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Original Article

Assessment of Knowledge, Attitudes, and Practices in relation to Mycotoxin Contamination in Tanzania

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ABSTRACT

This study assessed the knowledge, attitude, and practices (KAP) of the population in three districts in Tanzania on issues related to mycotoxin contamination and exposure. The study employed a cross-sectional design. Data were collected using a questionnaire survey, which was administered to gather quantitative data in 180 randomly selected households in three districts of Tanzania. In addition, qualitative data were collected using key informant interviews (KIIs) of 12 purposively selected respondents and 6 focus group discussions (FGDs) of six to twelve participants. Quantitative data were analysed in SPSS version 20 for Windows using descriptive statistics and a chi-square test. While the qualitative data were analysed in ATLAS.ti 8 for Windows. A majority of respondents (25.1%) had never heard of mycotoxins, 20.1% were not aware of how mycotoxins are acquired, and none (0%) of the respondents claimed to never become sick after eating moulded/contaminated crops. The majority, 14.5% and 2.8% of the respondents, were not aware of prevention measures for animals and humans from mycotoxins, respectively. Only 8.9% agree that they are at risk of getting mycotoxins, 14% agree that it is safe to eat contaminated food, and 52.5% do not discard the mycotoxins contaminated food. The majority, 81.6%, dry their crops on top of the floor or bare grounds, almost 42.5% do not sort their crops before storage, and 28.5% agree to consume the defective/sorted crops. Therefore, it is recommended that health education interventions to create awareness among the public should be a priority and should be integrated into the existing control strategies.

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INTRODUCTION

Mycotoxins are chemically and biologically active by-products of mould growth occurring naturally in a range of plant products and can grow almost anywhere, indoors and outdoors (Hussein, 2001). Mycotoxins have significantly contributed to agricultural loss (because of lack of acceptance post-harvest of contaminated foods and feeds), as well as negative health impacts on livestock and humans. It is estimated that mycotoxins contaminate 25% of Agricultural crops worldwide (Zain, 2011; Smith *et al*., 2015). There are several types of mycotoxins known today; these include Aflatoxin (AF), Fumonisins (FUM), Ochratoxins (OT), and Zearalenone (ZEA), yet the two most important mycotoxigenic moulds associated with maize and other crops are *Aspergillus flavus* that produce aflatoxins (Okoth and Kola, 2012; Wagacha and Muthomi, 2008), and *Fusarium verticillioides* (previously known as *F. moniliforme*), which produces fumonisins (Richard *et al*., 2007).

Aflatoxins are acute and chronic toxicity, immunosuppressive, mutagenic, teratogenic, genotoxic and carcinogenic compounds produced by two major *Aspergillus* species: *Aspergillus parasiticus* which produce aflatoxin G1, G2, B1 and B2 and *Aspergillus flavus* which produces aflatoxin B1 and B2, (JECFA, 2017). The order of acute and chronic toxicity is AFB1>AFG1> AFB2> AFG2 (JECFA, 2017). The IARC has classified AF-B1, AF-B2, AF-G1, and AF-G2 all as Group 1 mutagens, denoting their explicit carcinogenicity to humans, while AF-M1 is classified in Group 2B (IARC 2015; JECFA, 2017). AFs B1, B2, G1, G2 and M1 can be regarded as the most important mycotoxins due to their genotoxic carcinogenic properties. Indeed, AFs are amongst the most potent mutagenic and carcinogenic substances known. AFB1 is the most potent, followed by AFG1 and AFM1 (JECFA 2017). The chronic AF-exposure induces liver cancer, infections and growth impairment in humans, while high exposures cause acute symptoms, even death (IARC 1993, 2015; JECFA, 2017), retarded growth, compromised immunity, and aggravates infectious diseases such as tuberculosis, hepatitis, and Human Immunodeficiency Syndrome (HIV) (Kimanya *et al*., 2010; EAC policy brief, 2018). Commodities contaminated with aflatoxins have a lower market value and are often consumed locally since they cannot be exported. At the farm level, animals fed with aflatoxin-contaminated grains have lower productivity and slower growth, resulting in serious economic problems.

