2018) that training, seminar and workshops on aflatoxins increase awareness of maize traders. Likewise, a study conducted in Kenya found that most (56.6 %) traders were aware of aflatoxin contamination (Nyangaga, 2014). Furthermore, analysis shows that consumers (this categories mixed up with different field of people such as smallholder farmers (72%), primary school teachers (10%), secondary school student (10%) and entrepreneur, housewife were (<8%) had low awareness compared to other groups. Possible explanation for this observation is clearly depicted in this study. Education was an important mode of dispensing information and knowledge on aflatoxins contamination to public. This observation reflects Kamala et al. (2018) and Ezekiel et al. (2013) who reported the lowest (15%) level of consumers' awareness of aflatoxins contamination. This implies low public awareness of aflatoxins contamination affects mainly people from remote areas who have less access to information on aflatoxins as compared to those in urban areas. Respondents from Kondoa District were more aware compared to Chemba respondents, this is not unique as previous studies (Kimanya et al., 2014; Magembe et al., 2016) reported that in Tanzania, awareness of aflatoxins and health impacts varied between districts. The finding implies that the presence of projects dealing with aflatoxins in the districts and stakeholders' commitment and ability to implement the practice might have contributed to this awareness.

Aflatoxins contamination in maize samples

Findings in this study reveal the significant occurrence of important aflatoxins in main actors' samples in these districts maize supply chain. This is important because maize is dietary staple food in these districts affected by the aflatoxicosis outbreak, aflatoxins contamination from traders' samples therefore, is an important public health concern and these toxins may pose significant human health risks that may be increased by occurrence in the diet. Table 3 indicates that out of 90 maize grain samples collected from various villages in three different stakeholders in the maize value chain from the study area, five (5) samples were contaminated with aflatoxins B_1. Moreover, a high prevalence with AFB_1 and total aflatoxins were found in the samples taken from traders, there were low concentration detected in samples from smallholders' farmers while none of the consumers' samples was detected for aflatoxins contamination. The lower levels of aflatoxins contamination in farmers' maize samples probably was due to environmental conditions, such as change in temperature and relative humidity of surrounding as well as a good type of soil, since the moulds live in soil, surviving off dead plant and animal matter, but do spread through the air via airborne *conidia are* the natural factors that influence aflatoxins incidence during maize production (Atanda et al., 2013) good farmers' practices such as timely harvesting, ensuring uniform drying of maize to a safe moisture level and proper storage is critical in the maize value chain. Storage at less than 13% moisture content, 65% relative humidity and temperature of less than 25^0C prevents the growth of storage moulds (Ademola et al., 2021). Despite contamination increases with time in storage, the majority of the samples used in the analysis were stored in good condition for eight months at the farmers' store (Monyo et al., 2012; Ezekiel et al., 2013). The samples collected from traders demonstrate that mean levels of aflatoxins B_1 in stored maize was significantly higher compared to other actors (smallholder farmers and consumers). The drastic increase in aflatoxins probably was because traders usually purchase maize from different locations, different storage facilities as well as different maize varieties, which may also have aflatoxins contamination. Frequent opening and improper closing of the storage facilities could also add moisture from the atmosphere and thus the quality of dried grain be affected by the variation in final moisture content during storage. Besides, efforts to address the issue of aflatoxins prevention programs is geared very much to smallholder farmers and not traders and consumers. The prevalence of aflatoxins contamination obtained in trader's samples was significantly high which indicates the risk of chronic exposure to the consumers. The findings are similar to the study by Oyekale and Oladele (2012) who noted that traders' maize samples were contaminated with higher mean levels of aflatoxins B_1. Therefore, to ensure high quality during storage, maize should be protected from weather, growth of microorganisms, and insects (Oyekale and Oladele, 2012).

AFB_1 has been detected more frequently compared to other types of aflatoxins, similar to what was reported by Kachapulula et al. (2017) in Zambia that maize samples were contaminated with aflatoxins by 5%. The results of the present study were significantly lower than the study conducted by Dos Santos et al. (2013) in Brazil where 16% of the maize samples from farmers were contaminated with aflatoxins B_1 and contrary to Kaale et al. (2021) who report high aflatoxins B_1 contaminations in

Table 3. Percentage of maize contaminated with aflatoxins in Kondoa and Chemba.

