AWARENESS OF AFLATOXIN CONTAMINATION AND SAFETY OF MAIZE ALONG SUPPLY CHAIN IN KONDOA AND CHEMBA DISTRICTS IN DODOMA, TANZANIA

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EXTENDED ABSTRACT

Maize (Zea mays) is a staple food for the majority of people in Tanzania, which plays a key role in subsistence and as a cash crop among actors of the maize value chain. The study was conducted during the 2020–2021 cropping season in two districts, Kondoa and Chemba, in the Dodoma region of central Tanzania. The objectives were to assess stakeholders' awareness of aflatoxin contamination in maize (smallholder farmers, traders, and consumers), to assess post-harvest handling practices of maize among smallholder farmers, and to determine the current levels of aflatoxins B_1 contamination in maize. Structured questionnaires were used to collect the data. A cross-sectional survey was used in collecting primary data. A total of 380 respondents, including smallholder farmers, traders, and consumers from each ward, were selected. In addition, 90 maize samples (40 from smallholder farmers, 20 from traders, and 30 from consumers) were analyzed for aflatoxins using High-Performance Liquid Chromatography (HPLC). The results show about 56% of the smallholder farmers and 52% of the traders were aware of the contamination. However, the majority of the main stakeholder (consumer) was unaware of the contamination with aflatoxins (74%). Moreover, the result shows smallholder farmers had inadequate knowledge of best post-harvest practices and these were associated with post-harvest losses and the microbiological quality of maize. It was observed that the majority of smallholder farmers (75%) used traditional post-harvest handling practices such as harvesting maize and placing it on the ground, storing maize in galleries, drying (on the ground); use of polypropylene bags as a storage facility. Few samples of the maize value chain were contaminated with AFB_1 and total aflatoxins. Furthermore, the result shows five-point six percent (5.6%) of collected samples were contaminated with aflatoxins B_1, and 3.3% of the aflatoxins samples exceeded the

European Union (EU) and Tanzania Bureau of Standards (TBS) regulatory limits for AFB_1 and were mainly collected from traders in Kondoa district. Extension workers should train farmers on effective post-harvest management practices of maize in order to minimize losses and improve the quality. In addition, efforts should be made to educate the general public, particularly consumers, about the dangers of aflatoxins contamination, and affordable techniques should be made available to maize farmers in the Kondoa and Chemba districts of Dodoma, Tanzania, in order to reduce grain losses and increase income and food security.

DECLARATION

I, **ASHA HAMAD NDWATA**, declare to the Senate of Sokoine University of Agriculture that this dissertation is my original work and that it has neither been submitted nor being concurrently submitted in any other institution.

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DEDICATION

This dissertation is dedicated to my beloved husband Mohsin Kavishe, who has always been my inspiration. Our beloved sons Adam, Alyasa and Abrahim for their tolerance during my absence from home, my mother Hadija H. Mbaira, who has remained a source of motivation for my academic achievements and also in loving memory of my wonderful father, Hamad I. Ndwata, who inspired me to pursue a master’s degree.

LIST OF PAPERS

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AF	Aflatoxin
AF-alb	Aflatoxin albumin
AFB_1	Aflatoxin B_1
AFB_2	Aflatoxin B_2
AFG_1	Aflatoxin G_1
AFG_2	Aflatoxin G_2
AFs	Aflatoxins
AGRA	Alliance for a Green Revolution in Africa
DED	District Executive Director
EAC	East Africa Community
EU	European Union
FAO	Food and Agriculture Organization of United Nations
FDA	Food and Drugs Authority
FLD	Fluorescence Detection
HBV	Hepatitis B virus
HPLC	High Performance Liquid Chromatography
LC-MS/MS	Liquid Chromatography with tandem mass spectrometry (LC-MS-MS)
IARC	International Agency for Research on Cancer
ISO	International Organization for Standard
LOD	Limit of Detection
LOQ	Limit of Quantification
Mg/Kg	Milligram per Kilogram (ppm)
MTL	Maximum Tolerable Limits

N	Sample size
OECD	Organization of Economic Cooperation and Development
PICs	Purdue Improved Crop Storage
SE	Standard Error
SPSS	Statistical Package of Social Sciences
SUA	Sokoine University of Agriculture
TBS	Tanzania Bureau of Standard
UK	United Kingdom
URT	United Republic of Tanzania
USA	United States of America
USAID	United States Agency for International Development
UV	Ultra Violet
WHO	World Health Organization
μg/Kg	Microgram per Kilogram (ppb)

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

1.1.1 Agriculture and Mycotoxin

Agriculture is the backbone of the economy in most Sub-Saharan African (SSA) countries, contributing significantly to their Gross Domestic Product (GDP) (Salahuddin *et al.,* 2020). Agriculture provides a livelihood for multitudes of small-scale producers and employs people directly and within the rural population. Smallholder farms constitute approximately 80% of all farms in SSA (OECD/FAO, 2016). Tropical and sub-tropical countries are more conducive to mycotoxins accumulation in crops (Bjornlund *et al.,* 2020).

Mycotoxins are low molecular weight secondary metabolites synthesized by a variety of fungal species such as *Aspergillus*, *Penicillium*, *Fusarium*, and *Alternaria* (Misihairabgwi *et al.,* 2019). Mycotoxins have attracted worldwide attention due to their impact on human and animal health, and domestic and foreign trade (Cinar and Onbaşı, 2019). There are more than 400 types of mycotoxins worldwide, but groups of mycotoxins considered potentially dangerous are; aflatoxins, fumonisim, ochratoxins, citrinin, zearalenone and trichothecenes (Agriopoulou *et al.,* 2020).

Aflatoxins are produced by *Aspergillus* species, *A. flavus*, *A. parasiticus* and *A. niger*. The moulds produce four main types of aflatoxins namely: aflatoxin B_1 (AFB_1), aflatoxin B_2 (AFB_2), aflatoxin G_1 (AFG_1) and aflatoxin G_2 (AFG_2). In particular, Aflatoxin B_1 (AFB_1) is the most potent type of mycotoxin. Predominant species with aflatoxin production ability include *A. flavus* and *A. parasiticus, which* can contaminate a wide range of agricultural commodities either in the field or in storage they commonly infect food crops like maize, oilseeds, and peanuts (Mmongoyo *et al*., 2017). *Aspergillus flavus* is a primary producer of aflatoxin and it is present in the soil in many parts of the world, including the Southern United States, Eastern Europe, and Sub-Saharan Africa (Ehrlich *et al.*, 2015).

The predisposing conditions leading to fungal growth in maize are poor post-harvest handling management such as inadequate drying and improper storage, weather variability including high temperatures and humidity, biotic factors, poor soil fertility, drought and unexpected precipitation during harvest and drying (Sserumaga *et al.*, 2020). Strategies to reduce or prevent aflatoxin contamination include raising awareness on their effects such as health problems to communities; pre-harvest management practices that include the application of cultural control strategies, chemical control strategies and biological control (Udomkun *et al*., 2017). Bio-control agents (Aflasafe) usually dislocate and reduce the capability of resident toxigenic strains to produce the toxins (Agbetiameh *et al.*, 2018).

The Aflasafe products have been shown to consistently reduce aflatoxin contamination in the field (Udomkun *et al.*, 2017). Other strategies are post-harvest management practices; these are those practices following harvest and leading up to primary processing, such as rapid drying on platforms to avoid direct contact with soil and proper shelling methods to reduce grain damage. De-hulling of maize before milling was also found to remove significant amounts of aflatoxins in maize, with a reduction of up to 92% of aflatoxins (Colak *et al*., 2016).

1.1.2 Aflatoxins contamination and health consequences

Aflatoxins contamination is a complex and systemic process that begins in the field when fungal propagates infect the crop from crop debris and soil (Probst *et al.,* 2014). The contamination then extends during the growth of the crop in the field and continues after crop maturation and during storage, especially if the crop commodity is stored at higher moisture contents (Massomo, 2020). In maize, aflatoxins are almost extensively produced by *Aspergillus flavus*, which produces AFB_1 and AFB_2. Aflatoxigenic strains of A. *flavus* are capable of growing on maize in the field during storage. The optimum conditions for growth and subsequent production of aflatoxins by *A. flavus* include; moisture content above 14%, an optimum temperature of 28ºC- 30ºC and water activity of about 0.83 – 0.97 (Atherstone *et al.,* 2016). Immature, broken, discolored kernels are most likely to be contaminated with aflatoxins compared to mature sound kernels (Bereka *et al*., 2021).

Aflatoxins are of great concern to public health because of their ability to accumulate in the body, animal food products such as milk and eggs, in human maternal breast milk and maternal cord blood (Salas *et al.,* 2022). The adverse health effects of exposure to acute or chronic levels of aflatoxins in the diet relate to the ability of aflatoxins to react with cellular and nuclear proteins thus interfering with protein formation and maintenance of cellular integrity and function (Kamala *et al.,* 2015). The liver is the principal target organ for aflatoxins in the body and aflatoxins B_1 (AFB_1) have been extensively linked to human primary liver cancer in which they acts synergistically with hepatitis B virus (HBV) infection (Zhao *et al.,* 2022). However, aflatoxins have been reported to adversely other vital body organs such as the lungs, kidneys myocardium and brain in various animal species (Zhou *et al*., 2022).

Exposure to aflatoxins can lead to health-related complications; acute and chronic aflatoxicosis. Large doses of aflatoxins lead to acute poisoning (aflatoxicosis) that can be threatening, usually through liver damage. Long-term or chronic exposure to aflatoxins has several health consequences, such as immune suppression, mutagenicity, carcinogenicity, and children may become stunted (WHO, 2018). Aflatoxins contamination and aflatoxicosis outbreaks are very common in the East African regions (Kimanya, 2015). Aflatoxins contamination and aflatoxicosis outbreaks have been reported primarily in Africa and Asia following ingestion of highly contaminated maize. For instance, in November 2019, five brands of maize flour in Kenya were recalled due to aflatoxin contamination (Mutahi, 2019) and multiple aflatoxicosis outbreaks have been documented in Kenya since 2004, resulting in nearly 500 acute illnesses and 200 deaths (Kang'ethe *et al.*, 2017).

A recent outbreak of aflatoxicosis in the central zone of Tanzania (Dodoma and Manyara regions), affected 68 people resulting in 20 deaths and several others being hospitalized (Kamala *et al.*, 2018). The study found that maize was heavily contaminated with aflatoxins (362 ppb), over 300 times the recommended safe limit of 10 ppb acceptable levels that set by TBS limits in the country (Kamala *et. al.*, 2018).

1.1.3 Maize Production, consumption and awareness of aflatoxins in the country

Agriculture value chains link urban consumption with rural production (Jonson *et al.*, 2018). The value chain analysis has gained considerable importance in recent years because of the need to assess safety issues and quality along the value chain (Wilson and Lewis, 2015). Maize accounts for more than 70% of Tanzania's annual cereal production, and smallholder farmers contribute more than 85% of total national cultivation (URT, 2017) Tanzania ranks among 19 top maize producing countries in the world and the first in East *Africa* (Maziku, 2019). Maize production in 2019 was 6200 thousand tonnes, up from 637 tonnes in 1970 to 6200 thousand tonnes in 2019, growing at a 6.63 percent annual rate (URT, 2019).White maize is the most common staple grain consumed, and approximately 40% of maize produced is sold primarily to the local market (Mtaki, 2019).