Fumonisins (FUMs) are a class of mycotoxins primarily produced by *Fusarium verticillioides* and *Fusarium proliferatum*, but could also be produced by *F. anthophilum*, *F. becomiforme*, *F. dlamini*, *F. Globosum*, *F. napiforme, F. nygamai. F. oxysporum, F. polyphialidicum, F. subglutinans* and *F. thapsinum* (Richard et al., 2007). Of the FB-analogues, FB1 is the most predominant, FB2 and FB3 co-occur with FB1 but with lower concentrations (IARC 2015; JECFA, 2017). FB1, FB2, FB3 and FB4 and their modified forms have similar toxicological profiles, but the potencies of the modified forms are lower (EFSA 2018). FB1 is possibly carcinogenic to humans, and an association between chronic dietary exposure and human oesophageal and liver cancer has been claimed, but causality has not been confirmed (EFSA 2018; IARC 2002; JECFA, 2017). FUM B1 and B2 are of toxicological significance, while B3, B4, A1 and A2 occur in very low concentrations and are less toxic (Abel and Gelderblom, 1998). Fumonisins occur in maize, although noteworthy incidence has been found in sorghum, rice, and beer (Zain, 2011; Vismer *et al*., 2015). Maize is the major food crop affected by FMs, although noteworthy incidence has been found in sorghum and rice (Vismer *et al*., 2015). Fumonisin B1 is possibly carcinogenic to humans, and there is an association between chronic dietary exposure to human oesophageal

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and liver cancer, as well as neural tube defect, but causality has not been confirmed (Marasas *et al*., 2008; IARC 2002; JECFA 2017). Fumonisins also cause direct economic losses by spoiling grain, which can result in lowered export earnings by African countries that cannot comply with the strict market regulations (Hell et al., 2008).

DON occurs mostly in cereal grains alone or in combination with its relevant forms 3-acetyl-DON, 15-acetyl-DON and DON-3-glucoside (10–20% of the DON-levels) (Nathanail *et al*. 2015; Vanheule *et al*. 2014). The exposure is predominantly from cereals and cereal-based foods (EFSA, 2017b; JECFA, 2011). High exposure is associated with acute gastrointestinal symptoms in humans (e.g. vomiting), while the effects from chronic human exposure are unknown (EFSA 2017a; JECFA, 2011). Ochratoxins (OTs) are mainly produced by the genera of *Aspergillus ochraceus* and *Penicillium verrucossum*. Cereals, pulses, coffee beans, grapes, cacao beans, nuts, and spices are the crops most affected (Abdel-Wahhab *et al*., 2005; De Moraes and Luchese, 2003; García-Cela *et al*., 2012; IARC, 1993). Ochratoxin A (OTA) is the most toxic compound. Acute and chronic exposures are related to kidney function and cause lesions to form on the organs (Pfohl-Leszkowicz *et al*., 2002; Fusi *et al*., 2010). The International Agency for Research on Cancer (IARC) has defined OT-A as a Group 2B potential carcinogen (IARC, 1993).

Zearalenone (ZEN) is another common mycotoxin produced by various *Fusarium* fungi such as *F. culmorum*, *F. graminearum*, and *F. sporotrichioides*. Maize, and other grain crops such as wheat, barley, sorghum, millet, and rice are more susceptible to ZEN contamination (García-Cela *et al*., 2012; EFSA; 2017a; Nathanail *et al*., 2015). ZEN produces hepatotoxicity, cytotoxicity, genotoxicity, immunotoxicity, and hematotoxicity (Hassen *et al*., 2007; Tatay *et al*., 2013). ZEN has been classified due to its carcinogenicity in humans (IARC, 1993). ZEN can also be metabolised in the liver into a- zearalenol (a-ZOL) with estrogenic activity that is three to four times higher than that of ZEA (Minervini *et al*., 2005).

Therefore, control of mycotoxin contamination in foodstuffs is of the greatest importance. The control should be addressed at both the pre- and post-harvest levels. Understanding the farmers' KAP as the producer is the key to coming up with solutions. Several KAP studies have been conducted in several African countries to address awareness of the population on mycotoxin contamination (Azaman *et al*., 2016; Matumba *et al*., 2016; Biru and Gemta, 2022). The study aims to assess KAP as a key step toward control of mycotoxin contamination both in animals and plants.

METHODOLOGY

Study Area

The study was conducted in six villages of Mbarali, Sumbawanga, and Mbozi districts. The districts were purposively selected for being popular in the cultivation of crops, mainly maize and other crops like groundnuts and sunflower, which are prone to mycotoxins. Two villages were then purposively selected from each district.

Sample Size Determination

For the quantitative study, the sample size was estimated using the formula by Fisher et al. (1991) where:

$$n = \frac{z^2pq}{d^2}$$

where n is the sample size, z is the normal deviation (1.96) corresponding to 95% confidence.

interval, p (0.5) is the estimated prevalence of aflatoxin in the county, q is 1-p and d is the degree of the desired accuracy (5%). This yielded a total of 196 households plus a 25% attrition giving a sample size of 245 households. We ended up with a total of 270 household as we decided to have equal number of households of 45 from each of the 6 villages.

