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Adoption of Aflatoxin Smart Technologies among Smallholder Maize Farmers in Kongwa & Namtumbo Districts

Issaya G. Marijani [a,b*], Roselyne Alphonce [a] and Khamaldin D. Mutabazi [a]

[a] *Department of Agricultural Economics and Agribusiness, College of Economics and Business Studies, Sokoine University of Agriculture, P.O. Box 3007, Chuo Kikuu, Morogoro, Tanzania.*
[b] *Department of Socio- Economics and Market Research, Tanzania Agricultural Research Institute (TARI – Kifyulilo), P.O.Box 93 Mufindi - Iringa, Tanzania.*

Authors' contributions

The first author designed the study, collected data, analyzed data and wrote the paper. The second author and third author supervised all the activities from designing the study, data collection, paper write up, reviewed and edited the paper. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The study was designed to evaluate adoption of aflatoxin smart technologies among maize farmers.
Study Design: Cross sectional research design was used involving 344 respondents (300 maize farmers and 44 key informants).

**Corresponding author: E-mail: marijaniissaya@gmail.com;*

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Place and Duration of Study: The study was conducted in Kongwa district in Dodoma region and Namtumbo district in Ruvuma region of Tanzania.
Methodology: A survey questionnaire with open and closed ended questions was used to collect both quantitative from farmers while Key informant interview was conducted with traders, agricultural extension officers and input suppliers. The study used both descriptive and inferential statistics to analyse collected data, whereby mean, standard deviations, minimum and maximum were used to describe maize farmers in relation to adoption of aflatoxin smart technologies. Multinomial regression model was used to determine factors influencing adoption of aflatoxin smart technologies.
Results: Majority of maize farmers had low awareness level on aflatoxin. Low awareness level hindered the use of aflatoxin smart technologies. Moreover, results of multinomial logistic regression showed that farmer's experience on maize cultivations, household size, awareness on aflatoxin, and location of maize farmer, gender and access to credits were significant factors affecting the adoption of aflatoxin smart technologies and its intensities at $P = .05$.
Conclusion: It was concluded that with regard to how serious the problem of aflatoxin is, there is a need of high efforts of raising awareness to maize farmers to neutralize the spread of contaminations caused by careless farm practices. With the help of study's findings, it was recommended that there is a need to wide spread information on aflatoxin aiming to raise awareness of the maize farmers and increase physical access of aflatoxin smart technologies.

Keywords: Aflatoxins; awareness; aflatoxin smart technologies; Maize.

1. INTRODUCTION

Changes in food habit and increase in consumer awareness on food scares has created more attention on adherence to quality of what people consumes (Kariuki, 2022). Most of markets in developing nations are highly featured by fragile prices and unstandardized market qualities which further lessen the motivation of food producers to comply with the market qualities (Hoffmann & Treurniet, 2022). Aflatoxin being among food scares, are toxins resulting from fungi belonging to aspergillus flavus (Agape et al., 2021). Aflatoxin B1 is considered as the most dangerous mold which affects food quality and health of consumers (Hadipernata et al., 2021). Moreover, in recent years, aflatoxin has gained more attention and have fostered many countries' need of compliance with the tolerable amount of contaminations (Massomo, 2020).

Globally, data shows that more than five billion people are subjected to the risks associated with the exposure to the impacts of aflatoxin (Mtimet et al., 2015). But, developing countries are mostly susceptible to aflatoxin, causing health risks and economic hardships through loss of value on international food markets (Kumar et al., 2021). Health risks to human being from consumption of aflatoxin contaminated food may results in to short-term and long-term impacts like liver cancer, diarrhea, death and stunted growth to children (Lee et al., 2017). The economic losses include the increase in country's expenditures on medication, reduction in man power, and distortion of global food markets (Jolly et al., 2009). Speaking of international trade, aflatoxin has complicated and largely distorted the global food supply chain by inducing the compliances of the standard stipulated by trading countries. This increases shipment costs like testing costs, waiting for clearance costs, rejected shipments and many others. For instance it is estimated that the need of compliance on aflatoxin standards costs Africa USD $ 670 million annually through rejected shipments in the global markets (PACA, 2016).

In reducing the impacts of aflatoxins, there have been exertion of hug efforts in finding better ways of handling agricultural products along supply chains. Empirical shows that the use of good agronomic practices and recommended aflatoxin smart products largely reduces aflatoxin contaminations. This involves improvements on farmer's practices in to good agronomic practices as well as the use of recommended readily available aflatoxin smart products or technologies (Johnson et al., 2018). On other hand, it has been reported that there is low adoption rates of these recommended practices and technologies amongst farmers (Nakavuma et al., 2020). However, the problem persists in developing nations due to low awareness level on aflatoxin (Sasamalo et al., 2018). Whereby of agricultural products are poorly handled by farmers and stakeholders along supply chains since they don't understand the risks associated with aflatoxin (Magembe et al., 2016).

