American Journal of Public Health Research, 2022, Vol. 10, No. 4, 134-142
Available online at http://pubs.sciepub.com/ajphr/10/4/1
Published by Science and Education Publishing
DOI:10.12691/ajphr-10-4-1

Knowledge, Awareness and Post-harvest Practices Predisposing Stored Maize to Aflatoxin Contamination in Morogoro Municipality and Makambako District, Tanzania

Fadhili Mabruki[1,*], Isaac Makundi[1], Benigni. A. Temba[2]

[1]Department of Microbiology, Parasitology and Biotechnology, College of Veterinary Medicine and Biomedical Science, Sokoine University of Agriculture, P.O BOX 3019, Morogoro, Tanzania
[2]Department of Veterinary Physiology, Biochemistry and Pharmacology, College of Veterinary Medicine and Biomedical Science, Sokoine University of Agriculture, P.O.BOX 3017,Morogoro, Tanzania
*Corresponding author: mabrukifadhili@gmail.com

Received May 17, 2022; Revised June 21, 2022; Accepted July 01, 2022

Abstract Aflatoxin contamination in maize by *Aspergillus* species negatively affects the quality of food, economy as well as human and animal health worldwide and is hence a globally growing public health problem. This study aimed at assessing knowledge and awareness on aflatoxins as well as post-harvest practices predisposing stored maize to aflatoxin contamination in Morogoro municipality and Makambako district, Tanzania. A semi-structured questionnaire was administered to 226 stakeholders who responded to questions assessing their knowledge and awareness on aflatoxins and practices predisposing stored maize to aflatoxin contamination. Analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS) version 16.0 was conducted to determine the statistical significance of the practices predisposing stored maize to aflatoxin contamination by comparison of means among the study groups. Descriptive statistical analysis was employed to describe knowledge and awareness of aflatoxin contamination among respondents. The results based on the assessment criteria revealed that majority (71%) of the studied population in the study areas had low knowledge and awareness in relation to aflatoxin contamination on stored maize. The results also revealed that some aspects of post-harvest handling of maize including storage with other crops, mode of storage and storage duration positively influenced infestation of aflatoxigenic fungi on the maize stored. We recommend the provision of appropriate education via seminars and workshops to the respective stakeholders to help increase their knowledge and awareness on aflatoxin contamination.

Keywords: *awareness, knowledge, Aflatoxins, maize, Tanzania*

Cite This Article: Fadhili Mabruki, Isaac Makundi, and Benigni. A. Temba, "Knowledge, Awareness and Post-harvest Practices Predisposing Stored Maize to Aflatoxin Contamination in Morogoro Municipality and Makambako District, Tanzania." *American Journal of Public Health Research*, vol. 10, no. 4 (2022): 134-142. doi: 10.12691/ajphr-10-4-1.

1. Introduction

Aflatoxins are a group of mycotoxins commonly produced by two species of fungi namely *Aspergillus flavus* and *Aspergillus parasiticus* [1]. Under favourable climatic conditions particularly temperature and humidity, the species can grow and produce aflatoxins on wide range of agricultural products including maize [2]. Studies conducted by [3] and [4] reported that contamination by aflatoxins can occur at either the pre-harvest or post-harvest stages. Aflatoxin contamination may start in the field or during storage of maize and result into crop inedibility [5]. Currently aflatoxin contamination on agricultural commodities has gained global attention due to various deleterious effects that it has on human and animal health.

Negative effects of the toxins on human and animal health include; liver and kidney infections, immuno-suppression, mutagenesis, teratogenesis and carcinogenesis [4,5]. Chronic exposure to high levels of aflatoxin can cause various clinical problems such as bile duct proliferation (BDP), edema, anorexia, hepatitis, kidney malfunctioning, acute jaundice and fatigue, all of which may subsequently result into death of the individual [4,6]. Currently, it is estimated that about 25% of the world's crops are affected by aflatoxins and over 5 million people worldwide are at risk of chronic exposure to uncontrolled aflatoxins in their diet annually [5]. A study conducted by [7] reported that about 26,000 Africans living in Sub-Saharan countries die annually from a liver cancer associated with aflatoxin exposure. In Tanzania, recently conducted studies in Kilimanjaro, Iringa and Tabora regions showed that about 40% of children under five

years have stunted growth as a result of consuming food, mainly aflatoxin-contaminated maize [8,9]. Another study conducted by [8] reported the latest outbreak of aflatoxicosis with significant mortalities Tanzania in 2016.

Maize is an important staple food crop grown in all regions of Tanzania. In the country, the crop is used as a source of income to reduce poverty and ensure food security in various regions [10]. The crop is susceptible to fungal contamination during production and storage stages resulting to aflatoxins production [5]. The contamination of this crop by aflatoxins makes it undesirable for consumer health consequently suppressing economic opportunities by preventing its producers from accessing the international market [5]. Despite the efforts done by the Tanzanian government to combat this problem, the nation still faces challenges of post-harvest losses of maize during the storage period. Literature shows that practices including improper drying, famers' production practices, storage of the crop with other aflatoxin infected grains, pre and post-mature harvest as well as poor construction of storage structures are positively influencing fungal infestation and subsequent aflatoxin contamination on maize [11,12]. Literature also shows that other favourable climatic conditions particularly high relative humidity and temperature also favour fungal infestation and aflatoxin contamination on the crop [4,6]. Furthermore, [13] reported that high levels of aflatoxin contamination on stored maize is a result of low knowledge and awareness among the farmers, traders and consumers in relation to the toxins. This study was therefore conducted to determine the influence of post-harvest practices predisposing stored maize to aflatoxin contamination as well as the knowledge and awareness of the stakeholders in relation to this problem in Morogoro municipality and Makambako district. The output of this study will help to design and implement good maize storage practices with the aim of reducing aflatoxin contamination on stored maize.