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Study Design

A cross-sectional survey was conducted in the purposively selected villages. In each village, a total of 45 households were randomly selected from the list of potential maize farmers provided by the village extension officers, and in each household, one person (usually the head of the household) was interviewed using a semi-structured questionnaire with both open and close-ended questions. In the absence of the household head, the available adult person was interviewed.

Data Collection

The study employed a community-based mixed methods approach involving different qualitative and quantitative approaches for triangulation purposes as a means to increase the reliability and validity of the findings in this sociological research (CDC, 2013). And since research, especially qualitative research that relies on only one data collection method is subject to the errors associated with that approach, many researchers triangulate their data to validate the results and ensure that the information is complete (CDC, 2013). The mixed methods involve input from the questionnaire survey, focus group discussions (FGDs) with the village health committee (VHC), and key informant interviews (KIIs) with government officials to identify potential contamination risks in the study areas. The data collected using questionnaires, KIIs, and FGDs were used to assess farmers' KAP regarding mycotoxins (contamination, health effects, symptoms, treatment, and prevention).

Household Survey

A questionnaire (Supporting file 1), which included the KAP of the farmers, was administered in each of the selected households. The questionnaire comprised both closed and open-ended questions relating to demographics and pre- and post-harvest practices regarding mycotoxin contamination.

Focus Group Discussions (FGDs)

A purposive sampling technique was used to select participants for FGDs, i.e., Village Health Committee (VHC). A trained moderator who is fluent in Kiswahili, the national language, led the FGDs. The FGD was conducted using a FGD guide (Supporting file 2). The researchers also developed themes and sub-themes to guide the discussions. In addition to audio recording, the interviews were recorded in a notebook. This provided an opportunity for the note-takers to record non-verbal responses, gestures, and other non-verbal information. An evaluation was done at the end of each meeting by the research team to validate the information collected and make any necessary adjustments to improve the next interview. Five FGDs were conducted in all three surveyed districts (Mbarali, Mbozi, and Sumbawanga). Participants were asked to attend a specially arranged session of 60 to 90 minutes for FGDs. Each FGD contained a minimum of 6 and a maximum of 12 participants. Verbal consent was sought before the interview.

Key Informants Interviews (KIIs)

A purposive sampling technique was used to select key informants, which were local government officials, including village leaders. A total of 12 KIIs were conducted in six villages from the three districts. The KIIs guide (Supporting file 3) was developed and pre-tested for ten farmers in a village far from the study area and adjusted accordingly before the actual data collection. The KII was used to explore the individual's knowledge and practices related to mycotoxin contamination. The KIIs guide was used to explore KAP regarding both pre- and post-harvest practices that lead to mycotoxin contamination. Discussions were recorded in a digital voice recorder after their verbal consent.

Statistical Analysis

Quantitative Data Analysis

The data was exported to MS Excel and analysed using SPSS version 20.0. (Armonk, NY: IBM Corp). The association between socio-demographic factors and study districts, as well as the association between socio-demographic factors and awareness regarding mycotoxins, was analysed using the Chi-square test. A *P* value of

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less than or equal to 0.05 was considered statistically significant.

Qualitative Data Analysis

The audio recorded FGDs interviews were transcribed into MS Word documents and translated into English by two independent researchers and compared for consistency. To improve interpretation reliability, the written transcripts were reviewed independently by the same two researchers for consistency of the transcripts with the audio files to ensure the accuracy of the transcribed files before their analysis. The analysis of the transcripts of the FGDs was carried out in ATLAS.ti 8 for Windows (Scientific Software Development GmbH, Berlin, 2019). The software permitted the data to be coded systematically. Qualitative data were then analysed using content and thematic analysis to identify emerging themes (Nyangi *et al.*, 2024).

RESULTS

Socio-Demographic Characteristics of the Respondents

The study included 266 respondents, 68% male and 32% female; the distribution varies considerably between districts. The main occupation of the majority (98.1%) was farming. While the main source of income for the majority of the resident's activities was farming 97.4%, followed by business 2.6%. The majority (74.1%) of the respondents had primary school education, while 8.3% had secondary school education and 15.8% with no formal education. The majority of the household heads were male and were from the Mbozi district (76.7%) (*Table 1*).