Maize and groundnuts are the most susceptible crops to aflatoxin contamination in less developed nations (Mahuku et al., 2022; Nakavuma et al., 2020). The risk of exposure to aflatoxin is high to since it affects maize which is the mostly consumed staple crop. Also, many people get exposed since maize and groundnuts are home grown and consumed while produced under poor agronomic and postharvest handling practices that favor the growth of mycotoxins (Senghor et al., 2021). Tanzania is the main maize producer in the East Africa. The crop is also considered as an important staple and cash crops. It is estimated the total consumption is 5.4 million metric tons annually, providing 80% of source of carbohydrate, 35% source of proteins with estimated total exports 135,000 tons per year (Townsend & Mtaki, 2020). Despite the importance of the crop, it is highly subjected to the risks of aflatoxin contaminations (Galani et al., 2022). With regards to the nature of aflatoxins being invisible by bare eyes, it creates high chances of people being exposed to consumption of aflatoxins contaminated food (Chilaka et al., 2022). An increased awareness of farmers on aflatoxin, would enhance the adoption of good agronomic and the use of aflatoxin smart technologies to mitigate aflatoxin contamination for improved food safety and income through the grain trade. Therefore, this study aimed at evaluating the level of adoption of aflatoxin smart technologies among smallholder maize farmers.

2. METHODOLOGY

2.1 Study Area

The study was conducted in Kongwa district in Dodoma region lying between latitude 6° 200' S and longitude 36° 417' E and Namtumbo district in Ruvuma region lying between latitude 10°466' S and longitude 36° 130**'** E**.** As major zonal maize producers, the regions were selected purposively to evaluate the adoption of aflatoxin smart technologies while takig in to account the differences in agro-ecological zones. In Kongwa district the study was conducted in Banyibanyi and Mkoka villages while in Namtumbo the study was conducted in Limamu and Mwangaza villages (Fig. 1).

2.2 Sample and Selection Procedure

Cross sectional research design was used whereby data were collected once at a single point in time. A total of 344 respondents were involved in the study entailing 300 maize farmers, 20 maize traders, 20 agro-input dealers and 4 Extension Officers (172 in Kongwa - Dodoma and 172 in Namtumbo – Ruvuma). Both probabilistic and non-probabilistic approaches were used to select study respondents. Multistage sampling technique was used to select one ward from each district, two villages from each ward in the study areas. Simple random procedure was used to select 300 maize producing households. Purposively selection procedure were used in selecting 20 traders, 20 agro-input dealers and 4 Extension Officers.

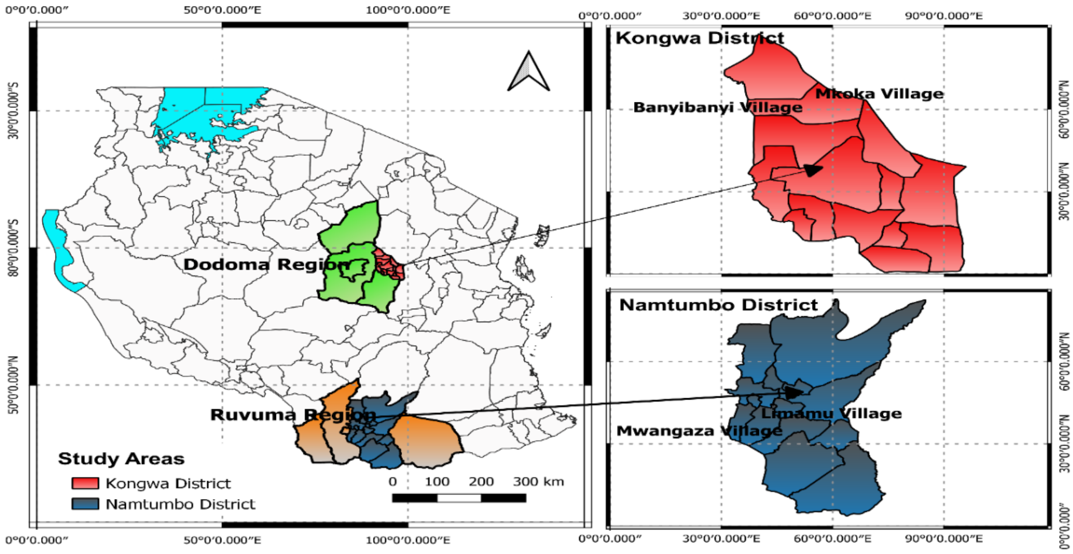

Fig. 1. The map of Tanzania showing study areas

Table 1. Variables and expected signs

Variable Name		Type	Measurements	Expected sign
Y	AST adopted	Categorical	Types of AST adopted by maize farmer	+
X_1	Age	Continuous	Number of years	+
X_2	Farm size	Continuous	Land size (unit) cultivated	+
X_3	Farm experience	Continuous	Number of years cultivating maize	±
X_4	Household size	Continuous	Number of people in household	±
Z_1	Sex	Categorical	1 = Male, 0 = Female	±
Z_2	Occupation	Categorical	1 = Farming only, 0 = Farming and others	±
Z_3	Marital status	Categorical	1 = Married, 0 = Otherwise	+
Z_4	Education level	Categorical	1 = Primary level, 0 = Otherwise	+
Z_5	Land ownerships	Categorical	1 = Owned land, 0 = Otherwise	±
Z_6	Location	Categorical	1 = Kongwa District, 0 = Namtumbo District	+

2.3 Methods of Data Collections

Primary data were collected through Key Informant Interviews, survey questionnaire, Focus Group Discussion (FGD) that were supplemented by observations. Structured interviews were conducted with key informants while questionnaire with both open – ended and close - ended questions were used to collect primary data. Two FGDs (1 in Kongwa and 1 in Namtumbo Districts) were conducted entailing 10 maize farmers per group (50% male and 50% female). The collected data were analyzed by using computer software statistical package for social sciences (IBM SPSS version 25).