2. Materials and Methods

2.1. Study Area

The study was carried out in six study sites (wards) selected from two study areas; three out of these were Kihonda, Uwanja wa Taifa and Kingo from Morogoro municipality in Morogoro region while the other three were Mwembetogwa, Mjimwema and Utengule from Makambako district in Njombe region. The wards were selected randomly based on the presence of maize wholesalers, storage facilities as well as their owners and personnel to maximize the chances of obtaining required information.

Morogoro municipality is one of the six districts of Morogoro region, it is the region's headquarters covering an area of 531 km^2 with a population of 396,481 according to population projection 2019. The municipality is located at about 195 kilometres West of Dar es Salaam and situated on the lower slope of Uluguru Mountains whose peak is about 1600 feet above the sea level [14]. The municipality lies at the crossings of longitudes 37°33' and 37°51'East of the Greenwich Meridian and between latitudes 6°37' and 6°55' South of the Equator. It is characterised by an annual average temperature ranging between 16°C to 28°C in the cold dry season and 21°C and 33°C in the warm wet season. The municipality receives average annual rainfall ranges between 821mm and to 1505mm [14]. The average relative humidity is 63-83% in March through May and 46-82% from July to September. The major economic activities in Morogoro municipality include primary and secondary industrial activities, commercial farming, small-scale enterprises and commercial wholesale and retail [14].

Makambako district is one among the six districts in Njombe region located at a junction between Njombe, Iringa and Mbeya region. The district lies approximately 40 miles North of the district capital of Njombe. The district is bordered by Mufindi, Njombe and Wanging'ombe districts in the North and East, South and West respectively [15]. It lies at the crossings Longitudes 33°05' and 35°08' East of the Greenwich Meridian and Latitude 8°08' and 9°08' South of the Equator. The district covers an area of 884km^2 with a population of 93,827 according to the 2012 Tanzania Nation Census (TNC) [15]. The district displays an annual temperature range between 15°C-25°C and experiences mild and sunny weather throughout the year, with maximum temperatures observed in September and December while minimum temperatures occur in June and August when the temperatures fall to 15°C. The rainy season starts between October and November and ends in March and April with an annual average rainfall range between 600 and 1000mm [15]. The average relative humidity is 80-91% in March through June and 58-75% from July to October. The major economic activities in Makambako district are agriculture and trade [15].

2.2. Study Design

This Study was conducted in different wards of Morogoro municipality and Makambako district in Tanzania between March and May 2021. A cross-sectional study design was adopted in this study. A simple random sampling technique was employed to administer questionnaires to respondents. A questionnaire was administered to maize wholesalers and storage facility owners and personnel to obtain relevant information regarding their knowledge and awareness on aflatoxin as well as factors predisposing stored maize to aflatoxin contamination.

2.3. Sample Size Determination

The sample size for the study was determined based on previously established prevalence by [9] using the formula; $n= [Z^2 P (1-P)]/ d^2$ .Whereby; n = Sample size, Z= Statistic for level of confidence (1.96 at confidence level of 95%), P= Expected prevalence (18% based on the study conducted by [9]), d= Precision (5%). Therefore; n=1.96x1.96 x0.18 (1-0.18)/ 0.05 x 0.05= 226. Therefore, the sample size required for respondents involved in questionnaire data from all six wards was 226.

2.4. Selection of Maize Wholesalers, Storage Facility Owners and Personnel

The maize wholesalers as well as storage facility owners and personnel eligible for participation in this study were randomly selected. The selection was based on information provided by District Agriculture and livestock Officers and Ward Executive Officers in the respective study areas. A verbal consent was obtained from the participants prior to questioning.

2.5. Assessment of Knowledge, Awareness and Factors Predisposing Aflatoxin Contamination to Stored Maize

A semi-structured questionnaire was administered to collect information related to knowledge, awareness and factors predisposing stored maize to aflatoxin contamination. The questionnaire was administered to seven maize wholesalers obtained by random sampling from Sabasaba ward in Morogoro municipality as a pilot prior to data collection. This pretesting was conducted to ascertain validity of the questions.

A total of 226 respondents including maize wholesalers, storage facility owners and personnel were selected randomly in all the six wards from the two study areas. Out of these, 113 respondents came from Morogoro municipality while the remaining others were from Makambako district. A semi-structured questionnaire prepared in English and translated to Kiswahili, and containing both open and closed ended questions was administered. Each question in the questionnaire was read to those who were not able to read and answer the questions on their own and their response was recorded. The questionnaires assessed respondents' general knowledge and awareness on aflatoxins as well as crucial factors predisposing stored maize to aflatoxin contamination. Some of the significant factors assessed included storage method, storage treatments, length of storage, storage with other crops and sorting practices.

2.6. Statistical Analysis

The data were analysed using Statistical Package for Social Sciences (SPSS) version 16.0. Prior to analysis, the data were verified, coded and stored in form of a spreadsheet using Ms Excel 2013. Analysis of variance (ANOVA) was used to determine the statistical significance of responses to the factors predisposing stored maize to aflatoxin contamination by comparison of means among the respective study groups. Descriptive statistical analysis was used to describe respondents' knowledge and awareness on aflatoxins.