Stakeholder	District	Sample(N)	Sample contaminated with aflatoxins B1	
			n	%
Consumer	Chemba	15	0	0.0
	Kondoa	15	0	0.0
Smallholder Farmer	Chemba	20	2	10.0
	Kondoa	20	0	0.0
Trader	Chemba	10	0	0.0
	Kondoa	10	3	30.0
Total		**90**	**5**	**5.6**

N is the total number of samples analyzed from two different districts and from different stakeholders (smallholder farmers, Traders and Consumers) and n is total number of contaminated samples from each district and from each stakeholder.
Source: Authors

maize samples. Three samples, which were all taken from Bambari and Haubi village in Kondoa District were found to be contaminated with aflatoxins B_1, exceeded the acceptable limits for aflatoxins B_1 of 5 µg/kg (TBS, 2018) with maximum concentrations of 46.99 µg/kg (Figure 3) and the concentrations were 42.69,10.11 and 46.99 µg/kg. Furthermore, high levels can occur if rodents and other pest attack and damage maize grain and if storage occurs under unfavorable conditions over long periods of storage. Two samples (2) of contaminated maize (Figure 3) from Kidoka and Pangalua villages in Chemba Districts were found to be below (5 µg/kg) acceptable TBS regulatory limits for AFB_1 and concentrations were 0.29 and 0.51 µg/kg. This supports a study by Ezekiel and Sombie (2014) in Nigeria which found that aflatoxins were present at the internationally recommended level for aflatoxins B_1 and total aflatoxins in the maize sample. Thus, the results indicated that consumers of maize in this area have been at significant risk for exposure to low levels of aflatoxins contaminations. The present study found low aflatoxins contamination at samples from farmers at levels below the maximum tolerated limit (MTL). Similar to the studies reported by Bonni et al. (2021) in Tanzania, and Kamika and Tekere (2016) in Congo whose findings indicated a low mean concentration of AFB_1 in maize samples. These observations might be a result of proper is result storage of maize along the maize value chain. Storage at less than 13% moisture content, 65% relative humidity; and temperature of less than 25°C prevents the growth of molds.

CONCLUSIONS AND RECOMMENDATION

The study shows that few samples were contaminated with AFB_1; however high AFB_1 levels were found in trader's sample which was above the recommended Tanzania Bureau of Standards (TBS) regulatory limit. A significant number of smallholder farmers and traders stakeholders in Kondoa and Chemba district in Dodoma Region were aware of aflatoxins contamination in maize, which is vital in improving food safety in the country. However, consumers in the research area have extremely low awareness level of aflatoxins contamination, which increases the risks of aflatoxins contamination along the maize value chains. Therefore, there is a need of introducing method of identifying and managing food safety risk and food safety program, Hazard Analysis Critical Control Point (HACCP), among stakeholders which can provide assurance to customer, the public and regulatory agencies of food safety in the country. The study recommends an urgent development of an effective and broad community awareness programme on aflatoxin contaminations in maize on occurrence, causes and health effects in humans. It is important that consumers and all stakeholders along maize value chain be educated on the potential harmful effects on AFB_1 on human health.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Questionnaire for Smallholder – Farmers

A. General information

1. Date ..../......../...................
2. Place (i) District........................ (ii)Ward……................…. (iii)Village…..................…
3. Age of respondent ……….........
4. Sex of respondent…………....
5. Occupation…..

6. Current education level

i)	Primary Education	( )	iv) Secondary education	( )
ii)	Not educated	( )	v) Tertiary education	( )
iii)	University	( )		

7. Marital status

i)	Single	( )	iii) Married	( )
ii)	Divorced	( )	iv) Widowed	( )