2.4 Analytical Framework

Both descriptive and inferential statistics were used to analyze collected data. Descriptive statistics like mean, standard deviations, minimum and maximum were used to analyze quantitative data. Furthermore, content analysis was used to analyze collected qualitative data. While chi-square and multinomial Logit model were used to determine the intensity on adoption of aflatoxin smart technologies. The multinomial Logit regression model was specified on equation (i) and variables specified on Table 1.

$$Y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \cdots \beta_i x_i + \gamma_1 z_1 + \gamma_2 z_2 + \cdots . \gamma_i z_i + e_i \; (i = 1 \ldots n) \ldots\ldots. \text{(i)}$$

Where:

Y = Number of Aflatoxin smart technologies adopted
x_i = Predictors for adoption o aflatoxin smart technologies (AST)
e_i = Error term
β *and* γ = Regression coefficients

3. RESULTS AND DISCUSSION

3.1 Demographic Characteristics of Respondents

Findings (Table 2) showed there was a statistical difference between gender of maize farmers in Kongwa and Namtumbo districts at *P = .00* (X^2 = 12.96) whereby about 75% of maize farmers were male (42% in Kongwa and 33% in Namtumbo Districts) while 25% of maize farmers were female (8% Kongwa and 17.3% in Namtumbo District). This is due to the fact that in most of the households men are heads which gave higher chance of participating in this survey than women as was also shown by (Ayo et al., 2018; Sasamalo et al., 2018). Also, the results showed that age of maize farmers were statistical different across study's districts at *P = .03* (X^2 = 13.779) such that 78.6% of maize farmers (37.3% in Kongwa and 41.3% in Namtumbo district) were aged between 18 to 53 years. Followed by age between 61 years and above who accounted 14% (8% in Kongwa and 6% in Namtumbo district) as well as age between

54 and 60 years who accounted 8.4% (5.7% in Kongwa and 2.7% in Namtumbo district) of the study' sample and the overall mean age of maize farmers was 42.7 years. Moreover, marital status of maize farmers was not statistical different at *P = .05,* between farmers in Kongwa and Namtumbo districts. However, maize farming was dominated by married maize farmers (79%) followed by 11.3% who were single, 4% were widowed as well as 5.7% were separated. Additionally, education of the maize farmers was not statistical different at *P = .05* between maize farmers in Kongwa and Namtumbo district, but it was found that large proportion of the farmers (77.3%) had primary education level, followed by secondary education level (13.4%), no formal education (5.7%), university education level (2%) and college education level (1.7%). Furthermore, there was no statistical difference between main occupation between maize farmers in the two districts at *P = .05,* but due to the nature of the study all respondents were farmers (100%), and few of them were also doing other non-farm activities such as business (10.3%), livestock keeping (8.0%), wage employments (3.7%) and artesian (3.3%). Moreover, the study found that the mean years of farming experience was 15 years, while the lowest experience being one (1) year and the highest experience being sixty (60) years. Also, the mean household size was 5 with lowest number being 1 and the highest being 12 members.

3.2 Awareness on Aflatoxin amongst Maize Farmers

The study found that majority of farmers had low awareness level on aflatoxin which triggered poor pre and post-harvesting handling of maize (Table 3). This was reported by 191 maize farmers' equivalent to 63.7% who completely did not understand what aflatoxin is. On other hand, about 109 (36.3%) maize farmers knew what aflatoxin is, though some had a better understanding while other had fairly understandings on aflatoxin which is in line with the results of (Sasamalo et al., 2018). It was found that the main reason for low awareness level among maize farmers was limited access to proper information. Furthermore, the results showed that only farmers who had access to sources of information understood what aflatoxin is. Among maize farmers who showed the understanding on the meaning of aflatoxin, mentioned seminars (38.5%) as the most used sources of exposing them to the meaning of aflatoxin followed by radio (31.2%), neighbors, (16.5%), television (7.3%), extension officers (3.7%) and maize buyers (2.8%). With regards to the nature of the problem and how serious it is, these sources are not enough in creating awareness especially in remote areas like where the study was conducted. In some areas, farmers had no access to radio, television, no seminars conducted, long distances from home to the village offices where they can access extension services and prevalence of wrong information amongst untrustworthy neighbors. Nonetheless, the study found that there is information dearth on the causes of aflatoxin which was subjected by guessing answers despite being collect. High moisture content (40.4%) was the most reported to be the cause of aflatoxin followed by poor crop handling (32.1%), use of non-tolerant maize varieties (9.2%), fungal infections (0.9%). While 17.4% didn't understood what caused aflatoxin. Moreover, maize farmers who understood the meaning of aflatoxin, also showed the understanding of its effects, whereby 46.8% responded that frequently consumptions of aflatoxin contaminated food may result to diseases mainly liver cancer and diarrhea. Followed by 35.8% who said aflatoxin contaminations leads in to a reduction of maize quality, 12.8% said the consumption of aflatoxin contaminated food over time may result in to death of people while 17.4% didn't understood the effects of aflatoxin. Additionally, the study found that measures taken to reduce aflatoxin includes; maize sorting (24.8%), proper drying (14.7%), improving farm practices (11.0%), use of tarpaulins (5.5%), burning the contaminated maize (4.6%), use of fungicides (4.6%), use of storage treatments (2.8%), crop rotations (1.8%), leaving contaminated maize on the field (1.8%), use of improved storage bags like PICS (0.9%), selling contaminated maize to local liquor makers (0.9%), use as animal feed (0.9%) while 19.2% didn't understood any measures. Poor measures taken by maize farmers on reducing aflatoxin contaminations in the study areas, proves the prevalence of low awareness level which was also found by the study conducted by Massomo, (2020). This observation is conforms with what was pointed out by the key informant interviews and focus group discussions (FGDs) and interviews with agro dealers and ward agricultural officer as shown in the quote below;