The level of awareness and knowledge of aflatoxin among people in the country is very low. About 80% of individuals interviewed in different regions were not aware of the aflatoxin contamination (Ngoma *et al*., 2016). Tanzania launched a five-year project in June 2018 that seeks to control Aflatoxin. The project dubbed 'Tanzania Initiative for Preventing Aflatoxin Contamination' (TANIPAC) under the Ministry of Agriculture. Among the objectives of the project is to improve pre and post-harvest infrastructure, technology and management as well as to improve public awareness of aflatoxins (URT, 2017).

1.2 Justification

Aflatoxin contamination has become a global issue and is important to farmers (producers), marketers, processors, and consumers because of its implications on the quality and quantity of maize produced and marketed. According to FAO (2015), developing countries are unable to sell large quantities of maize produced on the international market because of mycotoxins contamination, which does not meet the safety regulations, also, has effects on the health of those who consume the food. It is important to undertake research that can provide an estimate of the levels of contamination in the country associated with quality improvement activities. Climatic factors and poor post-harvest practices reported to contribute to fungi infestation and subsequent production of aflatoxin in crops (Suleiman *et al*., 2017). Moreover, various studies carried out in Tanzania indicated that 25 – 45% of maize stored at the household level contaminated with aflatoxins (Massomo, 2020 and Mtega *et al*., 2020).

Because foods in rural areas are consumed with little food safety inspection, there is a risk that maize flour processed and consumed at the household level will be contaminated with aflatoxins (Jonson *et al*., 2018).Immune suppression, stunting in young children, liver cancer, and death are among the risks associated with eating aflatoxins-contaminated maize (Kimanya *et al*., 2015; Shirima *et al.*, 2015).

Despite the fact that various measures such as Good Agricultural Practices, combined with Good Manufacturing Practices have been implemented to combat the problem in various regions, the implementation of these preventive measures is not well known (Massomo, 2020), so there is a need to know the current status of aflatoxins contamination awareness in vulnerable regions such as the Dodoma region As a result, the study aims to determine the current levels of AFB_1, assess awareness of aflatoxins contamination along the maize supply chain (smallholder farmers, traders, and consumers), and evaluate different post-harvest handling practices used by smallholder farmers in Dodoma's Chemba and Kondoa districts. The study area was purposively selected due to reported incidences of aflatoxins contamination. The generated information notifies the impacts of those measures adopted to reduce the level of contamination, stipulates the necessity of more efforts to alleviate the problems, and finally addresses food safety to key stakeholders in the maize market chain.

1.3 Objectives

1.3.1 Overall objective

The main objective of this study was to determine levels of aflatoxins B_1 contaminations and assessing awareness of aflatoxins contaminations in maize along the maize supply chain in Chemba and Kondoa districts, Dodoma Region.

1.3.2 Specific objectives

The specific objectives of the study were to:

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

ii. Assess post-harvest handling practices among maize farmers in Chemba and Kondoa districts of central Tanzania.

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CHAPTER TWO

Paper One

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

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2.1 Abstract

Aflatoxins B1 contamination levels in maize and awareness of aflatoxins among main maize stakeholders in Chemba and Kondoa Districts, Tanzania) Maize (Zea mays) is the staple food for the majority of people in Tanzania, which plays a key role in subsistence and a cash crop among actors of the maize value chain. Environmental factors such as soil contamination by fungi, water stress, warm and humid conditions are among several factors contributing to fungal growth and aflatoxins contamination in maize, leading to significant economic loss, reduced household income, health problems to humans and animals and interferes with food security to communities. Structured questionnaires were used to collect information on awareness associated with aflatoxins contamination in maize from 160 smallholder farmers, 160 consumers and 60 traders in Kondoa and Chemba districts in Dodoma Region. A total of 90 maize samples (40 from smallholder farmers, 30 from consumers and 20 from traders) were analyzed for AFB_1 using immunoaffinity high-performance liquid chromatography (HPLC) type Agilent Technologies 1200 serial. Data were statistically analyzed to assess awareness levels among maize main stakeholder and to check the current levels of aflatoxins B1 contamination in the study community. AFB_1 was detected in five samples. About 3.3% of the contaminated maize had AFB_1 levels above TBS acceptable levels (5 µg/kg). The highest mean concentration of AFB_1 was in maize samples taken from traders with a mean of 9.88±5.904 µg/kg. The majority 56% of smallholder farmers and 52% of traders were aware of aflatoxins contamination and associated health effects on animals and humans. However, 74% of consumers were unaware of aflatoxins contamination in maize. The levels of contamination are low in the sample taken along maize value chain. An effective and broad awareness programme for community especially consumers on good management for prevention of aflatoxins contamination is necessary, as maize is the most consumed grain in the study area.

Key words: *Aflatoxins contamination, smallholder farmers, consumers.*

2.2 Introduction

Agriculture accounts for 26.7% of Tanzania's GDP and provides employment for majority of the nation's population (FAO, 2020). The safety of food is a pervasive concern of general public health and government authorities' worldwide (Logrieco *et al.,* 2018). However, fungi producing a poison that contaminates foods crops are often found on the most important staple crops. Increasing awareness of its occurrence and contamination is important to all stakeholders due to adverse effects on human and animal health (Wild *et al.*, 2012).

Fungi are capable of producing hundreds of secondary metabolites but only a relative few are regulated (Ostry *et al.,* 2017). These metabolites include the widely regulated mycotoxins such as aflatoxins, fumonisins, trichothecenes (particularly deoxynivalenol), ochratoxins and zearalenone. Other mycotoxins that are less regulated include the ergot alkaloids, patulin and the T-2 and HT-2 toxins (Logrieco *et al.,* 2018). The three main genera of fungi that produce mycotoxins and toxigenic are *Aspergillus*, *Fusarium*, and *Penicillium*, that attack various food commodities. Aspergillus spp. is fungi that produce a group of toxins known as aflatoxins (Guchi, 2015). Specifically, *A. flavus* is the major aflatoxins producing species, which predominately contaminates maize (Samson *et al*., 2014; Iqbal *et al.,* 2015; Seetha *et al*., 2017).

Aflatoxins B_1 (AFB_1), the most potent of the aflatoxins is classified as a human carcinogen (Adekoya *et al*., 2017) and has been associated with child growth impairment, suppressed immune function, and death due to acute poisoning known as aflatoxicosis (Salano *et al.,* 2016; Shirima *et al.,* 2015). In 2016, death resulting from acute aflatoxicosis has also been reported in Tanzania and there were 68 cases of acute aflatoxicosis and 20 related deaths in central Tanzania (Manyara and Dodoma) (Kamala *et al.,* 2018).

In Tanzania, maize is the most important staple crop for the majority of the population and a major component of feed for livestock (URT, 2016). Smallholder farmers produce over 85% of the total national cultivation of maize, and production is growing at an average annual rate of 6.44% in 2020 (URT, 2020); it also serve as a source of 30% of dietary calories to millions of population (FAOSTAT, 2020). The majority of smallholder farmers produce maize as food and cash crop while consumers prefer white dent corn with a negligible amount of yellow corn grown in Tanzania (Mtaki, 2019). Thus, maize is important and therefore deserves adequate and effective monitoring in its production chain (Nyirenda *et al.,* 2021).

A recent review suggests that about 60 to 80% of the global food crops are contaminated with mycotoxins (Eskola *et al*., 2020). This estimation pushed back the widely cited 25% estimation attributed to the Food and Agricultural Organization (FAO) of the United Nations (WHO, 2018). Nonetheless, these figures are surprising because a large proportion of the world's population is faced with the risks associated with exposure to aflatoxins causing significant economic losses (Wu, 2015); interfered with food security; significant decline in agricultural trade between developed and developing countries (WHO, 2018).

In many developing countries, levels of aflatoxins awareness are extremely low or non-existent altogether. Awareness has been found to vary with various socioeconomic characteristics. For instance, in Tanzania, studies have shown that education level has a positive effect on aflatoxins awareness (Ngoma *et al.,* 2017; Magembe *et al.,* 2017). In Kenya, women were found more informed of the danger of fungal toxins and cautious to moldy feeds than men (Kiama *et al.,* 2016). Furthermore, in Vietnam, young farmers (at age of 21– 29) were more informed of aflatoxins in crops than the older groups (Lee *et al.,* 2017). The field of study particularly life sciences had a positive impact on aflatoxins awareness in Ghana (Ayo *et al.,* 2018) while individuals in other occupations are more informed of aflatoxins than farmers in Ethiopia (Ephrem *et al*., 2014).

Detection and quantification of aflatoxins levels in human food are important to compare levels of contamination with the recommended maximum residue limit (MRL), so that appropriate remedial action and preventive practices of aflatoxins contamination during handling and storage of foods can be implemented (Udomkun *et al.,* 2017). Aflatoxins contamination in maize can only be accurately quantified with laboratory testing along maize value chains, and hence significantly reduce risks of aflatoxins exposure (Hoffmann *et al.,* 2018). Therefore, the study aimed at assessing awareness of aflatoxins among stakeholders and determining the current levels of aflatoxins in maize stored among stakeholders in Chemba and Kondoa districts of Dodoma region.

2.3 Materials and Methods

2.3.1 Study design, sampling procedure and sample collection

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

2.3.2 Study area

The study was conducted during the 2020-2021 cropping season in the semi-arid agro-ecological zone (Kondoa and Chemba districts) of Dodoma Region (Figure 2.1). Kondoa District lies between latitude 4° 12` to 5° 38` South and longitude 35° 6` to 36° 2` East. Chemba District lies between 5° 14` to 36° 00` South and longitude 35° 53 to 24° 00 East. Its climate is wet savannah characterized by a long dry season (DEPRP, 2012). The districts were selected due to physical attribute and multiple threats experienced annually rendering their communities at risk. The main threats affecting the districts include drought, deforestation, soil degradation and hunger conditions which impose a pattern of risk evasion in traditional agriculture (URT, 2017). Furthermore, the reported epidemic of aflatoxicosis in 2016 (Kamala *et al.*, 2018) and the presence of the conditions conducive to the formation of aflatoxins production is another issue (Ngoma, 2019).