3. Results

3.1. Socio-demographic Characteristics of the Respondents

A total of 226 respondents from all wards were interviewed. Half of these were interviewed from three wards of Morogoro municipality while the remaining half of respondents were interviewed from three wards of Makambako district. Among the respondents 69.9% respondents were men while 30.1% were women. Age of the respondents ranged from 20 to 67 years with average of 37.6 years. Based on three-selected age categories, the largest proportion (47.3%) of these respondents were between 31 to 45 years old followed by ones between 18 to 30 years old (37.2%) while those with over 46 years old (15.5%) formed the smallest proportion. Education of the respondents ranged from non-formal education to various levels of formal education where 49.6% of the respondents had primary education level, 41.6% had secondary education, 3.5% had college education level and the rest of the respondents (5.3%) had not attended any formal education (Table 1).

3.2. Post-harvest Maize handling and Storage Practices

The main modes of storage identified in all wards were polypropylene sack storage and floor storage while the most common storage mode was the polypropylene sack storage. Majority (99.6%) of the respondents stored their maize grains using polypropylene sacks while the remaining (0.4%) of the respondents stored their maize directly on the floor (Table 2).

Table 1. Socio-demographic characteristics of the respondents

Characteristics	Surveyed Wards N (% of the respondents)						
	Uwanja wa Taifa	Kihonda	Kingo	Mjimwema	Mwembetogwa	Utengule	Total
Sex							
Male	27(17.1)	33(20.9)	25(15.8)	26(16.5)	23(14.6)	24(15.2)	158
Female	12(17.6)	6(8.8)	10(14.7)	15(22.1)	15(22.1)	10(14.7)	68
Age categories							
18-30	16(19)	17(20.2)	15(19.7)	15(17.9)	14(16.7)	7(8.3)	84
31-45	10(9.3)	21(19.6)	13(12.1)	24(22.4)	19(17.8)	20(18.7)	107
46 and above	13(37.1)	1(2.9)	7(20)	2(5.7)	5(14.3)	7(20)	35
Education Level							
Non-formal	3(25)	4(33.3)	5(41.7)	–	–	–	12
Primary	23(20.5)	17(15.1)	16(14.3)	22(19.6)	12(10.7)	22(19.6)	112
Secondary	11(11.7)	16(17)	12(12.8)	17(18.1)	26(27.7)	12(12.8)	94
College	2(25)	2(25)	2(25)	2(25)	–	–	8

Table 2. Storage practices used by respondents to store Maize in Warehouses

Practices	Surveyed Wards N (% of the respondents)						
	Uwanja wa Taifa	Kihonda	Kingo	Mjimwema	Mwembetogwa	Utengule	Total
Storage mode							
Floor storage	–	–	1(100)	–	–	–	1
Sack storage	39(17.3)	39(17.3)	34(15.1)	41(18.2)	38(16.9)	34(15.1)	225
Open field storage	–	–	–	–	–	–	–
Hermatic storage	–	–	–	–	–	–	–
Drying method							
Bare ground	4(80)	1(20)	–	–	–	–	5
Mats/Tarpaulin	35(15.8)	38(17.2)	35(15.8)	41(18.6)	38(17.2)	34(15.4)	221
Platform	–	–	–	–	–	–	–
Smoking	–	–	–	–	–	–	–
Other method	–	–	–	–	–	–	–
Sorting							
Yes	23(14.8)	30(19.4)	20(12.9)	28(18.1)	36(23.2)	18(11.6)	155
No	16(22.5)	9(12.7)	15(21.1)	13(18.3)	2(2.8)	16(22.5)	71
Grains treatment							
Pesticides	39(17.3)	39(17.3)	35(15.5)	41(18.1)	38(16.8)	34(15)	226
Smoking	—	–	–	–	—	—	–
Others	–	–	–	–	–	–	–
Storage with other crops							
Yes	5(11.6)	22(51.2)	2(4.7)	3(6.9)	11(25.6)	–	43
No	34(18.6)	17(9.3)	33(18)	38(20.8)	27(14.8)	34(18.6)	183
Storage duration							
< 1month	–	5(16.7)	12(40)	7(23.3)	6(20)	–	30
1 to 3 months	11(20.4)	8(14.8)	9(16.6)	10(18.5)	11(20.4)	5(9.3)	54
3 to 6 months	28(19.7)	26(18.3)	14(9.9)	24(16.9)	21(14.7)	29(20.4)	142
6 to 9 months	–	–	–	–	–	–	–
9 to 12 months	–	–	–	–	–	–	–
> 12 months	–	–	–	–	–	–	–

Majority (97.8%) of the respondents dried their maize on tarpaulin/mats while the rest (2.2%) dried their maize on bare ground. Sorting was another postharvest handling measure practised by the respondents in all wards. This study revealed that majority (69%) of the respondents sorted their maize manually by removing undesired grains considering coloration, size and physical damage before storage while (31%) of them did not. It was also observed that drying and sorting were conducted simultaneously before packing the maize grains into sacks (Table 2).

The results show that stored grains in all warehouses were chemically treated with pesticides before being introduced into storage facilities (Table 2). It was reported that the pesticides were applied once prior to storage or more than once in few cases depending on the length of the storage and the extent of pest infestation. Maize was stored together with other crops in all warehouses all wards except in Utengule ward in Makambako district where no single warehouse reported to practice combined storage of maize and other crops. The crops that were commonly stored with maize in warehouses included rice and beans (Table 2).