"*To be honest most of farmers have low awareness level on aflatoxin, to some of them the concept is completely new showing no measures are taken in to account in addressing the problem rather doing business as usual. Also, due to remoteness of villages, it is difficult* *to access agricultural inputs such as improved seeds, fertilizers, pesticides, storage facilities resulting to poor crops handling" (Key informants, and FGD 2023).*

Table 2. Socio economic characteristics of the respondents

Variable	Dodoma (Kongwa)	Ruvuma (Namtumbo)	Total	Chi - Square	Sig.
Gender					
Male	126 (42.0)	99 (33)	225 (75.0)	12.96***	0.000
Female	24 (8.0)	51 (17.3)	75 (25.0)		
Total	**150 (50.0)**	**150 (50.0)**	**300 (100.0)**		
Marital status					
Married	126 (42.0)	111 (37.0)	237 (79.0)	4.875	0.300
Single	14 (4.6)	20 (6.6)	34 (11.3)		
Widowed	4 (1.4)	8 (2.7)	12 (4.0)		
Separated	6 (2.0)	11 (3.7)	17 (5.7)		
Total	**150 (50.0)**	**150 (50.0)**	**300 (100.0)**		
Age category					
18 -35	43 (14.3)	73 (24.3)	116 (38.7)	13.779***	0.003
36 - 53	66 (23.0)	51 (17.0)	117 (39.0)		
54 - 60	17 (5.7)	8 (2.7)	25 (8.3)		
61 and above	24 (8.0)	18 (6.0)	42 (14.0)		
Total	**150 (50.0)**	**150 (50.0)**	**300 (100.0)**		
Education level					
No formal	10 (3.3)	7 (2.3)	17 (5.7)	6.908	0.329
Primary	121 (40.4)	111 (37.0)	232 (77.3)		
Secondary education	17 (5.6)	33 (7.7)	40 (13.4)		
College education	1 (0.3)	4 (1.3)	5 (1.7)		
Bachelor degree	1 (0.3)	5 (1.7)	6 (2.0)		
Total	**150 (50.0)**	**150 (50.0)**	**300 (100.0)**		
Occupation: Farming only					
Farming only	95 (31.7)	129 (43)	224 (74.7)	1.128	0.288
Occupation: farming and others					
Business	20 (6.6)	11 (3.6)	31 (10.3)	3.434	0.180
Livestock keeping	19 (6.4)	5 (1.6)	24 (8.0)	3.092*	0.079
Wage employment	11 (3.7)	0 (0.0)	11 (3.7)	.849	0.357
Artesian	5 (1.7)	5 (1.7)	10 (3.3)	3.724**	0.054
Years of farming experience					
Mean	15				
Std. deviation	11				
Minimum	1				
Maximum	60				
House hold size					
Mean	5				
Std. deviation	2				
Minimum	1				
Maximum	12				

****P<0.01, **P<0.05, *P<0.1, numbers in parenthesis are percentages*

Table 3. Awareness on aflatoxin among maize farmers

Parameter	Responses	Region		Pearson	
		Dodoma	**Ruvuma**	**Chi-Square**	**Sig.**
Do you know aflatoxin	No	82 (54.7)	109 (72.7)	10.505***	0.001
	Yes	68 (45.3)	41 (27.3)		
Where you heard the meaning of aflatoxin?	Extension officer	1 (0.7)	3 (2.0)	23.23**	0.026
	Maize buyers	2 (1.3)	0 (0.0)		
	Neighbors	9 (6.0)	8 (9.7)		
	On products purchased	1 (0.7)	0 (0.0)		
	Radio	23 (15.4)	11 (7.3)		
	Seminar	28 (18.7)	13 (8.7)		
	Television	3 (2.0)	5 (3.3)		
What are the causes of aflatoxin in your area?	Bacterial infestations	0 (0.0)	1 (0.7)	31.414***	0.000
	High moisture content	23 (15.4)	21 (14.0)		
	Low awareness level	0 (0.0)	3 (2.0)		
	Poor crop handling	28 (18.7)	3 (2.0)		
	Use of non-tolerant varieties	6 (4.0)	4 (2.7)		
	I don't know	10 (6.7)	9 (6.0)		
Effects of aflatoxin on maize					
Diseases	No	117 (78.0)	132 (88.0)	5.315**	0.021
	Yes	33 (22.0)	18 (12.0)		
Reduces maize quality	No	118 (78.7)	135 (90.0)	7.291***	0.007
	Yes	32 (21.3)	15 (10.0)		
Death of people	No	148 (98.7)	138 (92.0)	7.493***	0.006
	Yes	2 (1.3)	12 (8.0)		
Improve farm practices	No	142 (74.7)	143 (95.3)	0.07	0.791
	Yes	8 (5.3)	7 (4.7)		
Measures taken to reduce aflatoxin on maize					
Use of Tarpaulins	No	146 (97.3)	148 (98.7)	0.68	0.450
	Yes	4 (2.7)	2 (1.3)		
Maize sorting	No	134 (89.3)	139 (92.7)	1.018	0.313
	Yes	16 (10.7)	11 (7.3)		
Burning contaminated maize	No	148 (98.7)	147 (98.0)	0.203	0.652
	Yes	2 (1.3)	3 (2.0)		