Table 1: Social demographic characteristics of respondents in the study areas (n=266)

	Variable	Mbarali n (%)	Sumbawanga n (%)	Mbozi n (%)	Total n (%)
Gender	Female	33 (37.9)	31 (34.8)	21 (23.3)	85 (32)
	Male	54 (62.1)	58 (65.2)	69 (76.7)	181 (68)
Education level	No formal education	16 (18.4)	14 (15.7)	12 (13.3)	42 (15.8)
	Primary school education	63 (72.4)	65 (73.0)	69 (76.7)	197 (74.1)
	Secondary school education	6 (6.9)	8 (9)	8 (8.9)	22 (8.3)
	Tertiary education	2 (2.3)	2 (2.2)	1(1.1)	5 (1.9)
Occupation	Farmers	85 (97.7)	87 (97.8)	89 (98.9)	261 (98.1)
	Business	2 (2.3)	2 (2.2)	1 (1.1)	5 (1.9)
Household position	Father	51 (58.6)	57 (64.0)	66 (73.3)	174 (65.4)
	Mother	33 (37.9)	31 (34.8)	23 (25.6)	87 (32.7)
	Child	3 (3.4)	1 (1.1)	1 (1.1)	5 (1.9)
The main source of income	Farming	84 (96.6)	87 (97.8)	88 (97.8)	259 (97.4)
	Business	3 (3.4)	2 (2.2)	2 (2.2)	7 (2.6)

Knowledge about Mycotoxin Transmission, Health Effects, And Prevention

In the assessment of knowledge about mycotoxins, 21.4% of the respondents had heard of the mycotoxin, with most of the respondents (20%) coming from the Mbozi district. While (13.9%) mentioned radio as the source of information, with the majority of respondents (35.5%) coming from Mbozi district. This was followed by 15.9% who mentioned agriculture extension officers as the source of information. The knowledge of mycotoxin transmission was very low, with only 16.9% of the respondents being aware of how human beings acquired mycotoxins. Sumbawanga district had most of the respondents (20.2%) with knowledge of transmission. Only 19.9% of the respondents were aware of the health problems mycotoxins cause to human beings, with all respondents saying that they had never become sick from eating contaminated food. Only 3.8% of the respondents were aware that mycotoxin contamination could be prevented in human beings, while only 14.3% were aware that mycotoxin contamination could be prevented in crops (*Table 2*).

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Qualitative data confirmed these findings in terms of the level of knowledge among the participants regarding mycotoxin transmission as well as awareness of the health effects as echoed during FGD from Sumbawanga district, who agreed that *They are not aware of how mycotoxins are transmitted to human beings, animals, and crops.*

The FGD from Mbarali district further agreed that:

> *"When a person gets stomachache or discomfort and goes to the village dispensary, what they do is just give them medicine for treating the stomach without any clinical diagnosis. So, this makes them not aware of what was the exact health problem they are facing. But they all agree that with a proper diagnosis, there is a possibility that stomach problems may be related to mycotoxin contamination of food."*

A community key informant said:

> *"I know about moulded maize but not aware that they may contain toxin, we were taught that they are not good for food, but we can use them for feeding animals" (KII, Village executive officer, Mbozi district).*

This was further echoed by a key informant, a health worker from one the village in Sumbawanga district, who was quoted saying that *"bad/moulded maize can lead to mycotoxins contamination to human being and animals".*

Regarding the sources of information on mycotoxin, FGD from Mbarali agreed that: They usually hear about mycotoxins through news media (radio) but are not aware of its health effects on community members and animals and that even the village government leaders are not aware of it. They further echoed that they only hear that mycotoxins can contaminate maize, groundnuts, and paddy, but they do not know their health effects on human beings. They have seen the moulded maize, but they do not know the cause.

The quotations mentioned above further suggest that the awareness of the health effects of mycotoxins and how mycotoxins are acquired by human beings and crops may be due to the knowledge farmers received from the health workers and other extension officers in their respective wards/villages. The influence of location on the knowledge regarding mycotoxins may also be linked to the economic status and activities of the population in the study districts, as well as different government and non-government organisations' interventions in their respective districts.

Table 2: Correct knowledge about mycotoxin transmission, health effects, and prevention in the study area.

Variables	Mbarali n(%)	Sumbawanga n (%)	Mbozi n (%)	Total n (%)	p-value
Heard of mycotoxins	21 (24.1)	18 (20.2)	18 (20.0)	57 (21.4)	0.754[ns]
How mycotoxins are acquired	11 (12.6)	18 (20.2)	16 (17.8)	45 (16.9)	0.392[ns]
Become sick after eating moulded/contaminated crops	0 (0)	0 (0)	0 (0)	0 (0)	
Human health problems due to mycotoxins	13 (14.9)	21 (23.6)	19 (21.1)	53 (19.9)	0.335[ns]
Animal health problems due to mycotoxin	8 (9.2)	13 (14.6)	10 (11.1)	31 (11.7)	0.525[ns]
Preventing crops from mycotoxin	12 (13.8)	12 (13.8)	14 (15.6)	38 (14.3)	0.913[ns]
Preventing humans from mycotoxins	6 (6.9)	1 (1.1)	3 (3.3)	10 (3.8)	0.127[ns]

All P-values are based on chi-square analysis of numbers across three Districts.
**Statistically significant at $p \leq 0.05$,*
ns = not statistically significant,
[a] No statistics are computed because sickness after eating contaminated crops is a constant.