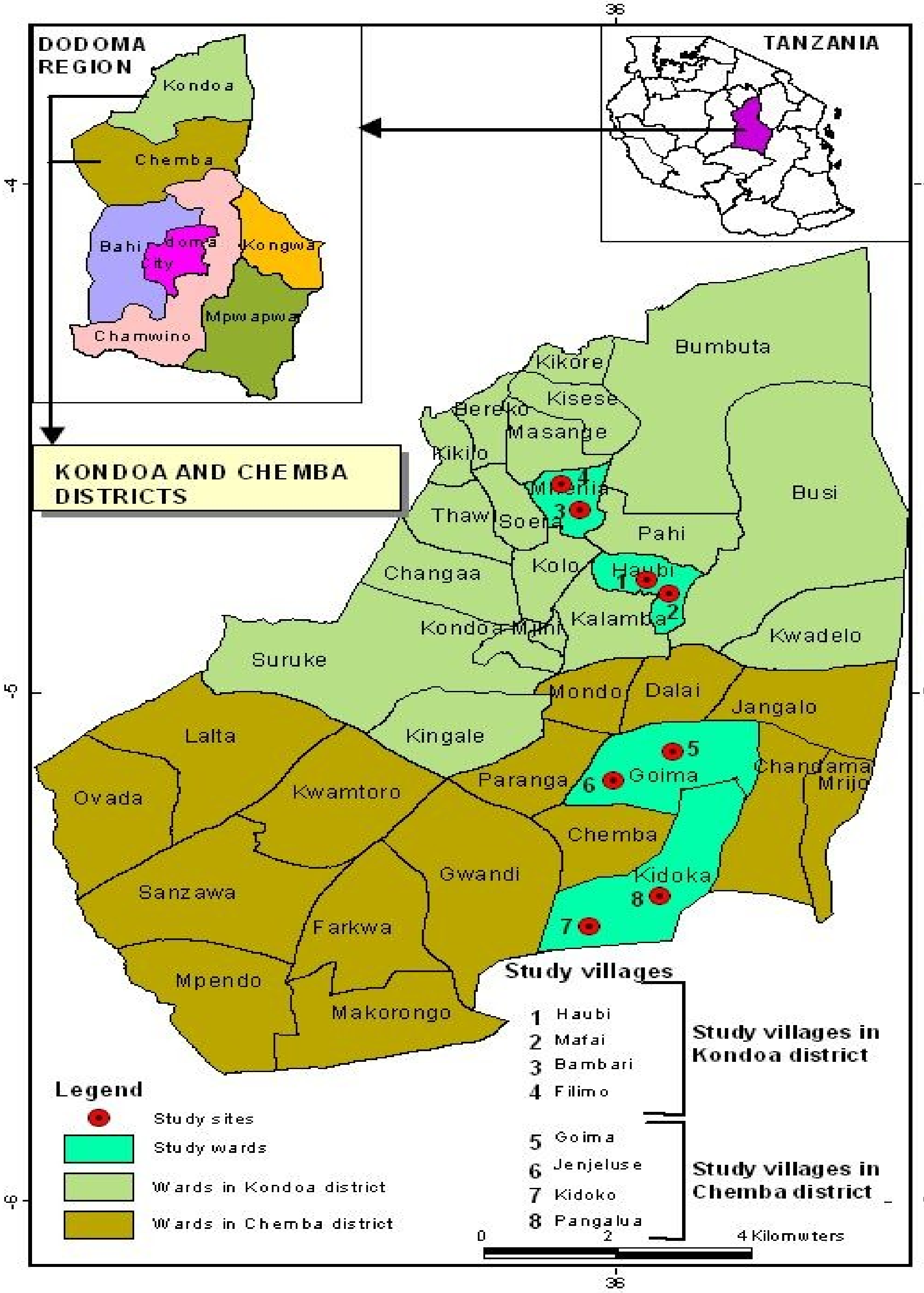

Figure 2.1: Map showing study sites in Kondoa and Chemba districts

2.3.3 Sample size estimation

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

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

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

Thus, the sample size of the study for assessment of awareness among stakeholders was: $n = 1.96^2 \times 0.5\ (1 - 0.5)/0.05^2$ n = 384 for respondents for interview.

And for samples used in determining the aflatoxins contaminations, maximum allowable error of 0.05% was used thus, the sample size of maize for analysis was: n =1.962 × 0.05 $(1 - 0.05)/0.045^2$ n = 90 for maize sample for aflatoxins analysis

2.3.4 Data collection tools

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

2.3.5 Aflatoxins analysis

2.3.5.1 Chemicals and standards, HPLC conditions and other materials

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

HPLC with a fluorescence detector (FLD) (Model Agilent ChemStation technology, series 1200, 5301 Stevens Creek Blvd, Santa Clara, CA 95051, USA). The HPLC system was equipped with a G1322A degasser, and a G1311A Quat pump. Chromatography separation was achieved by Zorbax 20 Rbax RX C18 column 5 µL particle size L × 1.D (250cm × 4.6 mm) (Agilent, USA) and maintained at 30°C and a flow rate of 1.2 ml/min. The analytical separation of aflatoxins (AFB_1, AFB_2, AFG_1 and AFG_2) was performed using the mobile phase contained water: methanol: acetonitrile (60:30:10, v/v) for both standard solution and sample extracts. After separation, AFG_1 and AFB_1 were derivatized to allow their detection with a fluorescence detector at an emission wavelength of 465 nm and an excitation wavelength of 360 nm.

2.3.5.2 Extraction of samples

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

2.3.5.3 Dilution stage

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

2.3.5.4 Clean-up of aflatoxins

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

2.3.5.5 Elution stage

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

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

The LOD and LOQ were established by analyzing successive lowest dilutions (0.1 µg/kg) of the standard solution in the matrix. These LOD and LOQ values were related to the signal to noise ratio considering the concentration generated at 3 and 10 times, respectively of the lowest calibration point. The limits of detection (LOD) and quantification (LOQ) of the HPLC method for AFB_1, AFB_2, AFG_1 and AFG_2 were 0.1 and 0.5 µg/kg, respectively. The precision of the method was determined by running the lowest standard of 0.1 ng/mL ten times for three days and precision was determined by calculating their relative standard deviation. The measurement uncertainty, expressed as relative standard deviation (RSD) was 1.402% and this is within the acceptable range of < 2.4%, ISO 16050:2003.

2.3.6 Data analysis

Statistical Package for Social Sciences (IBM SPSS® Version 20, Minnesota and USA) was used to analyze the obtained data. The analysis involved descriptive statistics to describe the sample population, socio-demographic of respondents and awareness of aflatoxins contamination of maize. The chi-square test was used for testing the association between study independent variables and dependent variable (aflatoxins contamination). Laboratory analysis data was entered and processed using Excel sheets and analyzed using R software (version 4.1.0, 2021) whereby Friedman’s test was used to test for significant differences between the combination of the type of stakeholder and districts in aflatoxins concentration from the maize grain samples. A probability value less than 0.05 was considered significant and the mean separation test was done using the Turkey HSD test.

2.4 Results

2.4.1 Recovery of aflatoxins B1

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

2.4.2 Social - demographic characteristics of respondents

Results in Table 2.1 show the socioeconomic characteristics of the respondents. Over 90% were married giving an indication of the importance of the marriage in the study area. About 75% of all stakeholders, that is smallholder farmers, traders and consumers completed at least primary school education indicating a measure of literacy.

Table 2.1: Socio-demographic characteristics of interviewed respondents (n=380)

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

Source: (Author survey, 2021)

2.4.3 Stakeholders' level of awareness on aflatoxins in maize contaminations

The overall score (Figure 2.2) indicate that more smallholder farmers and traders and a few consumers are aware of the occurrence, cause and effect of aflatoxins contamination in maize in Kondoa and Chemba districts.

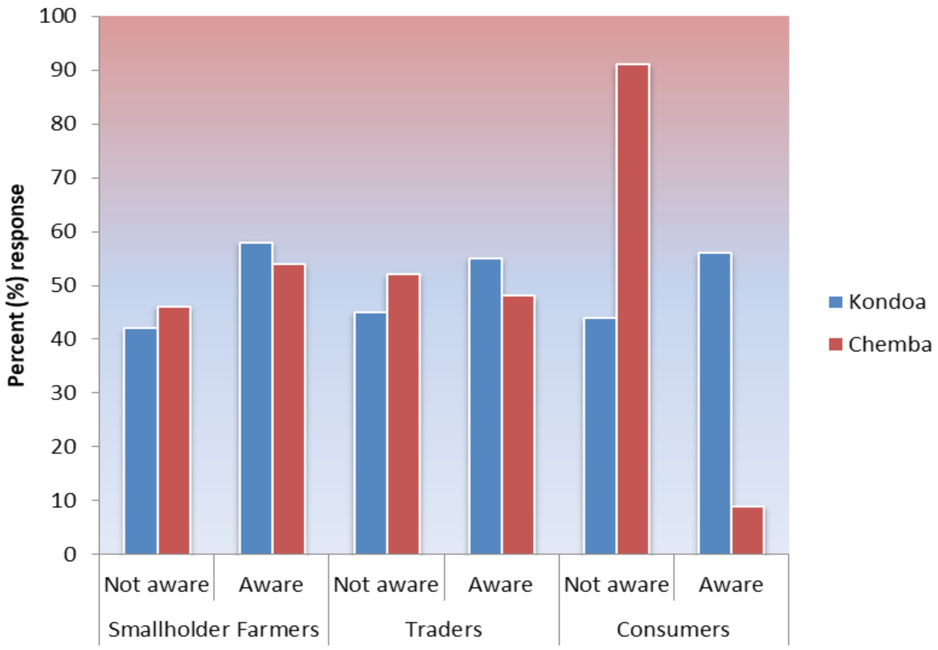

Figure 2.2: Respondents' overall score on awareness of aflatoxins contamination in maize

2.3.4 Aflatoxins contamination in maize samples

The mean values of aflatoxins AFB_1 and total aflatoxins in farmer, traders and consumer's maize samples ranged from 0.00±0.000 to 9.88±5.904 as shown in Table 2.2. The highest mean value for total aflatoxins was in traders' maize samples. However, there was a significant difference between the means at $p<0.05$. A higher number of samples were taken from smallholders farmers due to the availability of samples that is normally stored for sale at a higher price later. Mean ± SEM across the column with different statistical letters indicates statistical difference according to the Turkey HSD test.

Table 2.2: Mean aflatoxins concentration (µg/kg) in maize grains samples collected from different stakeholders in Kondoa and Chemba Districts (Mean ± SEM)

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

Mean ± SEM across the column with different statistical letters indicates statistical difference according to the Turkey HSD test.