B. Occurrence of molds and aflatoxins contamination in foods.

1.	Have you ever heard of a mould toxin that may be present in crops? (Y/N)
2.	Have you ever heard of a mould toxin that may be present in food? (Y/N)
3.	Have you ever heard about aflatoxin? (Y/N)
4.	Are you aware that aflatoxin can contaminate crops on farm? (Y/N)
5.	Are you aware that aflatoxin can contaminate crops in storage? (Y/N)
6.	Are you aware that aflatoxin can contaminate food? (Y/N)
7.	Are you aware that Aflatoxins can be transferred to animals? (Y/N)
8.	Are you aware that Aflatoxins can be transferred into milk and dairy products?
9.	Are you aware that Aflatoxins can be transferred into breast milk? (Y/N)
10.	Are you aware of aflatoxins contamination? in crops in the field and during storage? (Y/N)
	C. Cause of aflatoxins contamination
1.	Aflatoxins can be caused by fungi? (Y/N)
2.	Aflatoxins can be caused by high levels of rain during harvesting? (Y/N)
3.	Aware that fungi infect food when stored in moist conditions? (Y/N)
4.	Aflatoxins can be caused by delayed harvesting? (Y/N)
5.	Aflatoxins can be caused by delayed drying? (Y/N)
6.	Aflatoxins can be caused by Insect infestation? (Y/N)
7.	Broken and bruised crops increase a chance of contaminations?(Y/N)
8.	Crops which contain foreign materials promote aflatoxins?(Y/N)
9.	Poor storage conditions promote aflatoxins contamination in crops ?(Y/N)
	D. Effect of aflatoxins contaminations
1.	Aflatoxins contamination reduces animal productivity? (Y/N)
2.	Aflatoxins contamination causes stunting in animals? (Y/N)
3.	Aflatoxins contamination causes death in animals? (Y/N)
	F. Health effect associated with consumption contaminated food
1.	Are you aware of the harmful effects of aflatoxins on humans? (Y/N)
2.	Are you aware the effects of aflatoxins on animals? (Y/N)
3.	Some liver diseases have been linked to intake of aflatoxins?
4.	Aflatoxins cause cancer in humans? (Y/N)
5.	Aflatoxins delay child growth? (Y/N)
6.	Aflatoxin contamination can reduce the price of crops? (Y/N)

Questionnaire for Consumer

A. General information

1. Date ..../......../...................
2. Place (i) Region.............. (ii) District................ (iii)Ward……… (iv)Village……
3. Age of respondent ………....
4. Sex of respondent………….
5. Occupation…......................
6. Current education level

i) Primary Education ( ) iv) Secondary Education ( )
ii) Not educated ( ) v) Tertiary Education ( )
iii) University ( )

7. Marital status

i) Single ( ) iii) Married ( )
ii) Divorced ( ) iv) Separated ( )
iii) Widowed ( )

B. Occurrence of molds and aflatoxins contamination in foods.

1.	Have you ever heard of a mould toxin that may be present in crops? (Y/N)
2.	Have you ever heard of a mould toxin that may be present in food? (Y/N)
3.	Have you ever heard about aflatoxin? (Y/N)
4.	Are you aware that aflatoxin can contaminate crops on farm? (Y/N)
5.	Are you aware that aflatoxin can contaminate crops in storage? (Y/N)
6.	Are you aware that aflatoxin can contaminate food? (Y/N)
7.	Are you aware that Aflatoxins can be transferred to animals? (Y/N)
8.	Are you aware that Aflatoxins can be transferred into milk and dairy products?
9.	Are you aware that Aflatoxins can be transferred into breast milk? (Y/N)
10.	Are you aware of aflatoxins contamination? in crops in the field and during storage? (Y/N)
	C. Cause of aflatoxins contamination
1.	Aflatoxins can be caused by fungi? (Y/N)
2.	Aflatoxins can be caused by high levels of rain during harvesting? (Y/N)
3.	Aware that fungi infect food when stored in moist conditions? (Y/N)
4.	Aflatoxins can be caused by delayed harvesting? (Y/N)
5.	Aflatoxins can be caused by delayed drying? (Y/N)
6.	Aflatoxins can be caused by Insect infestation? (Y/N)
7.	Broken and bruised crops increase a chance of contaminations?(Y/N)
8.	Crops which contain foreign materials promote aflatoxins?(Y/N)
9.	Poor storage conditions promote aflatoxins contamination in crops ?(Y/N)
	D. Effect of aflatoxins contaminations
1.	Aflatoxins contamination reduces animal productivity? (Y/N)
2.	Aflatoxins contamination causes stunting in animals? (Y/N)
3.	Aflatoxins contamination causes death in animals? (Y/N)
	F. Health effect associated with consumption contaminated food
1.	Are you aware of the harmful effects of aflatoxins on humans? (Y/N)
2.	Are you aware the effects of aflatoxins on animals? (Y/N)
3.	Some liver diseases have been linked to intake of aflatoxins?
4.	Aflatoxins cause cancer in humans? (Y/N)
5.	Aflatoxins delay child growth? (Y/N)
6.	Aflatoxin contamination can reduce the price of crops? (Y/N)