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Attitude Toward Mycotoxins

With regard to attitude, 49.2% (p=0.002) of the respondents stated that it is not safe to eat contaminated food with mycotoxins, Mbarali had most of the respondents (66.7%) who said it is not safe to eat infected pork. Approximately 51.9% (p=0.930) were not aware of being at risk of being infected with mycotoxins, while only 8.4% agreed to be at risk. Approximately 15.4% (p<0.001) report discarding contaminated crops/food with mycotoxins, Mbarali had most of the respondents (18.4%) who report discarding contaminated crops/food (*Table 3*).

This was supported by qualitative data as narrated by a VHC in Sumbawanga district who agreed that it is not safe to eat moulded maize as it may not be safe, and it gives an odour flavour, making it not comfortable for human consumption. This was further supported by another FGD from Mbozi district, who agreed that they usually feed the moulded maize to animals instead of consuming them, although even sometimes the animals refuse to feed on the moulded maize especially when the contamination is heavy.

Another FGD from Sumbawanga *agreed that some of the farmers do not discard the moulded maize, instead, they usually mill and consume.* This practice should be discouraged, as there is a high possibility that the moulded maize may contain high levels of mycotoxins.

Qualitative data were further confirmed during KIIs as quoted from this statement from the agriculture extension officers from one the village in Sumbawanga village.

> *"I think they we are at risk because sometime people are preparing food from moulded maize, which is not 100% safe; this is usually practiced when the food is scarce, they also feed the highly moulded maize to animals mostly pigs and goats"* (KII, Sumbawanga district).

This was also echoed by one of the ward extension officers from Mbozi district who remarked: *"One of the risk factors is contaminated food; people are eating moulded maize which is not safe, and this can lead to mycotoxins infection in one or another way"* (KII, Mbozi district).

Table 3: Attitude toward mycotoxins in the study area.

Variables	Mbarali	Sumbawanga	Mbozi	Total
Are you at risk of getting mycotoxins? (χ^2=0. 862, DF=4, P=0.930)^{ns}				
Agree	7 (8.0)	8 (9.0)	6 (6.7)	21 (7.9)
Disagree	46 (52.9)	43 (48.3)	49 (54.4)	138 (51.9)
Neutral	34 (39.1)	38 (42.7)	35 (38.9)	107 (40.2)
Reporting to the agriculture extension officer when your crops are contaminated (χ^2=7.630, DF=4, P=0.106)^{ns}				
Agree	9 (10.3)	9 (10.1)	7 (7.8)	25 (9.4)
Disagree	58 (66.7)	43 (48.3)	52 (57.8)	153 (57.5)
Neutral	20 (23.0)	37 (41.6)	31 (34.4)	88 (33.1)
Is it safe to eat contaminated food (χ^2=16.679, DF=4, P=0.002)*				
Agree	9 (10.3)	13 (14.6)	12 (13.3)	34 (12.8)
Disagree	58 (66.7)	34 (38.2)	39 (43.3)	131 (49.2)
Neutral	20 (23.0)	42 (47.2)	39 (43.3)	101 (38.0)
Do you discard mycotoxin contaminated food (χ^2=30.962, DF=4, P<0.001)*				
Agree	16 (18.4)	10 (11.2)	15 (16.7)	41 (15.4)
Disagree	61 (70.1)	38 (42.7)	42 (46.7)	141 (53.0)
Neutral	10 (11.5)	41 (46.1)	33 (36.7)	84 (31.6)

All P-values are based on a chi-square analysis of numbers across two Districts.
**Statistically significant at p≤0.05,*
ns = not statistically significant

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Practices towards mycotoxins

Regarding practices, about 98.9% of the respondents were farmers, of which 66.8% were maize, followed by sunflower (19.4%) and groundnuts (13.3%). Approximately 88.3% (p=0.544) reported harvesting their crops when dry, with the majority of them coming from Mbozi district (91.7%). The most commonly used drying method was floor/ground, as reported by 81.2% of farmers, followed by mats (17.7%). Approximately 84.6% of respondents reported storing different crops in the same store, with the majority (87.6%) coming from the Sumbawanga district (*Table 4*).