2.3.5 Incidence of aflatoxins B1 contamination in maize grain samples that exceeding EU and TBS regulatory limits

Few samples were contaminated with AFB_1 (Figure 2.3), Samples from Filimo and Mafai wards did not detect to $AFB_{1,}$ also Jengeluse and Goima wards didn't detect for aflatoxins B_1 contaminations

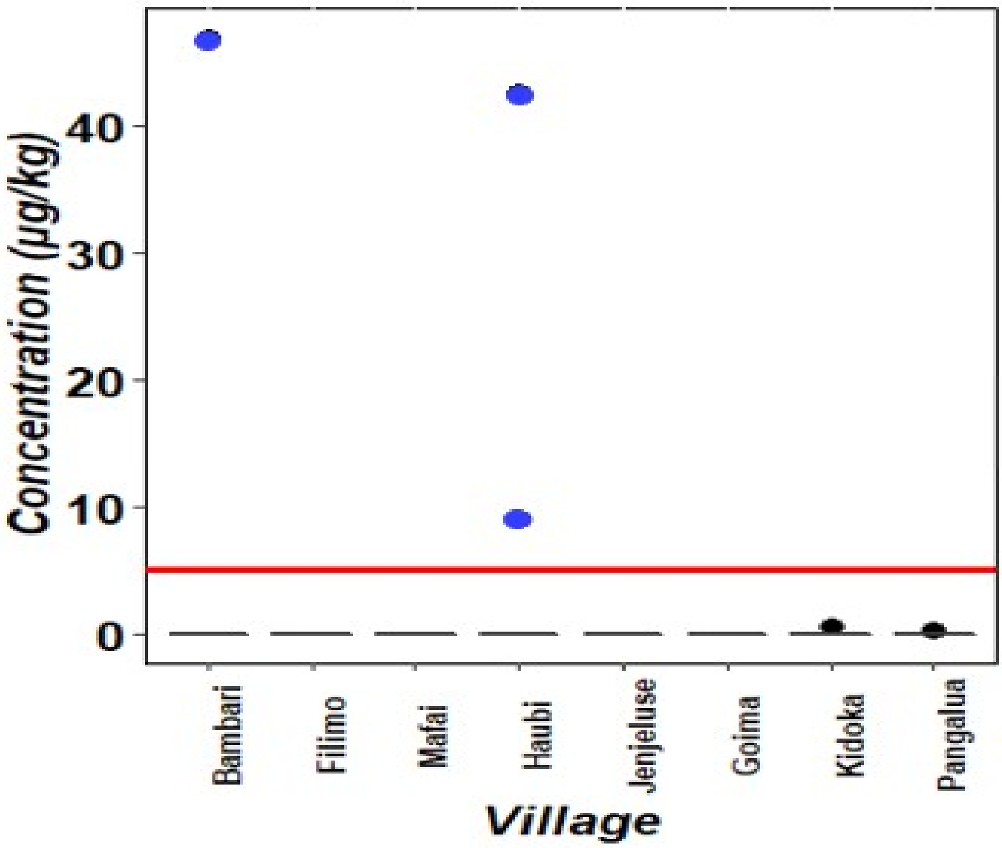

Figure 2.3 Incidence of aflatoxins B1 and total aflatoxins contamination in maize grain samples exceeding TBS regulatory limits

2.4 Discussion

2.4.1 Social-demographic characteristics of respondents

Generally, the study found that the number of males who participated in the study exceeded that of female. The male participants were 61% (Smallholder farmers 55%, Traders 89% and Consumer 59%) (Table. 2.1) while the female participants were 39%, this implied that male respondents were dominating the main supply chain. In the study area, traditional farming activities are dominated by women because it’s a tedious work.

Women in nature are tolerant as being seen in the way of taking care of the family hence, traditional believed that farming activities are women work. Lack of permanent market to sell maize was the reasons for men to engage in trading activities. Male respondents were dominating in trading activities, a trend found mostly in many developing countries actively engaged in trading activities and in providing information. A similar trend was observed by Toma (2019) in Ethiopia who found that farming activities and trades are dominated by males.

The study also noted that more than half (53%) of smallholder farmers were aged above 45 years of age. On the other hand, the majority (78%) of traders in the study area were aged between 36 – 45 while, the mean duration of involvement in the maize business was 8 years; Most (67%) of consumers were in the age group between 20 to 45 years old. This finding implies that maize value chain is a demanding activity; therefore, those involved ought to be physically energetic and able to supply the required labour so as to meet their responsibilities and goals.

Descriptive statistics showed that the majority (88%) of smallholder farmers interviewed had primary school education, 70% of traders had attained primary school education; while 67% of consumers had attained primary school education. These findings show that farmers, traders and consumers had at least a basic primary level of education. These imply that the majority of respondents were able to follow training and instructions as they could read and write in Kiswahili. Education may help them read and understand guidelines associated with occurrence, causes, health effects and prevention of aflatoxins contaminations. These findings conform to the study by Aulakh and Regmi (2013) who suggested that smallholder farmers and traders with at least basic education are needed to reduce food losses.

2.4.2 Stakeholders' level of awareness on aflatoxins in maize contaminations

This study revealed that level of education was directly related to aflatoxins contamination awareness. Maize value chain is highly dominated by Smallholder farmers, whose education level was primary school (88%) and very few respondents (<10%) in this category did not hear of aflatoxins contaminations in their lifetime. Awareness of aflatoxins contamination in maize was high among smallholder farmers (58%) and traders (55%), while it was low (42%) among consumers in Kondoa District. Similarly, smallholder farmers' awareness was 54%, traders 48% and the lowest (9%) among consumers in Chemba District.

The stakeholder farmers' knowledge of aflatoxins in a large amount is attributed to farmer field schools and training conducted with agricultural extension officers in the study area. Similar studies by Kamala *et al.* (2016) and Hell and Mutegi (2011).

According to Massomo (2020), the high level of awareness found in the area is attributed to the information that was communicated on contamination of food commodities, acute poisoning and deaths due to aflatoxins, during the outbreak in 2016. However, this conclusion is contrary to the studies done in Tanzania by Degraeve *et al.* (2016), Magembe *et al.* (2016) and Shabani *et al*. (2015) who found low level of awareness before the outbreak of the death related to aflatoxins. Traders scored higher than consumers (Figure 2.2) may be due to regular training on aflatoxins contamination, seminar and workshops. Similar observations were reported by James and Zikankuba

(2018) that training, seminar and workshops on aflatoxins increase awareness of maize traders.

Likewise, a study conducted in Kenya found that most (56.6 %) traders were aware of aflatoxins contamination (Nyangaga, 2014). Furthermore, analysis shows that consumers (this categories mixed up with different field of people such as smallholder farmers (72%), primary school teachers (10%), secondary school student (10%) and entrepreneur, housewife were (<8%) had low awareness compared to other groups. Possible explanation for this observation is clearly depicted in this study. Education was an important mode of dispensing information and knowledge on aflatoxins contamination to public. This observation reflects Kamala *et al.* (2018) and Ezekiel *et al.* (2013) who reported the lowest (15%) level of consumers' awareness of aflatoxins contamination. This implies low public awareness of aflatoxins contamination affects mainly people from remote areas who have less access to information on aflatoxins as compared to those in urban areas. Respondents from Kondoa District were more aware compared to Chemba respondents, this is not unique as previous studies (Kimanya *et al*., 2014; Magembe *et al*., 2016) reported that in Tanzania, awareness of aflatoxins and health impacts varied between districts. The finding implies that the presence of projects dealing with aflatoxins in the districts and stakeholders' commitment and ability to implement the practice might have contributed to this awareness.

2.4.3 Aflatoxins contamination in maize samples

Findings in this study reveal the significant occurrence of important aflatoxins in main actors' samples in these districts maize supply chain. This is important because maize is dietary staple food in these districts affected by the aflatoxicosis outbreak, aflatoxins contamination from traders' samples therefore, is an important public health concern and these toxins may pose significant human health risks that may be increased by occurrence in the diet. Table 2.2 indicates that out of 90 maize grain samples collected from various villages in three different stakeholders in the maize value chain from the study area, five (5) samples were contaminated with aflatoxins B_1. Moreover, a high prevalence with AFB_1 were found in the samples taken from traders, there were low concentration detected in samples from smallholders' farmers while none of the consumers' samples was detected for aflatoxins contamination.

The lower levels of aflatoxins contamination in farmers' maize samples, probably was due to environmental conditions, such as change in temperature and relative humidity of surrounding as well as a good type of soil. Since the moulds live in soil, surviving off dead plant and animal matter, but do spread through the air via airborne conidia are the natural factors that influence aflatoxins incidence during maize production (Atanda *et al.,* 2013) good farmers' practices such as timely harvesting, ensuring uniform drying of maize to a safe moisture level and proper storage is critical in the maize value chain. Storage at less than 13% moisture content, 65% relative humidity and temperature of less than 25^0C prevents the growth of storage moulds (Ademola *et al.*, 2021). Despite contamination increases with time in storage, the majority of the samples used in the analysis were stored in good condition for eight months at the farmers' store (Monyo *et al.,* 2012; Ezekiel *et al.,* 2013).

The samples collected from traders demonstrate that mean levels of aflatoxins B_1 in stored maize was significantly higher compared to other actors (smallholder farmers and consumers). The drastic increase in aflatoxins probably was because traders usually purchase maize from different locations, different storage facilities as well as different maize varieties, which may also have aflatoxins contamination. Frequent opening and improper closing of the storage facilities could also add moisture from the atmosphere and thus the quality of dried grain be affected by the variation in final moisture content during storage. Besides, efforts to address the issue of aflatoxins prevention program was geared very much to smallholder farmers and not traders and consumers.

The prevalence of aflatoxins contamination obtained in trader's samples was significantly high which indicates the risk of chronic exposure to the consumers. The findings are similar to the study by Oyekale and Oladele (2012) who noted that traders' maize samples were contaminated with higher mean levels of aflatoxins B_1. Therefore, to ensure high quality during storage, maize should be protected from weather, growth of microorganisms, and insects (Oyekale and Oladele, 2012). AFB_1 has been detected more frequently compared to other types of aflatoxins, similar to what was reported by Kachapulula *et al.* (2017) in Zambia that maize samples were contaminated with aflatoxins by 5%. The results of the present study were significantly lower than the study conducted by Dos Santos *et al.* (2013) in Brazil where 16% of the maize samples from farmers were contaminated with aflatoxins B_1 and contrary to Kaale *et al.* (2021) who report high aflatoxins B_1 contaminations in maize samples. Three samples, which were all taken from Bambari and Haubi village in Kondoa District were found to be contaminated with aflatoxins B_1, exceeded the acceptable limits for aflatoxins B_1 of 5 μg/kg (TBS, 2018) with maximum concentrations of 46.99 μg/kg (Figure 2.3) and the concentrations were 42.69,10.11 and 46.99 μg/kg. Furthermore, high levels can occur if rodents and other pest attack and damage maize grain and if storage occurs under unfavorable conditions over long periods of storage.

Two samples (2) of contaminated maize (Figure 2.3) from Kidoka and Pangalua villages in Chemba Districts were found to be below (5 μg/kg) acceptable TBS regulatory limits for AFB_1 and concentrations were 0.29 and 0.51 μg/kg. This supports a study by Ezekiel and Sombie (2014) in Nigeria which found that aflatoxins were present at the internationally recommended level for aflatoxins B_1 and total aflatoxins in the maize sample. Thus, the results indicated that consumers of maize in this area have been at significant risk for exposure to low levels of aflatoxins contaminations.

The present study found low aflatoxins contamination at samples from farmers at levels below the maximum tolerated limit (MTL). Similar to the studies reported by Bonni *et al.* (2021) in Tanzania, and Kamika and Tekere (2016) in Congo whose findings indicated a low mean concentration of AFB_1 in maize samples. These observations might be a result of proper is result storage of maize along the maize value chain. Storage at less than 13% moisture content, 65% relative humidity; and temperature of less than 25°C prevents the growth of molds.