Duration of storing maize in the warehouses varied among the respondents with majority (62.8%) of the respondents reporting to store for 3 to 6 months, 23.9% of the respondents for 1 to 3 months and the rest (13.9%) of the respondents reported to store their maize for less than one month (Table 2).

Seventy seven percent of the respondents reported to carry regular maintenance of the grains storage warehouses while the rest (23%) did not have a tendency for regular maintenance. Furthermore, all respondents reported to ensure that the maize stored in warehouses was as clean and dry as possible (Table 3).

Table 3. Respondent's responses on condition of building and state of stored maize

Variable	Surveyed Wards N (% of the respondents)						
	Uwanja wa Taifa	Kihonda	Kingo	Mjimwema	Mwembetogwa	Utengule	Total
Routine maintenances							
Once every 3 months	1(50)	–	–	–	1(50)	–	2
Once every 6 months	–	3(27.3)	1(9.1)	2(18.2)	3(27.3)	2(18.2)	11
Once per year	7(25)	2(7.1)	2(7.1)	2(7.1)	5(17.9)	10(35.7)	28
Whenever necessary	22(16.5)	19(14.3)	20(15)	27(20)	26(19.5)	19(14.3)	133
Never done	9(17.3)	15(28.8)	12(23.1)	10(19.2)	3(5.7)	3(5.7)	52
State of stored maize grains							
Clean	26(24.1)	21(19.4)	16(14.8)	16(14.8)	15(13.9)	14(13)	108
Spoilage	–	–	1(25)	2(50)	1(25)	–	4
Dried	13(11.4)	18(15.8)	18(15.8)	23(20.2)	22(19.3)	20(17.5)	114
Moist	–	–	–	–	–	–	–

3.3. Knowledge and Awareness of the Respondents on Aflatoxin Contamination in Stored Maize

Twenty nine percent of the respondents were aware of the culprit of aflatoxin in maize while 71% of the respondents were not aware of fungi causing aflatoxins contamination in crops (Table 4).

Majority (63.3%) of the respondents had never heard about mycotoxins. Among the ones who knew about mycotoxins, 30% got information from friends and 28.9% from mass media while the rest got the information from other sources (Table 5). Knowledge on mycotoxins among respondents was mainly assessed based on their score on the only open-ended question that inquired on understanding of aflatoxins. According to their response, majority (67.7%) had no understanding on aflatoxins, 19.9% had little understanding and 12.4% of the respondents had high understanding on the aflatoxin (Table 6). The results also showed that majority (69%) of the respondents were not aware of the aflatoxin contamination on maize during storage while the remaining (31%) of the respondents were aware of this phenomenon. In addition, 23.5% of the respondents were aware on the ill-health effects of aflatoxins in human beings and animals while 76.5% of the respondents were not (Table 5).

Respondents were asked whether they were able to identify the presence of fungal growth on cereal crops. Majority (66.8%) of the respondents were not able to identify the presence of fungal growth on cereals crops. Colour of the grains, spoilage and presence of mould on grains were major features considered by the respondents for identification of fungal presence in cereal grains. However, among the 33.2% (75 respondents) who were able to identify the presence of fungal growth based on the mentioned features, only 36% (27 respondents) of them responded correctly while 64% (48 respondents) did not. The results also showed that 67.3% of the respondents did not know the conditions which favour the growth of aflatoxin producing fungi, while 31% of them were aware (Table 7).

Table 4. Responses on type of pathogen causing aflatoxin contamination in crops

	Surveyed Wards N (% of the respondents)						
	Uwanja wa Taifa	**Kihonda**	**Kingo**	**Mjimwema**	**Mwembetogwa**	**Utengule**	**Total**
Pathogens							
Fungi	14(21.5)	8(12.3)	10(15.4)	9(13.8)	15(23.1	9(13.8)	65
Parasite	2(66.7)	–	–	1(33.3)	–	–	3
Bacteria	–	1(100)	–	–	–	–	1
Virus	1(50)	1(50)	–	–	–	–	2
Don't know	22(14.2)	29(18.7)	25(16.1)	31(20)	23(14.8)	25(16.1)	155
Total	**39**	**39**	**35**	**41**	**38**	**34**	**226**

Table 5. Respondent's awareness on aflatoxins contamination on crops

Variable	Surveyed Wards N (% of the respondents)						
	Uwanja wa Taifa	**Kihonda**	**Kingo**	**Mjimwema**	**Mwembetogwa**	**Utengule**	**Total**
Heard of aflatoxins							
Yes	21(25.3)	13(15.7)	14(16.7)	11(13.3)	15(18.1)	9(10.8)	83
No	18(12.6)	26(18.2)	21(14.7)	30(20.9)	23(16.1)	25(17.5)	143
Source of information							
School	1(16.7)	2(33.3)	2(33.3)	–	1(16.7)	–	6
Social media	3(25)	1(8.3)	2(16.7)	1(8.3)	3(25)	2(16.7)	12
Mass media	3(12.5)	3(12.5)	4(16.7)	7(29.2)	6(25)	1(4.2)	24
Friends	6(24)	6(24)	4(16)	3(12)	4(16)	2(8)	25
Other sources	7(43.8)	1(6.3)	2(12.5)	1(6.3)	1(6.3.)	4(25)	16
Aware of the aflatoxin contamination during storage							
Yes	18(25.4)	6(8.6)	11(15.7)	11(15.7)	15(21.4)	9(12.9)	70
No	21(13.5)	33(21.2)	24(15.4)	30(19.6)	23(14.7)	25(16)	156
Aware of the ill-health effects of aflatoxins							
Yes	5(9.4)	7(13.2)	6(11.3)	11(20.8)	15(28.3)	9(17)	53
No	34(19.7)	32(18.5)	29(16.8)	30(17.3)	23(13.3)	25(14.5)	173