Parameter	Responses	Region		Pearson	
		Dodoma	Ruvuma	Chi-Square	Sig.
Proper drying	No	135 (90.0)	149 (99.3)	12.94***	0.000
	Yes	15 (10.0)	1(0.7)		
Use of hermetic bags	No	150 (100.0)	149 (99.3)	1.003	0.317
	Yes	0 (0.0)	1(0.7)		
Use of pest and fungicides	No	150 (100.0)	145 (96.7)	5.085**	0.024
	Yes	0 (0.0)	5 (3.3)		
Crop rotations	No	148 (98.7)	150 (100.0)	2.013	0.156
	Yes	2 (1.3)	0 (0.0)		
Postharvest treatments	No	149 (99.3)	148 (98.7)	0.337	0.562
	Yes	1 (0.7)	2 (1.3)		
Left on field	No	149 (99.3)	149 (99.3)	0.000	1.000
	Yes	1 (0.7)	1 (0.7)		
Sold to local liquor makers	No	149 (99.3)	150 (100.0)	1.003	0.317
	Yes	1 (0.7)	0 (0.0)		
No measures taken	No	142 (94.7)	150 (100.0)	8.219***	0.004
	Yes	8 (5.3)	0 (0.0)		

****P<0.01, **P<0.05, *P<0.1, numbers in parenthesis are percentages*

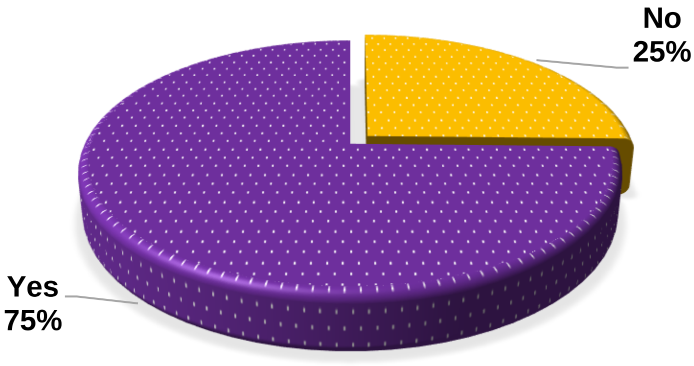

Fig. 2. Adoption of aflatoxin smart technologies to smallholder maize farmers

3.2.1 Adoption of aflatoxin smart technologies to smallholder maize farmers

Despite low awareness level on aflatoxin, yet the study found that 75% of farmers used various aflatoxin smart technologies. Among the users of aflatoxin smart technologies uses these technologies with prior information on reducing the contaminations. While others use without knowledge of reducing aflatoxin contaminations on maize, rather are it is among their routine in maize cultivations. However low awareness level on aflatoxin among users affected proper use of these technologies. On other hand, about 25% of maize farmers in the study are didn't use aflatoxin smart technologies (Fig. 2).

3.2.2 Types of aflatoxin smart technologies used among maize farmers

Aflatoxin smart technologies used by maize farmers were categorized in to pre and post-harvest technologies. Timely maize harvesting (13.3%) was among pre – harvest practice undertaken by farmers in ensuring that maize has properly matured before harvest. The aim of harvesting maize at its maturity level gives the signs to farmer that the maize is ready for harvests which guarantees good quality and inability to be infested by fungi. It was found that few farmers used insecticide (7.0%) to control insects which on their existence accelerates growth of fungus on maize. About 4.0% of farmers harvest maize when they are sure that has adequately dried with bearable moisture contents, however it was found that maize farmers use local methods of testing moisture contents such as cracking maize grain by teeth, seeing and mixing maize grains with salt in the bottle. Also, 3.7% of farmers used fungicides on farm to control the spread of fungal infections on maize.

On other hand, post-harvest technologies and practices; the study found that 14.6% of farmers dries maize properly after harvest whereby maize are dried until reaches 13% of the moisture content before packing in sacks or in local stores. However, it was found that some farmers harvest and sell maize with high moisture content since gets high selling weight and high prices during off seasons. Additionally, 19.7% of maize farmers used tarpaulins in pilling and drying maize. Even though, few of them used tarpaulin on both pilling when harvesting and drying but majority were using tarpaulins only when drying unshelled maize grains. About 12.3% used postharvest treatments, 12.0% used Purdue Improved Crop Storage bags (PICS) and 0.1% used metal storage facilities (Fig. 3).