Regarding the tillage method used, the FGD from Mbarali district echoed that:

> *"They usually till their land by using ox, hoes, and power tillers as they have no tractors in their village since it is costly. The farm is cleared by using slashers, machetes, and hoes. This is followed by seed planting in modern ways using ropes. The distance from one line to another should be one meter, while the distance from one maize crop to the next should be one foot. This is followed by the application of fertiliser (urea) to boost their growth, followed by weeding. The application of CAN fertiliser for the second time to continue boosting the plants' growth, followed by the second weeding and last application of Sulphate Ammonia (SA) fertiliser."*

This was further echoed by an FGD from Mbozi and Sumbawanga districts, who agreed that:

> *"They usually till the land before planting and that they are using fertiliser. They also plant with proper spacing, weed on time, and harvest their crops when fully matured and properly dry. The harvested crops are transported to their respective households where they are shelled and stored in sacks or mixed with insecticides/pesticides ready for storage."*

The above-mentioned practices are recommended pre- and post-harvest mitigation strategies and should be encouraged to farmers and consumers. The good knowledge of practices reported during FGDs and KIIs may be due to the knowledge farmers received from the agricultural extension officers, livestock field officers (LFO), and health workers in their respective wards/villages. The influence of location on the practices regarding mycotoxins may also be linked to the economic status and activities of the population in the study districts, as well as different government and non-government organisations' interventions in their respective districts.

This was confirmed by qualitative data as echoed by VEO from one of the villages in Sumbawanga district during a KII session who remarked:

> *"During the harvesting period, some families delay in harvesting waiting for the proper drying. Unfortunately, long waiting will cause the maize to be contaminated as a result of unexpected rainfall, this puts them at risk of consuming contaminated food with mycotoxins."* (KII, Mbozi district)."

This was further echoed by a KII from a village executive officer (VEO)

> *"When the crops are ready for harvesting, the rains continue, and sunlight is scarce. After the harvest, where proper sun drying is difficult to achieve and farmers are forced to put the grains in the house where space is limited. This usually led to maize become rotten. As the house is stuffed with cereal until farmers discover that the cereals have turned bad, they change colour, due to the weather they cannot be dried well, and the grains become moulded. (Key informant, VEO Mbozi)*

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Table 4: Practices towards mycotoxins (n=266)

Variables		Mbarali	Sumbawanga	Mbozi	Total
Do you cultivate crops? (χ^2=2.197, DF=2, P=0.333)^{ns}	Yes	86 (98.9)	89 (100)	89 (100)	264 (98.9)
	No	1 (1.1)	0 (0)	0 (0)	1 (1.1)
Crops cultivated	Maize	84 (66.1)	88 (62)	89 (73)	261 (66.8)
	Groundnuts	22 (17.3)	19 (13.4)	11 (9)	52 (13.3)
	Beans	2 (1.6)	0 (0)	0 (0)	2 (0.5)
	Sunflower	19 (15)	35 (24.6)	22 (18)	76 (19.4)
	Other crops (finger millet, rice paddy, Bambara nuts)				
What tillage methods are you using (χ^2=2.719, DF=4, P=0.606)^{ns}	None	3 (3.4)	1 (1.1)	5 (5.6)	9 (3.4)
	Hand hoe	22 (25.3)	24 (27)	23 (25.6)	69 (25.9)
	Ox	62 (71.3)	64 (71.9)	62 (68.9)	188 (70.7)
Do you harvest crops when dry/wet? (χ^2=3.084, DF=4, P=0.544)^{ns}	Wet	8 (13.4)	0 (0.0)	0 (0)	8 (4.5)
	Dry	49 (81.7)	54 (91.5)	55 (91.7)	155 (88.3)
	Don't know	3 (5)	5 (8.5)	5 (8.3)	13 (7.3)
What are the drying methods (χ^2=0.519, DF=4, P=0.971)^{ns}	Mats	14 (16.1)	15 (16.9)	18 (20)	47 (17.7)
	Floor/ground	72 (82.8)	73 (82)	71 (78.9)	216 (81.2)
	None	1 (1.1)	16 (1.1)	1 (1.1)	3 (1.1)
Do you sort crops before storage (χ^2=3.953, DF=2, P=0.139)^{ns}	Yes	43 (49.4)	57 (64.0)	53 (58.9)	153 (57.5)
	No	44 (50.6)	32 (36.0)	37 (41.1)	113 (42.5)
What is the use of defective/sorted crops (χ^2=2.418, DF=6, P=0.878)^{ns}	Animal feed	45 (51.7)	42 (47.2)	47 (52.2)	134 (50.4)
	Brew	4 (4.6)	8 (9.0)	7 (7.8)	19 (7.1)
	Human food	18 (20.7)	22 (24.7)	18 (20.0)	58 (21.8)
	Not sorting	20 (23.0)	17 (19.1)	18 (20.0)	55 (20.7)
Do you store different crops in the same store (χ^2=2.793, DF=2, P=0.247)^{ns}	Yes	69 (79.3)	78 (87.6)	78 (86.7)	225 (84.6)
	No	18 (20.7)	11 (12.4)	12 (13.3)	41 (15.4)