Table 6. Respondents' responses on understanding of aflatoxins

Surveyed Wards	Understanding on aflatoxins N (% of the respondents)			
	Poor	**Moderate**	**High**	**Total**
Uwanja wa Taifa	22(56.4)	11(28.2)	6(15.4)	39
Kihonda	30(76.9)	4(10.3)	5(12.8)	39
Kingo	22(62.8)	7(20)	6(17.2)	35
Mjimwema	31(75.6)	8(19.5)	2(4.9)	41
Mwembetogwa	23(60.5)	10(26.3)	5(13.2)	38
Utengule	25(73.5)	5(14.7)	4(11.8)	34
Total	**153(67.7)**	**45(19.9)**	**28(12.4)**	**226**

Poor= Respondents scored marks below 6
Moderate= Respondents scored marks ranged between 6.1 to 10.9
High= Respondents scored marks ranged between 11 to 15

Table 7. Respondent's perceptions on fungi that produce aflatoxins

Variable	Surveyed Wards N (% of the respondents)						
	Uwanja wa Taifa	Kihonda	Kingo	Mjimwema	Mwembetogwa	Utengule	Total
Can identify the presence of fungi in cereal by your naked eyes							
Yes	18(24)	11(14.7)	10(13.3)	12(16)	15(20)	9(12)	75
No	21(13.9)	28(18.5)	25(16.6)	29(19.2)	23(15.2)	25(16.6)	151
Features that ascertain presence of fungi in food							
Colour	6(40)	4(26.7)	1(6.7)	2(13.3)	1(6.7)	1(6.7)	15
Spoilage	2(20)	2(20)	2(20)	1(10)	2(20)	1(10)	10
Mouldy	1(4.3)	3(13)	2(8.7)	5(21.7)	9(39.1)	3(13)	23
All the above	9(30.7)	2(7.7)	5(19.2)	4(15.3)	3(11.5)	4(15.3)	27
Conditions which favours growth of fungi that produce aflatoxins							
Moisture and high temperature	17(24.3)	10(14.3)	10(14.3)	10(14.3)	14(20)	9(12.9)	70
Dust and very cold	–	–	–	1(100)	–	–	1
All the above	1(50)	–	–	–	1(100)	–	2
Don't know	21(13.7)	29(18.9)	25(16.3)	30(19.6)	23(15)	25(16.3)	153

Table 8. Assessment of knowledge and awareness based on desired response

Awareness/Aspects	Question number	Desired response	Percentage
Existence of aflatoxins	18	Yes	36.7
Knowledge regarding aflatoxins	19	High	12.4
Awareness the aflatoxin contamination on maize	21	Yes	31
	23	Yes	23.5
Pathogen responsible for aflatoxin contamination	22	Fungi	28.8
Ability to identify fungal presence	24	Yes	33.2
Features exhibiting fungal contamination on food	25	All the above	36
Conditions favouring fungal growth	26	Moisture and conducive temperature	31
Mean			29.075

The mean percentage of scores regarding the knowledge and awareness was the final result interpreted in the assessment. Knowledge and awareness of the respondents on aflatoxin contamination in crops was considered either low or high if the mean score was less or more than 50% respectively. In this case, the mean scores of 29.1% reflected that majority of the respondents in Morogoro municipality and Makambako district had low knowledge and awareness regarding aflatoxin contamination in stored maize (Table 8).

4. Discussion

The current study reports that majority of individuals (69.9%) partaking in storing and selling of maize as an economic activity are men. These results are in line with findings of another study by [16] who reported that majority (89%) of people involved in storing maize in Kongwa district, central Tanzania were men. This implies that the cultural practices and local customs in many Tanzanian communities exclude women from ownership of assets as well as limit them from engaging in some economic activities. Age group is an important factor in social analysis since different age groups perform variety of activities as described by [17]. This study indicates that (47.3%) of storage facilities owners and workers are aged between 31 to 45 years old. According to United Nation's Convention on the Rights of the Child (UNCRC) (1989), a person with $\geq$ 18 years of age is responsible for his/her own decisions [18], and hence involvement in appropriately age grouped works as adhered to legal standards. Furthermore, nearly half (49.6%) of the respondents had primary education level which might be not adequate for attaining optimum awareness and knowledge compared to those with higher education [13]. The results are in line with findings of [16] which indicated that majority of the farmers had primary education level. This implies that the low level of education among the respondents hinders implementation of good storage practices and prevention of aflatoxins contamination in crops in the surveyed area [13].