3.2.3 Hindrances on the use of aflatoxin smart technologies

Results showed that failure to use aflatoxin smart technologies amongst maize farmers was caused by several factors. Low awareness level (59.3%) made farmers not taking in to account the risk of exposing maize in to aflatoxin. High input prices (16.0%) was among hindrances which deterred farmer's abilities to buy farm inputs and various aflatoxin smart technologies. Maize farmers also reported that limited access to aflatoxin smart technologies (13.3%) was among hindrance resulting from limited supply of aflatoxin smart technologies in remote areas. Also, it was reported that low capital (6.0%) was among hindering factors which affects the ability to meet costs of productions and meeting the additional costs for handling maize against aflatoxin contaminations. Moreover, climatic challenges (4.7%) was among challenges hindering use of these technologies in a way that is it difficult to control the climate like heavy rainfall which increases moisture content on maize. Lastly, limited access to experts (0.7%) was among hindrance in the way that geographical areas are large but the number of extension officers is limited which affects their ability to reach each and every farmer (Table 4).

3.2.4 Adoption incentives for aflatoxin smart technologies

Results (Table 5) showed that there was statistically significant difference on adoption incentives or adoption potentials for aflatoxin smart technologies between Kongwa and Namtumbo Districts at *P = .00.* However maize farmers showed several factors which may influence their adoption of these technologies. Awareness on aflatoxin was the most reported factor influence adoption of various aflatoxin smart technologies (62.6%) followed by access to aflatoxin smart technologies in remote areas (19.7%). Additionally, the study found that when prices of aflatoxin smart technologies are lower may influence adoption of these technologies (7.4%), the same when credit access is easy (2.6%) as well as access to extension services (2.6%) and when the capital is adequate (5%).

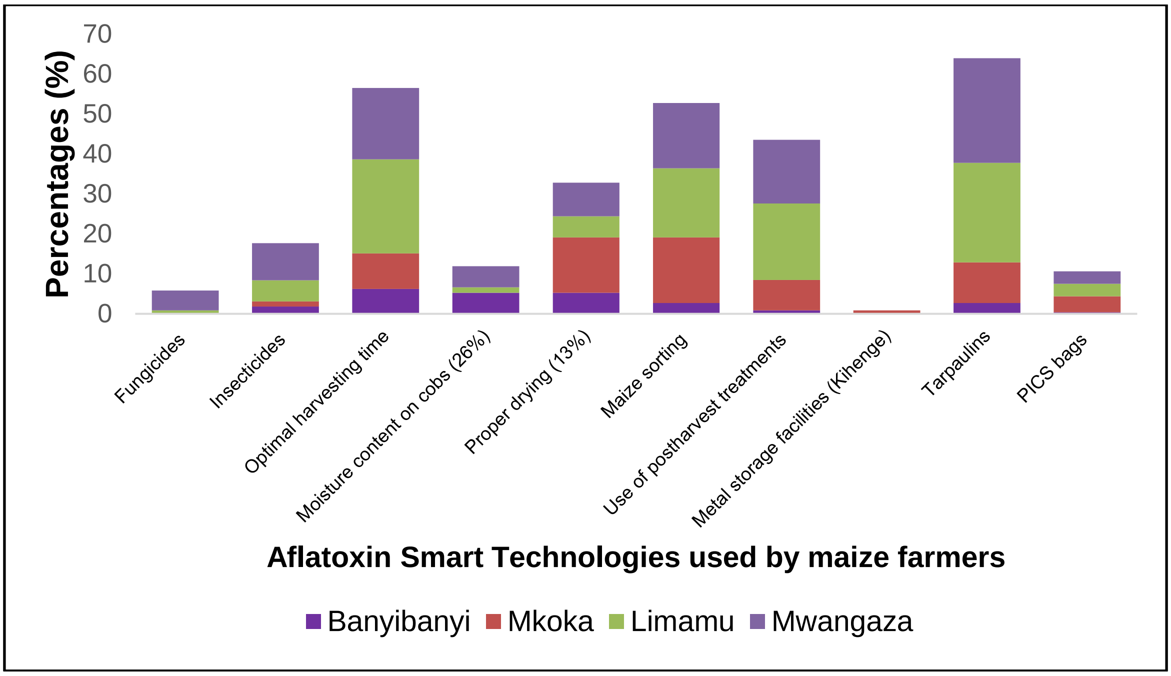

Fig. 3. Types of aflatoxin smart technologies used among maize farmers (n = 225)

Table 4. Hindrances on the use of aflatoxin smart technologies (n = 150)

Challenge (s)	District		Pearson	
	Kongwa	Namtumbo	Chi - square	Sig.
Climatic challenges	2 (1.3)	6 (4.0)	26.001***	0.000
Low awareness level	57 (38.0)	25 (17.7)		
High input prices	14 (9.3)	11 (7.3)		
Limited access to aflatoxin smart technologies	14 (9.3)	9 (6.0)		
Inadequate capital	5 (3.3)	5 (3.3)		
Inadequate number of expertise	1 (0.7)	0 (0.0)		