All P-values are based on a chi-square analysis of numbers across two Districts.
**Statistically significant at p≤0.05,*
ns = not statistically significant
mr= multiple response variables based on number of the responses

DISCUSSION

The survey was conducted to assess the respondents' knowledge, attitudes, and practices (KAP) on mycotoxin contamination and exposure to humans and animals. The majority of the respondents declare that they never heard of mycotoxin and do not know how mycotoxins are acquired. Surprisingly, all respondents responded that they never become sick after eating food prepared from moulded/contaminated crops; this may be because the symptoms of chronic exposure are difficult to detect. The majority of the respondents also showed low knowledge regarding human and animal health problems due to mycotoxin contamination and preventive measures for mycotoxin contamination on humans, animals, and crops (*Table 2*). The results were contrary to the findings from studies conducted in Tanzania, Kenya, and Pakistan (Nyangi *et al*., 2016; Mwihia *et al*., 2008; Naeem *et al*., 2018).

Mycotoxins are associated with several severe human and animal health conditions (Lewis *et al*., 2005; Jolly *et al*., 2007). In its acute stages, aflatoxicosis is associated with high fever, rapid progressive jaundice, oedema of the limbs, pain, vomiting, and swollen livers (Lewis *et al*., 2005; Bbosa *et al*., 2013). Whereas chronic aflatoxicosis has no clear symptoms and results from sustained exposure at sub-lethal doses and is characterised by suppression of immunity and nutritional status (Kimanya *et al*., 2010).

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With regard to the knowledge of how mycotoxins are acquired, the health effects on humans and animals, and risk factors associated with mycotoxins such as aflatoxins and fumonisins, the result indicates that most of the respondents showed low knowledge. This is comparable to the study which reported that a large number of people in both developing and developed countries are not aware of the risks associated with contaminated food and feed (Nyangi *et al*., 2016; Naeem *et al*., 2018; Sasamalo *et al*., 2018). The results are also comparable to those reported from a study conducted in Nigeria (Ityo *et al*., 2021) which reported a low level of knowledge of aflatoxin among groundnut retailers (<40%). Unlike microbial contaminants, mycotoxins often occur in doses far below those accountable for acute effects but may induce long-term conditions (such as cancer) (Ghazi *et al*., 2020), cause stunting, and depress immunity (Kimanya *et al*., 2010). Respondents could not link the health effects to mycotoxin exposure since these effects are long-term. It is noteworthy that Tanzania has the oesophageal cancer prevalence rate (9.2 per 100,000 people), which is the second highest cancer in Tanzania (IARC, 2024), this could be attributed to high dependence on maize as a staple food (Matumba *et al*. 2014). Dietary exposure to fumonisin is linked to oesophageal cancer (Marasas *et al*., 2008; Kimanya *et al*., 2010). Unfortunately, the current national efforts are solely focused on aflatoxins.

In this study, the respondents showed a general lack of awareness of the health effects associated with moulds and mycotoxins on humans and animals, as well as prevention measures (*Table 2*). This is comparable to a study conducted in Malawi (Matumba *et al*., 2016) and contrary to a study conducted in Malaysia (Azaman *et al*., 2016), which reported that the stakeholders have adequate knowledge, favourable attitude, and high hygiene practices towards aflatoxin contamination in peanut-based products with mean scores of 2.54, 4.27, and 2.61, respectively.

Regarding the attitude towards mycotoxins, the results indicated a poor attitude towards being at risk of getting mycotoxins, whether it is safe to eat contaminated food, and discarding the contaminated crops (*Table 3*). The results are contrary to those reported from a study conducted in Malaysia and Ethiopia (Azaman *et al*., 2016; Biru and Gemta, 2022), which reported a favourable attitude towards aflatoxin contamination in peanut-based products with mean scores of 4.27 and 4.16, respectively. The results are comparable to those reported from a study conducted in Pakistani (Naeem *et al*., 2018) and reported negative attitudes toward food safety awareness.

Mycotoxins development and production are highly dependent on environmental factors such as temperature, moisture content, humidity and pre- and post-harvest cultural practices (Milani, 2013; Nyangi *et al*., 2016; Sasamalo *et al*., 2018). Another common pre-harvest practice influencing mycotoxin contamination is the tillage method; it has been reported from several studies that the tillage method is one of the major management practices affecting soil physical parameters (Helgason *et al*., 2009; Janusauskaite *et al.*, 2013) as *A. flavus* and Fusarium inoculum sits on soil surface and jumps up to maize ears due to rain splash or wind, tillage will submerge this fungi/mould population and prevent them from contaminating grains or pods as cannot reach soil surface. This is because the quality of the soil highly depends on several factors, such as soil structure, natural productivity and human influence.