Based on the findings of this study, sack and floor storage were major modes of maize storage used in warehouses. Majority (99.6%) of respondents store maize in sacks and the rest store them on open floor. This finding is similar to the one reported by [13, 19] who also found that majority of the farmers in various parts of Tanzania stored their maize and groundnuts in sacks. The sack storage mode is the most commonly practiced mode probably due to affordability of the polypropylene (POP) sacks and their capacity to protect crops from pests like rodents and insects. However, a study conducted by [16] in Dodoma, Tanzania reported that POP sacks facilitated the infestation of *Aspergillus* species and aflatoxin contamination in stored maize compared to Purdue improve crop storage (PICS) bags. Similarly, the study conducted by [12] in Kaiti district, Kenya, found that there was a high prevalence of *Aspergillus* species and aflatoxins contamination in maize stored in POP sacks compared to PICS bags. On the other hand, POP sacks retain moisture and are impermeable to free air circulation within them and hence facilitate growth of aflatoxigenic moulds on the stored grains; PICS bags are able to reduce chance of aflatoxins contamination in stored crops by 55% as reported by [12]. Based on the results of this study, it was revealed that majority of respondents dry their maize prior to packaging into sacks and storing in warehouses.

Furthermore, it was observed that the method used by most of the respondents to dry their maize was spreading them on tarpaulin sheets or bare ground. This was similarly reported by [20] in Uganda that the practice of drying maize on tarpaulin and bare ground was mostly employed by maize wholesalers before storing the crop. Proper drying of crops prior to storage minimizes chances of fungal infestation and hence prevents consequent aflatoxins contamination [21,22]. Although drying of maize helps in reducing aflatoxins contamination on maize, unlike using tarpaulin, spreading on bare ground might increase aflatoxin contamination risks from infection by fungal spores exposed to the maize dried on the soil [23]. Regarding the sorting practice, this study found that majority of the respondents (69%) sorted their maize before storing them in warehouses, similar findings were reported from other studies conducted in various parts of Tanzania by [13,16]. [8] reported that sorting reduces the rate of aflatoxin contamination in maize, it was also reported by [21] in Nigeria that there was a higher level of aflatoxin contamination in unsorted maize compared to sorted ones. Furthermore, [21] reported that the sorting practice reduced the levels of aflatoxin contamination in grains by 40%-80%.

Treating maize, especially with pesticides was reported by almost all respondents; similar findings were reported by [13,24]. Treating of maize with pesticides before storage is related to lower levels of aflatoxin contamination in maize [25,26]. Furthermore, [26] reported that the use of pesticides in maize has a significant effect on reducing the infestation of aflatoxigenic fungi by 70%. Based on the results of this study, maize is stored together with other crops particularly rice and beans in all wards in Morogoro, whereas such practice was observed in only two wards from Makambako district. Storing maize with other crops is a common practice and has been reported also by [27] who reported that majority of local farmers in Dodoma and Manyara regions stored their maize together with sunflower seeds and beans. This implies that majority of agricultural stakeholders in the country are unaware of risk of increasing the chances of aflatoxin contamination in maize when the crop is stored with other crops as reported in several other studies including that conducted by [13,24]. Majority of the respondents (62.8%) reported to store maize for 3 up to 6 months while the rest store for less than three months. Similarly, studies by [16,24] reported the same scenario in various parts of Tanzania. This fact could be influenced by the tendency of farmers and traders to store crops for long time and await the rise of prices during off season. Prolonged storage has been associated with aflatoxin contamination in maize [28].

This study also found that majority of storage facilities were routinely maintained with varying intervals annually. Studies reported by [29,30] showed that poor conditions of storage facilities resulting to floor and roof leakages may influence aflatoxins contamination in stored crops as they favour infestation and survival of aflatoxigenic fungi. Furthermore, a study carried by [25] in Benin, reported that prolonged usage of stores without maintenance amplifies the risk of stored crop infestation with fungal species that produce aflatoxins. This study found that more than half of the respondents (71.2%) were ignorant of the type of pathogens causing aflatoxins contamination in crops. However, this finding is in contrast to the finding from another study conducted in Ibadan, Nigeria by [31] who found that majority (92.8%) of the health workers were aware of the pathogen that produces aflatoxins in groundnuts. This implies that great variation in education level between respondents from the two nations (Tanzania and Nigeria) could be the reason influencing the varying awareness of respondents on the pathogen causing aflatoxin contamination between the two countries. This study found that over half of the respondents (63.3%) had never heard about aflatoxins contamination in crops. This finding goes in line with the findings of other studies conducted by [24] in Tanzania and [32] in Ethiopia who also found that over half of the respondents had never heard about aflatoxins. Furthermore, there was variation on the level of understanding among those who had heard about aflatoxins. This finding is closely related to the finding of another study conducted by [24] who found that there was variation on the understanding of mycotoxins among the maize local farmers and traders. This implies that the education level of respondents is relatively low and could reflect inadequate dissemination of information on aflatoxins by the responsible sectors.

More than half of the respondents (69%) in the study were unaware of the aflatoxins that contaminate maize during storage. This finding is similar to the findings of other studies conducted in Tanzania by [24,33] who found that majority of the stakeholders (farmers, traders and consumers) were unaware of the aflatoxins that contaminate crops. This unawareness might be positively influencing aflatoxins contamination on crops in many regions of the country as little attention is given to proper handling and good storage practices as reported by [8]. In relation to awareness of ill health effects of aflatoxins, this study found that 76.5% of the respondents were not aware of the ill health effects of aflatoxins in humans and animals. This finding is comparable to the finding of the study conducted in Dar es Salaam, Tanzania by [33] who reported that about 94.9% of the spice traders were not aware on the ill-health effects of aflatoxins to humans. This implies that the health status of consumers unaware of aflatoxin contamination in the study areas and different parts of the African continent is highly risked to aflatoxins exposure, as they are most likely to neglect safety and protective measures.