****P<0.01, **P<0.05, *P<0.1, numbers in parenthesis are percentages*

Table 5. Adoption incentives for Aflatoxin Smart Technologies (AST)

Adoption incentives	District		Pearson	
	Kongwa	Namtumbo	Chi - Square	Sig.
Awareness on Aflatoxin	62 (41.3)	32 (21.3)	32.138***	0.000
Access to aflatoxin smart technologies	14 (9.3)	16 (10.7)		
Low prices of aflatoxin smart technologies	10 (6.7)	1 (0.7)		
Access to credits	2 (1.3)	2 (1.3)		
Access to extension services	2 (1.3)	2 (1.3)		
Sufficient capitals	3 (2.0)	3 (3.0)		

****P = .01, **P = .05, *P = 0.1, numbers in parenthesis are percentages*

Table 6. Determinants for adoption of Aflatoxin Smart Technologies (AST) and its intensity

Variable	Details	Number of aflatoxin smart technologies adopted					Overall Var. Sig.
		1	2	3	4	5	
		Coeff.	*Coeff.*	*Coeff.*	*Coeff.*	*Coeff.*	
Age	Years	0.048**	0.074***	0.041	0.036	0.061**	0.172
Education	Years	0.036	0.087	0.159*	0.098	0.084	0.786
Land size	Acres	-0.011	-0.008	-0.007	-0.05*	-0.113	0.128
Experience	Years	0.067**	0.086***	0.002	0.015	0.053	0.025**
HH size	Number	0.221**	0.067	-0.009	0.211*	0.064	0.077*
Awareness	Yes	0.409	0.413	1.112**	2.038***	1.897***	0.002***
District	Kongwa	-4.777***	-4.551***	-4.82***	-5.192***	-5.441***	0.000***
Gender	Female	-1.416**	-0.426	-0.976	-0.77	0.052	0.022**
Marital status	Single	0.981	0.688	0.807	-0.085	-2.579	
	Married	-0.028	0.685	0.073	-0.634	-1.215	
	Divorced	1.253	1.767	-12.814	0.149	-1.833	0.146
Access to credit	Easy	14.023	0.718	14.36	13.107***	8.808***	
	Moderate	15.282	12.98	13.794	12.916***	7.764***	0.003***
	Difficult	-14.809	-14.504	-13.918	-11.555***	-8.174***	
Intercept		-13.678	-14.873	-14.011	-11.526	-7.195	
Dependent Var.		Adoption intensity of AST					
Number of observations		300					
Chi – Square		273.941					
Pseudo R-Square		0.599					

****P<0.01, **P<0.05, *P<0.1*

3.2.5 Determinants for adoption of Aflatoxin Smart Technologies (AST) and its intensities

The study found several factors that influence adoption of aflatoxin smart technologies and its intensity amongst maize farmers (Table 6). The number of adopted aflatoxin smart technologies varied from one (1) to five (5) technologies. Predictors for adoption and intensity of one (1) of aflatoxin smart technology were; age of the maize farmer was statistical significant at *P = .05* with an odd ratio of 0.048, years of experience of maize farmer was statistical significant at *P = .1* with an odd ratio of 0.067, number of people in the household was also statistical significant at *P = .05* with odds ratio of 0.221, location of maize farmer (Kongwa in Dodoma) was statistical significant at *P = .01* and odd ratio of -4.777, gender (female) of maize farmer was also statistical significant at *P = .05* with odd ratio of -1.416. It was found that predictors of adoption and intensity of two (2) aflatoxin smart technologies were; age of maize farmer was statistically significant at *P = .01* with odd ratio 0.074, farm experience was statistically significant at *P = .01* with odds ratio 0.086, while location of maize farmer was statistically significant at *P = .01* with an odd ratio of -4.551. Additionally, predictors for adoption and its intensity of three (3) aflatoxin smart technologies were; years of education was statistically significant at *P = .1* with odd ratio 0.159, awareness level on aflatoxin was statistically significant at *P = .05* with odd ratio of 1.112, as well as location of maize farmer was statistically significant at *P = .01* with odd ratio of -4.82. Furthermore, predictors for adoption and its intensity of four (4) aflatoxin smart technologies were; land size under maize cultivations significant at *P = .1* with odd ratio -0.05, number of people in the household which was significant at *P = .1* with odd ratio of 0.221, easy access to credit was significant at *P = .01* with odd ratio 13.107, moderate access to credit also positively influenced adoption at *P = .01* and odd ration of 12.916 as well as difficult access to credits was statistical significant at *P = .01* with odd ratio of -11.555. Furthermore, predictors for adoption and its intensity of five (5) aflatoxin smart technologies were; age of the maize farmer was statistical significant at *P = .05* with odd ratio of 0.061, awareness on aflatoxin was significant predictor at *P = .01* and odd ration of 1.897, location of maize farmer was significant at *P = .01* with odd ratio -5.441, while easy access to credits was significant predictor at *P = .01* and odd ratio of 8.808, the same to moderate access to credit was statistical significant determinant factor at *P = .01* with odd ratio 7.764 and difficult access to credit was significant factors at *P = .01* with odd ratio of -8.174.