The respondents' practices were reported to be poor regarding crop drying methods and sorting before storage, with 50.4% of the respondents using the badly sorted crops as animal feed. The majority of the respondents were storing maize with other crops in the same storage (*Table 4*). The practice of drying maize on the bare ground may increase mycotoxin contamination. In this study, the majority of the farmers 81.2% (216/266) are drying their crops on top of the floor/ground. Several studies reported that drying maize on bare ground was found to have higher levels of aflatoxin contamination compared to drying on top of platform/mats (Kaaya *et al*., 2006; Atukwase *et al*. 2009; Kamala *et al*., 2016).

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However, the majority of the population in Tanzania are subsistent farmers/consumers, and a large proportion of houses in Tanzania are poorly maintained with a poor storage facility (URT, 2008), which unsurprisingly may also increase the risk of mould growth and mycotoxins contamination.

Farmers were found to store maize with other crops; this practice is associated with higher aflatoxin levels, as reported by Gill *et al*. (1983), who found that the aflatoxin contamination was higher in maize stored with other crops, the most common crops that are usually stored alongside maize, were finger millet, rice paddy, and Bambara nuts. These other crops may become infected with *A. flavus* in the field and lead to aflatoxin development during storage. Another poor practice reported during this study was sorting crops before storage, with 42.5% (113/266) of respondents not sorting their crops. Sorting out physically damaged and infected grains (based on their colouration, odd shapes, shrivelled, and reduced size) from the intact commodity was reported to reduce aflatoxin levels by 40-80% (Park, 2002).

Most mycotoxins are known to be generally thermally stable and are, therefore, not destroyed during most normal cooking processes (Kabak, 2009; Raters & Matissek, 2008). Regarding the effect of mouldy feedstuff on livestock, studies have shown that toxins consumed by livestock negatively affect productivity and may potentially be carried on into other animal products such as eggs, meat, and milk (Becker-Algeri *et al*., 2016; Flores-Flores *et al*., 2015). Therefore, the low knowledge of these facts demonstrated by some respondents in the current study shows that mycotoxins dietary exposure from associated foodstuffs is most likely.

Since the tropical conditions predominant in Tanzania favour the proliferation of fungi in crops, the risk of mycotoxin dietary exposure to these crops is likely to be high (Nyangi *et al*., 2016). It is, therefore, of vital importance that Tanzanians should be informed about achievable and easy-to-handle strategies for the control of fungal infection of crops (Nyangi *et al*., 2016).

CONCLUSION AND RECOMMENDATIONS

Overall, the study found low knowledge, attitude, and practices (KAP) in most of the aspects regarding mycotoxin contamination, prevention, and its effects on human and plant health as well as economic impact. These current findings call for holistic measures that will integrate the education interventions (creating awareness) into other existing control strategies. This will further support the development of a community-based health educational package (HEP) that can be locally adapted and used to create awareness of the control measures as well as the awareness of the health and economic impact of mycotoxin contamination. HEP will be used as one of the control strategies in combination with other available control strategies. The collected information will also help to inform the development of comprehensive national information, education, and communication (IEC) programs aimed at mycotoxins (aflatoxin and fumonisin) prevention and management. This will also ensure the delivery of safe products to both urban and rural consumers along the maize, and groundnut food and feed value chain.

Limitations

In general, this finding meets all food safety research methods based on the stated objective. However, the comprehensive knowledge collected during the household survey about mycotoxins was not confirmed by observation of household infrastructure. In survey studies, the respondents are likely to respond to questions in a socially desirable way. Without conducting household infrastructure observations, we were not able to confirm or discard some of the responses to the questionnaire. Another limitation was that a pilot study was only conducted in seven households due to logistic reasons and time constraints. Another limitation was that our questionnaire used pre-specified answers, which permitted the prediction of correct answers. However, this was controlled by using

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enumerators during the household survey. The trained and experienced enumerators asked questions without first revealing the possible answers. Another limitation was that the questionnaire was administered by two different people, but as answers were pre-specified, this may not have had a large effect. Mycotoxins were likely prevalent in the study villages, but as we did not investigate this, we were not able to establish the relationship between low or incorrect KAP and high prevalence of mycotoxins.

AUTHORS' CONTRIBUTIONS

Mr. Chacha Nyangi, Ms. Prisca Siyame & Dr. Zaharan Mgina (PhD); Conceptualization; Data collection; Investigation; Methodology; Validation; Writing-original draft; revision, rewriting, proofreading, editing, and submission of the article.

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Conflict Of Interest

The authors do not have any conflict of interest.

Data Availability

Data will be made available on request.

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