This study indicated that over 60% of the respondents were unable to identify the presence of fungi on cereal crops and were unaware of the conditions which favour the growth of fungal species on such crops. This finding is in line to the finding of a study by [32] who found that over 50% of the farmers and trades in Uganda were unaware of the conditions that favour growth of mycotoxigenic fungi in poultry feed. This implies that storage facility owners and personnel are at risk of introducing contaminated maize into storage facilities due to their inability to notice and recognize the presence of the fungi in such maize prior to storage.

5. Conclusion and Recommendation

Results obtained showed that some of the aspects including storage mode, nature of storage (alone /with

other crops), storage duration and condition of the storage building significantly influenced aflatoxin contamination on the stored maize. The study also indicated that respective stakeholders in Morogoro municipality and Makambako district had low knowledge and awareness regarding aflatoxin contamination on stored maize. Therefore we recommend that the improvement of several practices including sorting, construction of storage structures, use of appropriate storage fungicides and optimum storage duration should be observed by respective stakeholders to reduce fungal infestation and aflatoxin contamination in stored maize. Furthermore the respective stakeholders should be provided with adequate education on mycotoxins contamination on agricultural products. This will make stored maize grains less susceptible to fungal infestation and aflatoxins contamination thereby ensuring the safety of the consumers.

Funding

This study was Self-funded.

Conflict of Interest

The authors declare that they had no competing interests.

Acknowledgments

The authors are highly grateful to the authority of the Sokoine University of Agriculture for their support in doing this research. Authors also express sincere thanks to people who helped in the execution of this study, particularly the Staff members of the Department of Microbiology, Parasitology and Biotechnology of Sokoine University of Agriculture, Morogoro, Tanzania.

References

[1] Wacoo, A. P., Wendiro, D., Vuzi, P. C. and Hawumba, J. F., 2014. Methods for Detection of Aflatoxins in Agricultural Food Crops. *Journal of Applied Chemistry*. 2014: 1-15.

[2] Adejumo, T. O. and Adejoro, D. O., 2014. Incidence of aflatoxins, fumonisins, trichothecenes and ochratoxins in Nigerian foods and possible intervention strategies. *Food Science and Quality Management Journal* 31: 127-146.

[3] Darwish, S. W., Ikenaka, Y., Nakayama, S. M. M. and Ishizuka, M., 2014. An Overview on Mycotoxin Contamination of Foods in Africa. *Journal of Veterinary Medicine Science* 76(6): 789-797.

[4] Odhiambo, B. O., Murage, H. and Wagara, I. N., 2013. Isolation and characterisation of aflatoxigenic Aspergillus species from maize and soil samples from selected counties of Kenya. *African Journal of Microbiology Research* 7(34): 4379-4388.

[5] Wu, F., 2015. Global impacts of aflatoxin in maize: trade and human health. *World Mycotoxin Journal* 8(2): 137-142.

[6] Eshetu, E., Habtamu, A. and Gebretensa, A., 2016. An overview on major mycotoxin in animal: its public health implication, economic impact and control strategies. *Journal of Health, Medicine and Nursing* 25: 64-73.

[7] Unnevehr, L. and Grace, D. (2013). *Aflatoxins: Finding Solutions for Improved Food Safety*. Focus No. 20. International Food Policy Research Institute, Washington DC. 62pp.

[8] Kamala, A., Kimanya, M., De Meulenaer, B., Kolsteren, P., Jacxsens, L., Haesaert, G. and Lachat, C., 2018. Post-harvest interventions decrease aflatoxin and fumonisin contamination in maize and subsequent dietary exposure in Tanzanian infants: cluster randomised-controlled trial. *World Mycotoxin Journal* 11(3): 447-458.

[9] Seetha, A., Munthali, W., Msere, H. W., Swai, E., Muzanila, Y., Sichone, E. and Okori, P., 2017. Occurrence of aflatoxins and its management in diverse cropping systems of central Tanzania. *Mycotoxin Research* 33(4): 323-331.

[10] Suleiman, R. A. and Kurt, R. A. (2015). *Current* Maize Production, Postharvest Losses and the Risk of Mycotoxins Contamination in Tanzania. *Presentation at the 2015 American Society of Agricultural and Biological Engineers Annual International Meeting*. New Orleans, Louisiana. 127pp.

[11] Akowuah, J. O., Mensah, L. D., Chan, C. and Roskilly, A., 2015. Effects of practices of maize farmers and traders in Ghana on contamination of maize by aflatoxins: Case study of Ejura-Sekyeredumase Municipality. *African Journal of Microbiology Research* 9(25): 1658-1666.

[12] Maina, A. W., Wagacha, J. M., Mwaura, F. B., Muthomi, J. W. and Woloshuk, C. P., 2016. Postharvest practices of maize farmers in Kaiti District, Kenya and the impact of hermetic storage on populations of Aspergillus spp. and aflatoxin contamination. *Journal of Food Research* 5(6): 53-66.

[13] Magembe, K. S., Mwatawala, M. W., Mamiro, D. P. and Chingonikaya, E. E., 2016. Assessment of awareness of mycotoxins infections in stored maize (Zea mays L.) and groundnut (Arachis hypogea L.) in Kilosa District, Tanzania. *International Journal of Food Contamination* 3(1): 1-8.

[14] United Republic of Tanzania President's Office/Regional Administration and Local Government., 2017. *Morogoro Municipal Council Strategic Plan 2016/2017 – 2020/2021*. Morogoro Municipal Council, Morogoro. 213pp.