2.5 Conclusions and Recommendation

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

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CHAPTER THREE

Paper Two

3.0 Assessment of Post-harvest Handling Practices among smallholder maize farmers in Chemba and Kondoa Districts of Central Tanzania

A manuscript accepted for publication in Journal of Stored Product and Post-harvest Research

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3.1 Abstract

Post-harvest losses are recognized as an important challenge that exacerbates food insecurity in sub-Saharan Africa. The objective of this study was to assess post-harvest handling practices among smallholder farmers of maize in Chemba and Kondoa districts, Dodoma Region, Tanzania. During the 2020-2021 cropping season, data were collected using questionnaires and observation checklists in a cross-sectional field survey of 120 smallholder farmers chosen at random for the study. Results show the majority (75%) of smallholder farmers use traditional post-harvest handling practices such as harvesting maize and placing it on the ground, drying (on the ground) and storing it in polyethylene bags. Moreover, very few farmers 25% are aware that improper handling practices cause post-harvest losses. The findings revealed that the use of traditional post-harvest practices is not influenced by age at ($\chi2$ = 6.268, P = 0.989) and level of education at ($\chi2$ = 1.599, P =1.000). It was concluded that, inadequate knowledge of proper post-harvest practices in the study area, may affect the quality of maize grains. Improving post-harvest management practices such as using technologies (moisture meters, portable dryers and hermetic storage devices) could help to reduce PHLs of maize and hence contribute to reducing poverty and food insecurity in the country.

Keywords: Aflatoxins contamination, maize, smallholder farmers, post-harvest handling practices, Tanzania.

3.2 Introduction

Proper post-harvest handling practices are important in maintaining grain quality and safety while being brought to consumers and meeting trade requirements. However, lack of knowledge among smallholder farmers and other factors along the value chain remains a major challenge to reducing post-harvest loss and maize grain contamination by aflatoxins in Sub-Saharan Africa (SSA) (Kachapulula *et al.,* 2017).

Weather conditions and poor posh-arvest management practices have been reported as major factors in fungi infestation and subsequent production of aflatoxins in crops (Suleiman *et al*., 2017). Furthermore, various measures such as Good Agriculture Practices (GAPs) such as timely planting and harvesting, the use of resistant crop varieties, good storage (at controlled humidity and temperatures), and Good Manufacturing Practices (GMPs) (sorting, washing) have been reported to be beneficial in combating the problem of PHLs and mycotoxins contamination in grains (Massomo, 2020). However, the implementation of these measures is not well understood by the majority of smallholder farmers in SSA.

Post-harvest losses (PHLs) continue to be a problem in Africa; according to the World Resources Institute, approximately 23% of available food in SSA is lost or wasted (Global Knowledge Initiative, 2014). According to FAO, around 2 million African smallholder farmers would benefit in terms of income and increased food and nutritional security through the reduction of PHLs (FAOSTAT, 2015).

Maize (*Zea mays*) is a major food staple in Tanzania, and its production is dominated by small-scale farmers, who constitute about 75% of the total production (URT, 2019). It is widely cultivated all over the country. Maize accounts for 31% of the total food production, constitutes more than 75% of cereal consumption and contributes about 34% to 36% of the total average daily calorie intake in Tanzania (Zorya *et al.,* 2011). In the country, maize used is to prepare a variety of meals including '*Ugali'*, *'Makande'*, porridge and traditional alcohol. The importance of maize in Tanzania suggests that serious efforts must be made to reduce crop losses at all levels, especially in the post-harvest part (Suleiman and Rosentrater, 2015).

The problem of food shortages in developing countries could be overcome through the use of a variety of modern agricultural technologies (URT, 2012). Experience shows that the Tanzanian government's efforts to improve the agriculture sector have resulted in increased food crop production, including maize. Despite the increased maize production, periodic food shortages have been experienced, one of the reasons being PHLs of cereals such as maize (Twilumba *et al.,* 2020). In Tanzania, PHL remains serious and a persistent challenge; the current level of PHL of maize is 20% to 40% in some rural areawhich has a significant impact on the food security and economy of the smallholder farmers (Maziku, 2019).

Improving post-harvest management practices could help mitigate losses along the maize value chain and contribute to poverty reduction and food insecurity in the country. Farmers must have access and understanding of good post-harvest practices in order to ensure food availability throughout the year. Good post-harvest practices include proper harvesting and drying practices, good transport infrastructure; and the use of improved storage technologies, such hermetic storage bags and metal bin/silo. This could help to decrease the problem of PHLs in Africa (Twilumba *et al.,* 2020). The study's findings will help smallholder farmers reduce PHLs as a result increase food security furthermore, data would guide the selection of better intervention steps in order to ensure public safety.

3.3 Materials and Methods

3.3.1 Study area

The study was conducted in Kondoa and Chemba districts in the Dodoma region, Tanzania (Figure 2.1). All other information is obtained in chapter 2.3.2. Multiple threats affecting the districts, including drought, deforestation, soil degradation, and hunger, impose a pattern of risk evasion in traditional agriculture (URT, 2017), an outbreak of aflatoxicosis in 2016 (Kamala *et al.*, 2018), and climatic conditions that favor the growth and development of aflatoxins (Ngoma, 2019).

3.3.2 Research design, sampling procedure and sample size

This study adopted a cross-sectional research design and a multi-stage sampling technique as suggested by Etikan and Bala (2017). First, the district and wards were purposively selected based on the reasons stated above. Secondly, simple random sampling was employed to select study villages, namely Haubi, Mafai, Filimo, Bambari, Kidoka, Pangalua, Jenjeluse and Goima. Thirdly, one hundred and twenty (120) respondents, fifteen (15) households from each village were randomly selected from smallholder maize farmers.

3.3.3 Data collection procedure and instrumentation

Data was collected in face-to-face interviews with respondents by using a semi-structured questionnaire, which were all pre-tested for improvement before actual data collection. The statement-wise analysis was carried out to determine the most post-harvest practices applied by respondents; nineteen statements were used to measure respondents' understanding of post-harvesting practices as shown on INPhO-Post-harvest Compendium (Mejia, 2013). For each statement, respondents were required to indicate their position concerning their level of understanding of the content contained in the statement by writing one (1) for poor practice, two (2) for moderate practice and three (3) for high practice. If one practice was marked poor for each of the 19 statements, it would have scored 19 (i.e. 1 × 19); if one practice was selected moderate for each of the 19 statements, it would have scored 38 (i.e. 2 ×19); and if one practice was selected high for each of the 19 statements, it would have scored 57 (i.e. 3 ×19). Scores were combined to give a score range of 19 to 57.

A score above 19 was considered highly experienced practice, a score of 19 represented moderately experienced practice and a score below 19 indicated poorly experienced practice. The mean score of each practice was obtained by adding the weights given to the standard by each respondent divided by the total number of respondents. The mean score was worked out for each practice and rank positions were assigned based on the mean score obtained after calculation.

3.3.4 Data analysis

The collected quantitative data were coded, entered in Statistical Package for Social Sciences (SPSS), edited and analyzed using the SPSS version 20 Computer software. Descriptive statistics for different measures were performed to compute relative variables. The mean, standard deviation of post harvest handling for each district were computed. A correlation analysis was undertaken to determine which handling practices were found to be common.

3.4 Results

3.4.1 Demographic characteristics of respondents

The socio-economic and demographic characteristics of the smallholder farmers' and their effects on the handling of post-harvest maize management technologies are described. As a result, respondents responded to questions about their gender, age (the actual age of respondents was recorded during data collection and later categorized into groups), levels of education, and land family size, as shown in Table 3.1.

Table 3.1: Demographic characteristics of respondents (n=120)

Variable	Description	Frequency n =120	Percentage (%)
Sex	Male	65	54.2
	Female	55	45.8
Marital status	Married	115	95.8
	Single	5	4.2
Level of education	No education	7	5.8
	Primary education	109	90.8
	Secondary education	4	3.3
Age in years	15 - 35	23	19.1
	36 - 55	62	51.7
	55 < above	35	29.2
Size of a farm in an acre	1 – 5 acre	82	69.3
	6 – 10	24	20
	11 – above	14	11.7

Source: (Author survey, 2021)

3.4.2 Post-harvest handling practices used by respondents

Table 3.2 shows different handling practices used by respondents in the study area. The smallholder farmers in Kondoa and Chemba districts do not have a long chain from harvesting to storage. They only harvest, transport, shell, thresh, clean, dry and finally store the grains for consumption or sale purposes; the grains are typically stored in a living room in the house or a brick and mortar storeroom. Some of the farmers produce only for consumption, while others produce for food and cash crop.

Table 3.2: Responses on the maize handling practices

Category	Description	Percentage (%)
Harvesting	Manual	100
Harvesting operations	Bare ground	85.0
	Tarpaulin	12.5
	Plastic/synthetic B.	1.0
	Raised platform	2.0
Action on unexpected rain	Cover	60.0
	Not cover	24.0
	Protected area	15.5
Sort/clean before storage	No	51.7
	Yes	48.3
Drying	Sun drying	100
Drying days	1 - 10days	27.5
	11 - 30days	32.5
	30 days and above	40.0
Shelling/thresh	Hand shelling	63.3
	Motorized	26.7
	Hand operated machine	9.2
Mode of transportation	Bicycle/ motorcycle	29.0
	Open vehicle	6.0
	By head	35.8
	Animal and wheelbarrow	30.0
Infestation control practice	No	53.3
Use pesticide	Yes	46.0
Storages	Bin/silo	5.0
	Polypropylene bags	88.8
	PICS	5.8
	Kirindo	3.0

Source: (Author survey, 2021)

3.4.3 Post-harvest Practices mostly used by respondents

To establish the extent to which the practice was applied by smallholder farmers. The mean score was worked out for each practice and rank positions were assigned based on the mean score obtained after calculation (Figure 3.1). The number in brackets are the mean scores of each handling practice.