Open structured questionnaire for Traders

A. General information

a. Date ..../......../...................
b. Place (i) District................ (ii)Ward……… (iii)Village....
c. Age of respondent ………....
d. Sex of respondent…………
e. Occupation…......................
f. Current education level
i) Primary education ( ) iv) Secondary education ( )
ii) Not educated ( ) V) Tertiary education ( )
iii) University ( )
g. Marital status
i) Single ( ) iii) Married ( )
ii) Divorced ( ) iv) Separated ( )
iii) Widowed ( )

B Postharvest handling practices

1) Which crop do you sell?
a) Maize ( )
b) Others (please mention)..
2) How do you keep your maize after buying?
a) Bare ground ( ) d) Raised platforms ( )
b) Tarpaulin ( ) e) Jute/Sisal bags ( )
c) Plastic/synthetic bags ( ) f) others (specify) ……………………………..
3) How do you transport your maize after buying?
a) Bicycle ( ) d) Open vehicle ( )
b) Closed vehicles ( ) e) Head ( )
c) Others (Please specify)………………………………………………..
4) What action do you take if it rains while your maize is at an open space?
a) Cover ( ) c) Take to the protected area ( )
b) Not cover ( ) d) others …………………………
5) Do you sort or clean grains before storage? (Yes/ No)..........
6) If yes, how do you sort?
a) By separating from coloured grain ( ) c)Separate damage/broken grain ( )
b) By separating rotten grain ( ) d) other...........................
7) What type of storage/facility do you use to store your maize?
a) Bins /Silo ( ) d) Jute/Sisal bags ( )
b) Plastic/synthetic bags ( ) e) Granaries ( )
c) Others (Please specify) ………….…..…………..............
8) How long do you store your maize before selling? …………… (months)
9) How do you store your maize?
a) As cobs ( ) c) As grain ( )
b) As pods ( ) d) others (Please specify) ………….
10) Do you fumigate storehouse/warehouse before storing your maize? (Yes/No).............
11) Which of the following losses do you encounter?
a) Insect and rats infestation (Yes/No)........,
b) Mouldy/rotting (Yes/ No)...........
c) Mechanical damage of grains (Yes/No)..........
d) Loss of grains during shelling, storage and transport (Yes/No)........
e) Others (Please specify) …………………………

12) Do you use pesticides to store your maize? (Yes/No)....................

B. Occurrence of molds and aflatoxins contamination in foods.

1.	Have you ever heard of a mould toxin that may be present in crops? (Y/N)
2.	Have you ever heard of a mould toxin that may be present in food? (Y/N)
3.	Have you ever heard about aflatoxin? (Y/N)
4.	Are you aware that aflatoxin can contaminate crops on farm? (Y/N)
5.	Are you aware that aflatoxin can contaminate crops in storage? (Y/N)
6.	Are you aware that aflatoxin can contaminate food? (Y/N)
7.	Are you aware that Aflatoxins can be transferred to animals? (Y/N)
8.	Are you aware that Aflatoxins can be transferred into milk and dairy products?
9.	Are you aware that Aflatoxins can be transferred into breast milk? (Y/N)
10.	Are you aware of aflatoxins contamination? in crops in the field and during storage? (Y/N)
	C. Cause of aflatoxins contamination
1.	Aflatoxins can be caused by fungi? (Y/N)
2.	Aflatoxins can be caused by high levels of rain during harvesting? (Y/N)
3.	Aware that fungi infect food when stored in moist conditions? (Y/N)
4.	Aflatoxins can be caused by delayed harvesting? (Y/N)
5.	Aflatoxins can be caused by delayed drying? (Y/N)
6.	Aflatoxins can be caused by Insect infestation? (Y/N)
7.	Broken and bruised crops increase a chance of contaminations?(Y/N)
8.	Crops which contain foreign materials promote aflatoxins?(Y/N)
9.	Poor storage conditions promote aflatoxins contamination in crops ?(Y/N)
	D. Effect of aflatoxins contaminations
1.	Aflatoxins contamination reduces animal productivity? (Y/N)
2.	Aflatoxins contamination causes stunting in animals? (Y/N)
3.	Aflatoxins contamination causes death in animals? (Y/N)
	F. Health effect associated with consumption contaminated food
1.	Are you aware of the harmful effects of aflatoxins on humans? (Y/N)
2.	Are you aware the effects of aflatoxins on animals? (Y/N)
3.	Some liver diseases have been linked to intake of aflatoxins?
4.	Aflatoxins cause cancer in humans? (Y/N)
5.	Aflatoxins delay child growth? (Y/N)
6.	Aflatoxin contamination can reduce the price of crops? (Y/N)