[15] United Republic of Tanzania President's Office/Regional Administration and Local Government., 2017. *Makambako Town Council Strategic Plan 2016/17 – 2020/21*. Town Directors Office, Makambako, Njombe. 189pp.

[16] Sasamalo, M. M., Mugula, J. A. and Nyangi, C. J., 2018. Aflatoxins contamination of maize at harvest and during storage in Dodoma, Tanzania. *International Journal of Innovative Research and Development* 7(6): 11-15.

[17] Verbrugge, L. M., Gruber-Baldini, A. L. and Fozard, J. L., 1996. Age differences and age changes in activities: Baltimore Longitudinal Study of Aging. *The Journals of Gerontology Psychological Sciences and Social Sciences* 51(1): 30-41.

[18] Engdahl, I., 2019. OMEP policy forum: UN convention on the rights of the child has become policy in many countries. *International Journal of Early Childhood* 51(3): 259-264.

[19] Boni, S. B., Beed, F., Kimanya, M. E., Koyano, E., Mponda, O., Mamiro, D. and Mahuku, G., 2021. *Aflatoxin Contamination in Tanzania: Quantifying the Problem in Maize and Groundnuts from Rural Households*. Wageningen Academic Publishers, Wageningen. 12pp.

[20] Kaaya, A. N. and Kyamuhangire, W., 2006. The effect of storage time and agroecological zone on mould incidence and aflatoxin contamination of maize from traders in Uganda. *International Journal of Food Microbiology* 110(3): 217-223.

[21] Hell, K. and Mutegi, C., 2011. Aflatoxin control and prevention strategies in key crops of Sub-Saharan Africa. *African Journal of Microbiology Research* 5(5): 459-466.

[22] Jnr, E. Z., Muitia, A., Amane, M. I., Brandenburg, R. L., Emmott, A. and Mondjana, A. M., 2018. *Effect of Harvesting Time and Drying Methods on Aflatoxin Contamination in Groundnut in Mozambique*. IntechOpen, Mozambique. 17pp.

[23] Udoh, J. M., Cardwell, K. F. and Ikotun, T., 2000. Storage structures and aflatoxin content of maize in five agro ecological zones of Nigeria. *Journal of Stored Products Research* 36(2): 187-201.

[24] Suleiman, R. A., Rosentrater, K. A. and Chove, B., 2017. Understanding postharvest practices, knowledge, and actual mycotoxin levels in maize in three agro-ecological zones in Tanzania. *Journal of Stored Products and Postharvest Research* 8(7): 73-84.

[25] Hell, K., Cardwell, K. F., Setamou, M. and Poehling, H. M., 2000. The influence of storage practices on aflatoxin contamination in

maize in four agroecological zones of Benin, West Africa. *Journal of Stored Products Research* 36(4): 365-382.

[26] Lagogianni, C. and Tsitsigiannis, D., 2018. Effective chemical management for prevention of aflatoxins in maize. *Phytopathologia Mediterranean* 57(1): 186-197.

[27] Abass, A. B., Ndunguru, G., Mamiro, P., Alenkhe, B., Mlingi, N. and Bekunda, M., 2014. Post-harvest food losses in a maize-based farming system of semi-arid savannah area of Tanzania. *Journal of Stored Products Research* 57: 49-57.

[28] Kaaya, A. N. and Kyamuhangire, W., 2006. The effect of storage time and agroecological zone on mould incidence and aflatoxin contamination of maize from traders in Uganda. *International Journal of Food Microbiology* 110(3): 217-223.

[29] Achaglinkame, M. A., Opoku, N. and Amagloh, F. K., 2017. Aflatoxin contamination in cereals and legumes to reconsider usage as complementary food ingredients for Ghanaian infants: A review. *Journal of Nutrition and Intermediary Metabolism* 10: 1-7.

[30] Mutegi, C. K., Wagacha, J. M., Christie, M. E., Kimani, J. and Karanja, L., 2013. Effect of storage conditions on quality and aflatoxin contamination of peanuts (Arachis hypogaea L). *International Journal of Agri-Science* 3(1): 746-758.

[31] Ilesanmi, F. F. and Ilesanmi, O. S., 2011. Knowledge of aflatoxin contamination in groundnut and the risk of its ingestion among health workers in Ibadan, Nigeria. *Asian Pacific Journal of Tropical Biomedicine* 1(6): 493-495.

[32] Guchi, E., Ayalew, A., Dejene, M., Ketema, M., Asalf, B. and Fininsa, C., 2014. Stakeholders' awareness and knowledge about aflatoxin contamination of groundnut (Arachis hypogaea L.) and associated factors in eastern Ethiopia. *Asian Pacific Journal of Tropical Biomedicine* 4(1): 930-936.

[33] Fundikira, S. S., De Saeger, S., Kimanya, M. E. and Mugula, J. K., 2021. Awareness, handling and storage factors associated with aflatoxin contamination in spices marketed in Dar es Salaam, Tanzania. *World Mycotoxin Journal* 14(2): 191-200.

[34] Nakavuma, J. L., Kirabo, A., Bogere, P., Nabulime, M. M., Kaaya, A. N. and Gnonlonfin, B., 2020. Awareness of mycotoxins and occurrence of aflatoxins in poultry feeds and feed ingredients in selected regions of Uganda. *International Journal of Food Contamination* 7(1): 1-10.