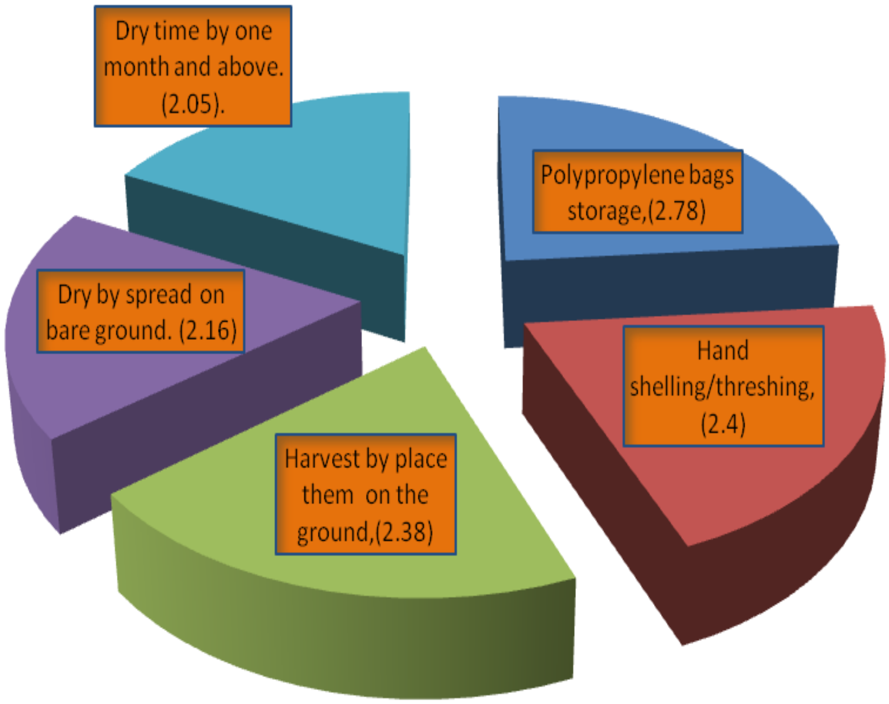

Figure 3.1: Mean score of post-harvest handling practices done by respondents. Total number respondents = 120**.**

Furthermore, general post-harvest maize practices by smallholder farmers were the majority of farmers' used traditional practices in maize handling management (Figure 3.2), implying that poor post-harvest handling practices and low awareness levels among maize farmers. That can lead to post-harvest losses due to poor handling practices and improper management, posing a threat to human food safety. This necessitates interventions aimed at improving post-harvest practices.

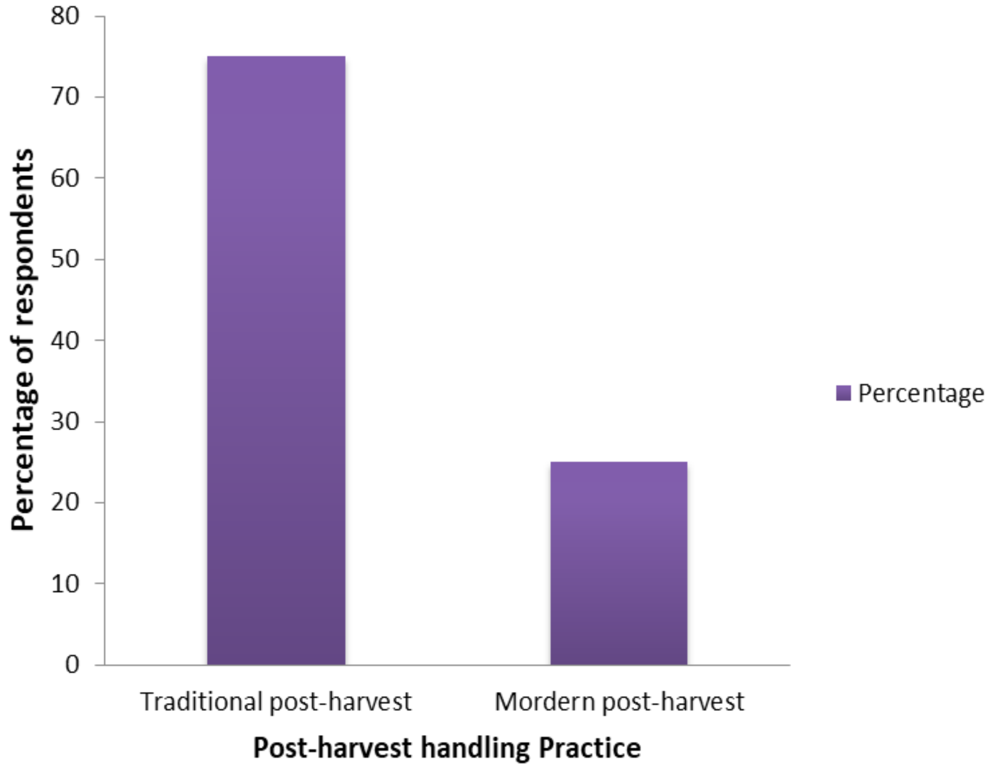

Figure 3.2: General post-harvest maize practiced by small - holder farmers.

3.5 Discussion

3.5.1 Demographic characteristics of respondents

As illustrated in Table 3.1, the majority (95.8%) of the respondents were married, and most (90%) of them had attended primary school education. It is also shown that more than two-thirds (69.3%) of the respondents cultivate one to five acres of land, which is typically characteristic of smallholders' farmers as reported by Mrutu *et al.* (2014) which indicates a high dependence ratio. In addition, the study observed that about 54.2% of the farmers surveyed in both districts were male. This concurs with the finding of Ssebaggala e*t al*. (2016) that males were the most active people in agriculture activities and giving information about post-harvest handling technology.

However, this is contrary to other studies that show the majority of the people involved in agricultural activities in SSA are female (FAO, 2013). The socio-demographic data show that all age groups participate in post-harvest handling practices, with males with low education levels dominating. Hence, the information is significant for targeting the design of post-harvest technologies to the needs of specific users.

3.5.2 Post-harvest handling practices used by respondents

The most common harvesting and post-harvest handling methods were laborious and time-consuming. The analysis of the data acquired also reveals ineffective post-harvest procedures that have the potential to degrade food quality. Poor threshing methods, inappropriate storage facilities, improper drying surfaces, placement of crop storage containers directly on the ground during storage, lack of testing for adequate drying, and poor transportation of maize were all discovered to be common. These findings highlight the need for measures that encourage proper post-harvest management throughout the maize value chain.

3.5.2.1 Harvesting

All farmers (100%) harvest maize by hand or manually (Table 3.2). Due to the economic situation, most smallholder farmers are unable to engage hired labor or machines for harvesting a practice. This leads to either incomplete harvesting or leaving some maize in the field, resulting in post-harvest losses (Dudi, 2014). The majority of the farmers (85%) kept their maize on the ground after harvest on the farm for large farmers and at home for small farmers. This exposes them to pests, soil, and dust that reduce the quality of maize and contribute to post-harvest losses. A similar study in Peru reported that about 90.1% of farmers laid the harvested crop directly on the ground (Diaz-Valderrama *et al.* 2020).

Likewise, in Kenya, Dudi (2014) found over 90% of small-scale farmers in the Eastern province kept the maize cobs on the ground during harvesting, which led to losses of 30-50 percent. Farmers were asked whether they knew how to test for dryness before harvesting and the majority 73% reported using visual assessment while 27% bit them with their teeth. A similar finding was reported in Ghana where farmers check for maize dryness using their teeth by biting (Akowuah *et al*., 2015). Also, Mendoza *et al.* (2017) found that farmers in Guatemala use traditional practices like fingernail and mouth tests to check for maize dryness before harvesting. These techniques are not accurate, and therefore, harvested maize may still have high moisture content that attracts pests and possible contamination by yeast and molds (Kamala *et al.*, 2016).

3.5.2.2 Transportation

For fear of theft, crops were not stored in the field after harvest in surveyed districts. As a result, farmers only harvest the amount of maize they can transport in a single day. Given that the primary mode of transportation from the farm was 35.8% carried by the head, while 30% used animals such as donkeys and cows, and 24% of the respondents use bicycles or motorcycles to transport maize from the farm to home.

Except for a few farmers who own more than 5 hectares of land leaving their maize in the field after harvest is a minority about 6% use tractors truck to transport harvested maize. The use of one method over the others depends on several factors, such as the socio-economic status of the farmer, production capacity, distance, infrastructure and availability of animals. This data suggests that a transportation intervention could help reduce harvest losses before or as crops leave the fields. It is necessary to evaluate the impact of actions aimed at reducing transportation limitations on these field losses.

The study supports the findings by Dudi (2014) who found that maize was transported using different means that included wheelbarrows (33.3%), heads (25%), pack animals (donkeys and cows) (20%) and other means.

3.5.2.3 Drying

The study found that all respondents (100%) used open sun drying for drying maize (Table. 3.2). The study further observed that 65% of respondents dried the maize on bare ground and 12.5% dried it on tarpaulin/canvas sheet/mat. In addition, the study found other different ways of drying, like drying on galleries made at home and on top of corrugated iron roofs. Drying maize down on the floor exposes the maize grain to soil contamination, domestic animals, and bad weather infection, causing both quality and quantity losses as opposed to air-dryers and electric dryers. A similar result was reported by Njoroge *et al.* (2019) that about 65.4% of farmers dried on the ground while 21.7% used tarpaulin for drying.

It was observed that the majority of the respondents (59.2%) dry their maize within 30 days after harvest and about 40% take more than 30 days for drying. The variation was believed to be due to the intensity of the sun. The findings are contrary to what Diaz-Valderrama *et al.* (2020) reported that 71% of the farmers' drying process may take at least seven days when the weather is favorable. Farmers experience difficulties in drying maize because sometimes they experience unexpected rain while the maize is in open space. Rain was mentioned by all farmers as a challenge during the drying period, causing discoloration to grain as a result of mould development and thus aflatoxins contamination. A similar study done by Njoroge *et al.* (2019) found that over half of farmers were challenged by rain during drying their grains.

3.5.2.3 Threshing / Shelling and cleaning

The result indicates a majority (63%) of the farmers use hand shelling or manual shelling of maize. This traditional shelling of maize is done by women and children. It is done either by pressing the grain off the cob by hand, rubbing two cobs together while holding one in each hand, or beating the cobs in a sack with a stick. Threshing losses happened as a result of spillage, inadequate grain removal, or grain damage during the threshing process. These methods are labor-intensive, time-consuming, and may result in broken maize that makes it more susceptible to insect and mould attacks, hence increasing the PHLs of maize. These findings highlight the need to adapt existing technologies to improve their performance, or to create new devices that can recover grain more efficiently and with less grain damage. A small number of respondents 26% use motorized threshers and only 9% use hand-operated machines. In contrast to the findings of this study, Mutungi *et al*. (2019) reported that more than half of the smallholder farmers in the Northern Highlands of Tanzania use mechanical threshers for shelling.

3.5.2.4 Storage

(a) Improved storage practices

The findings in Table 2 reveal that only 5.8% of the respondents use PICS bags and about 5% use silos for storage of maize. Smallholder farmers revealed that bin and silos need space and are expensive to purchase. Maize grains stored in the metal silo are hermetically seal inaccessible to rodents, efficient against insects, and sealed against entry of water; therefore, metal silos are excellent grain storage containers for grains. However, they should be guarded against direct sunlight and other sources of heat and stored in a shaded and well-ventilated environment to avoid condensation (Adejumo, 2013). It was narrated by Okoedo-Okoije and Onemolease (2019) that the high initial cost of improved storage such as silos limited usage among smallholder farmers. Similarly, Kassie *et al*. (2013) reported that the poor adoption of improved storage technologies in India was caused by the high initial cost of the improved storage technologies. This implication is supported further by Ndunguru *et al.* (2016), who found that most (86%) small-scale farmers in Tanzania have limited knowledge of how to use improved storage methods for proper maize grain storage management.