3.3 Discussion

This paper was designed to evaluate adoption of aflatoxin smart technologies among small holder maize farmers. Results on demographic characteristics of maize farmers varied across districts where the study conducted. On its findings, the study showed that majority of maize farmers were male since most of them were considered as heads of households which gave them higher chance in participating the study as it was found by Nakavuma et al., (2020). Likewise, the study found that large proportion of maize farmers were married and had primary education level, which is considered as low education level to some extent affected the effectiveness in adoption of aflatoxins smart technologies as reported by Nakavuma et al., (2020). Also, findings showed that most of maize farmers had age categorized in to adult age with full abilities to make their own decisions as to whether to use or not use aflatoxin smart technologies as it was reported by Ayo et al., (2018).

In addition, the study found that majority of maize farmers had low awareness level on aflatoxin. Low awareness level was among hindering factors on the abilities to cut off the chain of aflatoxin along maize supply chain. Low awareness level blind fold the initiatives on reducing the contaminations on maize which is also linked with low level of education among maize farmers. This is line with the findings of the study by Magembe et al., (2016) on the survey conducted in Kilosa, Tanzania which found that awareness on mold infection was high the less educated maize farmers. Same as the findings by Negash, (2018) who showed that low awareness level affects the abilities of farmers to apprehend the knowledge on aflatoxin. In line with results of studies by Jolly et al., (2009) and Johnson et al., (2018) who also reported that the education of a farmer was a significant determinant factor to the awareness on aflatoxin. The cause for low awareness level on aflatoxin among maize farmers is highly linked to inaccessibility of adequate and credible sources of information. The determined sources of information were not user friend to all types of farmers (Fundikira & De Saeger, 2020).

Moreover, it was found that large proportion of maize farmers adopted aflatoxin smart technologies which involved practices and products at pre and post-harvest stage as part of daily routine. However, their uses were subjected to poor practices which increased chances of aflatoxin contaminations on maize as also reported by Johnson et al., (2018) and Kumar et al., (2021). Low adoption of aflatoxin smart technologies was found to be accelerated by number of factors. Whereby, the study found that climate challenges, low awareness level, high input prices, limited access to aflatoxin smart technologies, low capitals and inadequate number of expertise, at large hindered adoption of aflatoxins smart technologies amongst maize farmers as also reported by a study conducted by Ayedun et al., (2017) and Nyangi et al., (2016). Moreover, the study found that increase in awareness to maize farmers, increase access to AST, lowering price of AST, increase access to credits, increase access to extension services and promotion of access to capitals may increase the likelihood of a farmers to adopt aflatoxin smart technologies amongst maize farmers aligning with a study by Migwi et al., (2020).

With an aid of multinomial logit regression model the study found that demographic characteristics and socio- economic factors of maize farmers in the study areas, influenced the adoption of different aflatoxin smart technologies. However, factors influencing the intensity of adoption varied from one (1) to five (5) aflatoxin smart technologies. Farmers experience on maize cultivations, household size, awareness on aflatoxins, location of maize farmers, gender and access to credits were overall factors significant influencing the adoption of various aflatoxin smart technologies in line with study by Rwebangira et al., (2022) on a study “Factors that influence smallholder farmers ' decisions to employ hermetic bag technology for maize grain storage in Kilosa District, Tanzania”. As well as these findings aligns with studies by Stepman,(2018) and Bandyopadhyay et al., (2020).

4. CONCLUSION

Generally, it was found that majority of maize farmers had low awareness level on aflatoxin. This hindered their abilities to improve practices and use of various aflatoxin smart technologies. Therefore, there is a need of mass investments on awareness creations to farmers and actors along maize supply chain so as to cope with the stipulated domestic and international standards on aflatoxin. Also, the study found that farmers had limited access to extension services who may be helpful in sensitizing the awareness on aflatoxin, due to large geographical areas aflatoxin, which cater for the need to increase number of extension officers in remote areas. Additionally, price of aflatoxin smart technologies needs to be decreased and there is also a need to increase physical access of these technologies. On other hand, the multinomial logistic regression analysis helped the study to determine which socio – economic factors strongly explain the chances of maize farmers to adopt aflatoxin smart technologies. The significant factors may be helpful to signify which areas may need more emphasis in case there is planning and implementations of interventions aiming to create awareness and the adoption of aflatoxin smart technologies.

Basing on the study’s results it is highly recommended that;

i. **To farmers:** the study would like to recommend the improvements in farm practices and the use of various aflatoxin smart technologies as these have proven to be useful in reducing the contaminations.
ii. **To researchers:** there is need to disseminate knowledge on good agronomic practices (GAP) since improvements on better practices guarantees much the reduction on chances for contaminations. Also, more researches has to be done to determine ways to physically determine contaminations rather the current ways using laboratory results.
iii. **To agricultural extension officers:** the study would like to recommend the minimization of existing gap between farmers and extension officers since it was found that most of farmers have no access to extensions services.
iv. **To policy makers:** there is a need to put forward policies that promotes awareness and access to aflatoxin smart technologies so as to promote its uses among maize farmers.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors declares that no generative technologies such as language models like ChatGPT, COPILOT; and text image generators have been used during writing or editing of this work.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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