(b) Traditional storage technology

The findings (Table 3.2) show over 80% of the respondents use polypropylene/synthetic bags with or without pesticides to store their maize. The disadvantage of using polypropylene sacks (bags) is that they can be easily destroyed by pests and are not airtight so grains are prone to insects and fungal contamination. This concurs with the finding of Mendoza *et al*. (2017) who observe over 81%of farmers upon drying prefer to store maize in polypropylene bags. It was also observed that only 3% of the respondents use traditional storage structures (*Kilindo*) for the storage of maize. This type of storage is locally constructed and was found in store rooms or living rooms. The minority of respondents 3% from the study area store maize in a homemade gallery. This finding is similar to what was reported by Gitonga *et al.* (2015) and Abass *et al.* (2014) that most African communities still rely on unimproved storage technologies for maize storage because they are simple and inexpensive to construct but cannot guarantee protection against major storage pests and quality product.

3.5.2.5 Insect control

The researchers noted that nearly half of farmers (46%) use pest controls methods, where the most commonly used were chemical pest control (26%) and traditional pest control (20%), while 54% use sun-drying. This could be due to the cost of storage chemicals which was perceived by respondents as relatively high and therefore not affordable for them to buy. However, the effectiveness of traditional insect control methods such as the use of ash, *Shumba* is not known and needs to be evaluated further.

A few smallholder farmers pointed out they were storing their maize in their houses thus making it difficult to apply pesticides or fumigate the living rooms for storage of their maize. These findings are contrary to those of ANSAF (2016) which found that a large proportion of farmers (67.7%) in Dodoma and Manyara districts of Tanzania use storage chemicals. Likewise, Koskei *et al.* (2020) found that (70.7%) use chemical insecticides while 32.5% use ash to control insect infestation.

3.5.3 Post-harvest practices mostly used by respondents

The highest mean score of mostly used handling practices is 2.78 (Figure. 3.1). That means the storage methods mostly used by respondents are "*Polypropylene/synthetic bags as storage practices*". These results reveal that stored maize is a very important subject for sustainable food security in the production of maize areas. It helps the farmers on with their of storing food for future use. However, polypropylene bags are not recommended in post-harvesting practices because they are not airtight hence susceptible to water and are easily accessed by pests and rodents. Moreover, polypropylene bags are considered spillage and easy inspect. The study findings revealed that smallholder farmers were highly practicing this practice, which has a direct negative effect on the quality of the maize produced because the technique is cheaper compared to other storage types.

The second-highest ranked practice used was the way of shelling/threshing of maize, *“That was hand shelling/threshing”* demand (2.40) manual shelling (beating maize in bags). The process is done to loosen the edible part of grain from the straw, which is attached after drying to facilitate easy storage of grain. The practice is not recommended because losses are in terms of broken grains. Then followed by “*harvesting maize and placing it on the ground”* (2.38) which ranked third. This practice was highly practiced because the majority of smallholder farmers use local equipment or traditional ways of harvesting their maize. The practice is unhygienic because it exposes the maize grain to soil contamination and bad weather infections causing both quality and quantity losses; although it is also considered to be slow and time-consuming.

Other practice methods were drying maize “*by spreading on the ground*” (2.16), which ranked fourth and “Time used to dry maize more than one month” (2.05) ranked fifth. These practices were widely implemented because the majority of smallholder farmers are still using traditional post-harvesting handling practices. Additionally, the findings show that 75% of the respondents had used traditional practice on maize post-harvesting processes and only 25% had used modern practice (Figure 3.2). These results imply that about half of the respondents in the study area had practiced traditional post-harvesting. Traditional technologies are poor in maintaining the quality and quantity of stored maize, but most of the smallholder farmers argue that these traditional practices are easy, inexpensive and not safe compared to new post-harvest technologies. This affects the quality of maize as poor post-harvest practices expose the maize grains to the contamination that might cause health effects on humans. Since, maize is a staple crop for many farmers in the country, there is a need to improve and promote post-harvest handling procedures, including the use of modern technology like moisture meters, portable dryers, and hermetic storage devices. Therefore, it is necessary to inform farmers about appropriate post-harvesting techniques to reduce the amount of post-harvest losses in maize production and thus contribute to food security and poverty reduction.

3.5.4 Conclusion

Post-harvest loss is a complicated issue, and its scale varies with different crops, handling practices, climatic conditions, and countries' economies. The majority of harvested maize grains are held in traditional storage structures, which are insufficient in preventing insect infestation and mold growth during storage, resulting in significant losses. Generally, the respondents' post-harvest behaviors were linked to post-harvest losses, indicating that they lacked awareness of optimal post-harvest techniques. However, few of the farmers were aware of improved post-harvest technologies, but could not afford to buy them as they sold at a high price, since their income is very low. Storage losses account for the bulk of all post-harvest losses for maize grains in the study area and hence have a negative influence on farmers' livelihoods. Reduced post-harvest losses and increased farmer revenues can be aided by technological interventions and improved storage structures.

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CHAPTER SIX

6.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS

6.1 General Conclusions

Aflatoxin is a potent secondary metabolite of the fungus *Aspergillus* species mainly *A. Flavus* and *A. Parasticus*. These fungi grow on a wide variety of cereal grains including maize. It can cause cancer, stunted growth, and in extreme instances rapid death in humans. The aim of the study were to assess stakeholders' awareness of aflatoxin contamination in maize (smallholder farmers, traders, and consumers), to assess post-harvest handling practices of maize among smallholder farmers, and to determine the current levels of aflatoxins B_1 contamination in maize in Chemba and Kondoa districts of Dodoma region.

According to the findings of the study, the majority of maize farmers and traders are aware of aflatoxins contamination and its occurrence, causes, and health effects in humans; however, consumers are unaware of aflatoxins contamination in maize. Farmers in Kondoa were more aware of aflatoxins contamination than those in Chemba district.

Contamination of maize by aflatoxins is a serious public health threat that requires attention to ensure that proper actions are taken to limit its health effects. The study revealed a few samples contaminated with AFB_1. 5.6% of samples were contaminated with aflatoxins B_1; out of which 3.3% of samples were found to exceed the Codex Alimentarius and TBS regulatory limits for AFB_1 contamination. All the exceeding samples were taken from traders, and none of the samples taken from smallholders farmers exceeded the maximum regulatory limit for aflatoxins B_1. All samples were found to be below acceptable Codex Alimentarius and TBS regulatory limits for AFB_1 (5 µg/kg) and the maximum concentrations were 0.51µg/kg.

When it comes to food safety, the maize value chain is weak because of its weakest link. A robust, diverse, and integrated approach is required if all areas are to advance in prevention. The prevention strategies should also be taken into consideration by all value chain stakeholders as they would be mainly concerned with the implementation of good storage management practices.

Smallholder farmers had inadequate knowledge of proper post-harvest practices, with some of their practices being associated with post-harvest losses. This affects the quality of maize as poor post-harvest practices expose the maize grains to aflatoxins contamination. It was also found that the majority of smallholder farmers were using traditional post-harvest handling practices such as drying practices (drying on bare ground or drying on top of the iron sheet). Storing maize in compact rooms with poor ventilation. To reduce post-harvest losses in maize production and thus contribute to food security and poverty reduction, smallholder farmers must be informed about appropriate post-harvest handling practices, such as harvesting techniques, drying practices, and improved storage systems.

6.2 Recommendations

Extensive awareness programmes across Dodoma Region of aflatoxins problem and management strategies should be provided to inform farmers, traders, processors and consumers about the risk of toxin contamination.

More efforts are needed to convince smallholder farmers of the use of hermetic storage containers such as PICS bags, which are sold everywhere in the country. Hermetic bags s not only keep mould and aflatoxins at bay, but they also keep moisture out and cereal loss at bay due to grain damage and infestation.

There is a need for interventions through training to build the capacity of maize farmers on proper post-harvest handling techniques such as control of moisture content, prevention of condensation attacks of the grain by insects, appropriate shelling technologies that can reduce damage to grain and other practices that will reduce post-harvest losses in Kondoa and Chemba districts in Dodoma, Tanzania.

Raising public awareness about the importance of GAPs, GMPs, and GSPs in controlling aflatoxins contamination and post-harvest losses in food is critical for ensuring food safety and protecting human and animal health.

APPENDICES

Appendix 1: Questionnaire to assess awareness of aflatoxins contamination in maize among stakeholders and post-harvest handling practices

My name is **ASHA HAMAD NDWATA**. I am a Masters student at Sokoine University of Agriculture I would like to study the aflatoxins contamination in maize in your area. In order to do this, I have a few questions to ask you. Your households have been randomly chosen to participate in this study and you are one of the household members chosen to give detailed information. **The purpose of this study is to establish the area within maize value chain influencing contamination with aflatoxins by smallholder farmers, consumers and traders in Kondoa and Chemba**. The results are expected to generate information on area influencing food contamination by small scale farmers in these districts. The information obtained is strictly confidential and will be used for academic purposes only, to facilitate the intended learning at the Sokoine University of Agriculture. Please feel free to answer the questions that will be asked.

Questionnaire for Smallholder – Farmers

A. General information

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

6. Current education level

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

7. Marital status
   i) Single ( ) iii) Married ( )
   ii) Divorced ( ) iv) Widowed ( )

B. Production and Post-harvest handling practices

1. What are your main agriculture activities?
   a) Crop farming ( )
   b) Livestock keeping ( )
   c) Off-farm activities ( )
2. Have you acquired any training that is relating to post harvest handing practices?
   a. Yes ( ) b). No ( )
3. If yes, mention type of training (s) that you have attended
   ……………………………………………………………………………
4. What is the size of your maize farm in (acre)? ....
5. How much maize grains did you produce in bags (kg) in last season? ………
6. What time do you normally harvest maize
   a. Any time when crops are ready for harvest ( )c) Dry season( )
   b. Rain season ( ) d) Others (Please specify) .....
7. What method do you use to harvest your maize?
   a. Manual ( ) b) Combine harvester ( )
   c. Others (Please specify) ……………..,.,,,,,,,…………
8. What method do you use to shell/ thresh your maize?
   a. Hand shelling ( ) c) Hand operated machine ( )
   b. Motorized thresher ( ) d) Others (specify) ………....
9. How How do you keep your maize during harvesting operations?
   a. Bare ground ( ) d) Raised platform ( )
   b. Tarpaulin ( ) e) Jute/Sisal bags ( )
   c. Plastic/synthetic bags ( )f) Others (specify) .....……….
10. How How do you transport your maize after harvest?
    a. Bicycle ( ) d) Open vehicle ( )
    b. Closed vehicles ( ) e) Head ( )
    c. Others (Please specify)……………………………………
11. What action do you take if it rains while your maize is at an open space?
    a. Cover ( ) c) Take to the protected area ( )
    b. Not cover ( ) others (specify)…………….
12. For how long do you temporarily store your maize in the field before transporting to a permanent store? ………… (days)
13. How do you dry your maize?
    a. Sun drying ( ) d) Air drying ( )
    b. Indirect solar drying ( ) e) Not drying ( )
    c. Other specify..
14. How long does it take to dry your harvested maize? …………… (Days)

15. How do you know that your maize is well dried?
    a. Measure moisture content ( ) c) Bite the grains ( )
    b. Visual assessment ( ) d) others………………………
16. Do you sort or clean maize before storage?
    a. Yes ( ) b) No ( )
17. If yes, how do you sort?
    a. By separating from Coloured grain ( )c) separating damage/broken grains( )
    b. By separating from rotten grain ( ) d) others…........................

18. What type of storage/facility do you use to store your produce?
    a. Bins /Silo ( ) d) Jute/Sisal bags ( )
    b. Plastic/synthetic bag ( ) e) Granaries ( )
    c. Others (Please specify) …………….……..…………..........
19. How many bags/kg of maize can you store? (Capacity) ....
20. Do you think the store can accommodate all of your maize? (Yes/No)......................
21. If you are using bags to store your maize, where do you keep them?
    a. Warehouses ( ) c) Under the shed ( )
    b. Outside covered by tarpaulin ( ) d) others ………………………….
22. How long do you store your maize …...............? (Months)
23. How do you store your maize?
    a. As cobs ( ) c) As grain ( )
    b. As pods ( ) d) others (Please specify) …………..
24. Do you fumigate storehouse/warehouse before storing your maize? (Yes/ No).............
25. Which of the following losses do you encounter?
    a. Insect and rats infestation (Yes/No)........,
    b. Mouldy/rotting (Yes/ No) ....
    c. Mechanical damage of grains (Yes/No)..........
    d. Loss of grains during shelling, storage and transport (Yes/No)........
    e. Others (Please specify) …………………………
26. Do you use pesticides to store your grain? (Yes/No)....................

(If Yes please request to see them and take a photo including expire date

27. Which are the common pesticides do you apply during grain storage?
    a. Pirimiphos methyl (Actellic) ( ) c) Dichlorvos ( )
    b. Permethrin ( ) d) Others …………………
28. During planting, where do you get your seeds?
    a. Buying seeds ( ) c) Recycle from the previous harvest seeds ( )
    b. Recycle from the previous harvested grain ( ) d) others ……………….
29. If you buy seeds during plantation where do you buy them?
    a. Open market ( ) c) Colleague ( )
    b. Official agrovet ( ) d) others..
30. Do you use pesticides treated seeds during planting? (Yes/ No).............
31. What do you do with the fungal or rotten maize?
    a. Use as a food ( ) d) Livestock/Poultry ( )
    b. Sell ( ) e) Mix with fresh harvest ( )
    c. Discard ( ) f) Others……………………
32. What do you think are the primary causes of post-harvest losses?
    a. Poor drying ( ) e) Improper storage ( )
    b. Hipping grains on floor ( ) f) Use of expired pesticides
    c. Use of poor seeds ( ) g) others ………...……….
    d. Use improper pesticide ( )

33. Can you identify maize with fungi? (Yes/No).......
34. How can you identify maize with fungi?
    a) Rotten /Mould ( ) d) Discoloration
    b) Off smell ( ) e) others ……………………………

35. Has any member of your family gotten ill following consumption of fungi/ Mouldy food? Yes/ No...............
36. Which of the following measures reduce fungal contamination and spoilage of maize in store?
    a) Dry maize to the safe moisture level ( )

b) Keep out insect and pests from the storage ( )
c) Maintenance of container or warehouse at low temperature and humidity
d) Removal of contaminated maize ( )
e) Use of Purdue Improved Crop storage bags (PICS) ( )
f) Others (Please specify) ……………………………………..

C. Occurrence of molds and aflatoxin contamination in foods

1) Have you ever heard of a mould toxin that may be present in crops? (Y/N)
2) Have you ever heard of a mould toxin that may be present in food? (Y/N)
3) Have you ever heard about aflatoxin? (Y/N)
4) Are you aware that aflatoxin can contaminate crops on farm? (Y/N)
5) Are you aware that aflatoxin can contaminate crops in storage? (Y/N)
6) Are you aware that aflatoxin can contaminate food? (Y/N)
7) Are you aware that Aflatoxins can be transferred to animals? (Y/N)
8) Are you aware that Aflatoxins can be transferred into milk and dairy products?
9) Are you aware that Aflatoxins can be transferred into breast milk? (Y/N)
10) Are you aware of aflatoxins contamination? in crops in the field and during storage? (Y/N)

D. Cause of aflatoxins contamination

1) Aflatoxins can be caused by fungi? (Y/N)
2) Aflatoxins can be caused by high levels of rain during harvesting? (Y/N)
3) Aware that fungi infect food when stored in moist conditions? (Y/N)
4) Aflatoxins can be caused by delayed harvesting? (Y/N)
5) Aflatoxins can be caused by delayed drying? (Y/N)
6) Aflatoxins can be caused by Insect infestation? (Y/N)
7) Broken and bruised crops increase a chance of contaminations?(Y/N)
8) Crops which contain foreign materials promote aflatoxins?(Y/N)
9) Poor storage conditions promote aflatoxins contamination in crops ?(Y/N)

E. Effect of aflatoxins contaminations

1) Fungi produce toxic compounds? (Y/N)
2) Aflatoxins contamination reduces animal productivity? (Y/N)
3) Aflatoxins contamination causes stunting in animals? (Y/N)
4) Aflatoxins contamination causes death in animals? (Y/N)

F. Health effect associated with consumption contaminated food

1) Are you aware of the harmful effects of aflatoxins on humans? (Y/N)
2) Are you aware the effects of aflatoxins on animals? (Y/N)
3) Some liver diseases have been linked to intake of aflatoxins?
4) Aflatoxins cause cancer in humans? (Y/N)
5) Aflatoxins delay child growth? (Y/N)
6) Aflatoxin contamination can reduce the price of crops? (Y/N)

Questionnaire for Consumer

A. General information

1. Date ..../......../....................
2. Place (i) Region.............. (ii) District................ (iii)Ward……… (iv)Village……
3. Age of respondent ………....
4. Sex of respondent………….
5. Occupation…......................
6. Current education level
   - **i.** Primary Education ( ) iv) Secondary Education ( )
   - **ii.** Not educated ( ) v) Tertiary Education ( )
   - **iii.** University ( )
7. Marital status
   - **i)** Single ( ) iii) Married ( )
   - **ii)** Divorced ( ) iv) Separated ( )
   - **iii)** Widowed ( )

B. Occurrence of molds and aflatoxins contamination in foods (Same As Farmers Questions)

C. Causes, effects of aflatoxins contamination and Health effect associated with consumption contaminated food (Same as Farmers questions)

Open structured questionnaire for Traders

A. General information

a. Date ..../......../....................

b. Place (i) District................ (ii)Ward……… (iii)Village....

c. Age of respondent ………....

d. Sex of respondent…………

e. Occupation….......................

f. Current education level

i) Primary education ( ) iv) Secondary education ( )

ii) Not educated ( ) V) Tertiary education ( )

iii) University ( )

g. Marital status

i) Single ( ) iii) Married ( )

ii) Divorced ( ) iv) Separated ( )

iii) Widowed ( )

B Post-harvest handling practices

1) Which crop do you sell?

a) Maize ( )

b) Others (please mention)..

2) How do you keep your maize after buying?

a) Bare ground ( ) d) Raised platforms ( )

b) Tarpaulin ( ) e)Jute/Sisal bags ( )

c) Plastic/synthetic bags ( ) f) others (specify) ……………………………..

3) How do you transport your maize after buying?

a) Bicycle ( ) d) Open vehicle ( )

b) Closed vehicles ( ) e) Head ( )

c) Others (Please specify)…………………………………………………..

4) What action do you take if it rains while your maize is at an open space?

a) Cover ( ) c) Take to the protected area ( )

b) Not cover ( ) d) others …………………………

5) Do you sort or clean grains before storage? (Yes/ No)..........

6) If yes, how do you sort?

a) By separating from coloured grain ( ) c)Separate damage/broken grain ( )

b) By separating rotten grain ( ) d) other............................

7) What type of storage/facility do you use to store your maize?

a) Bins /Silo ( ) d) Jute/Sisal bags ( )

b) Plastic/synthetic bags ( ) e) Granaries ( )

c) Others (Please specify) ……………….……..……………................

8) How long do you store your maize before selling? …………… (months)

9) How do you store your maize?

a) As cobs ( ) c) As grain ( )

b) As pods ( ) d) others (Please specify) …………..

10) Do you fumigate storehouse/warehouse before storing your maize? (Yes/No)..............

11) Which of the following losses do you encounter?

a) Insect and rats infestation (Yes/No)........,

b) Mouldy/rotting (Yes/ No) ....

c) Mechanical damage of grains (Yes/No)..........

d) Loss of grains during shelling, storage and transport (Yes/No)........

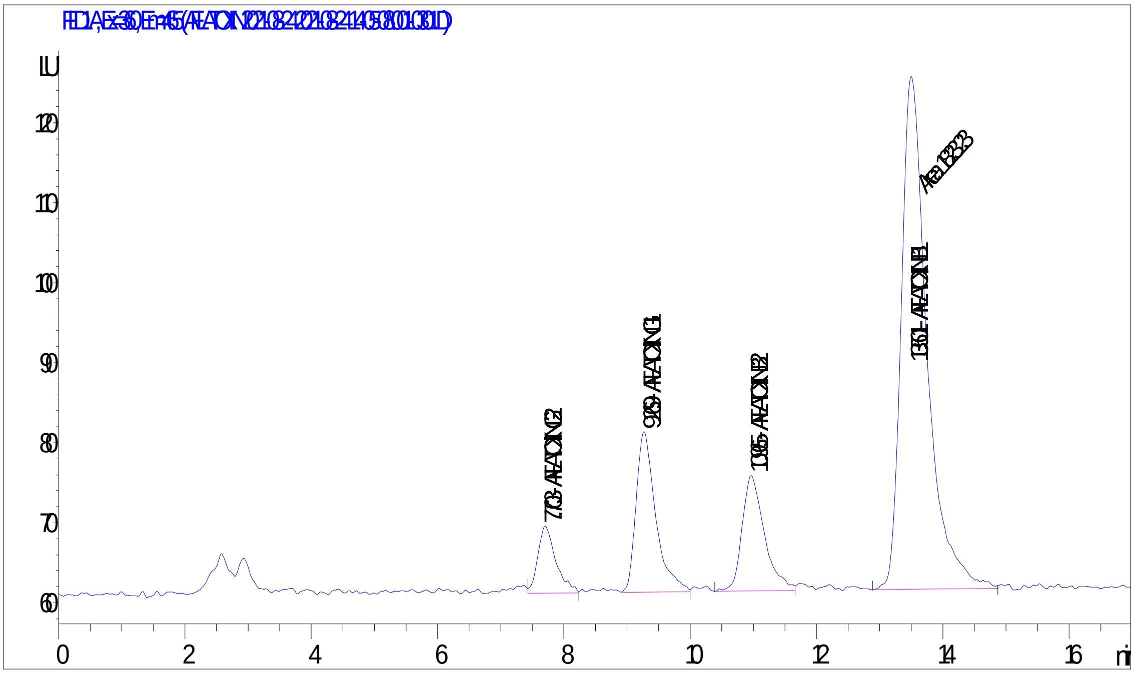
e) Others (Please specify) …………………………

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

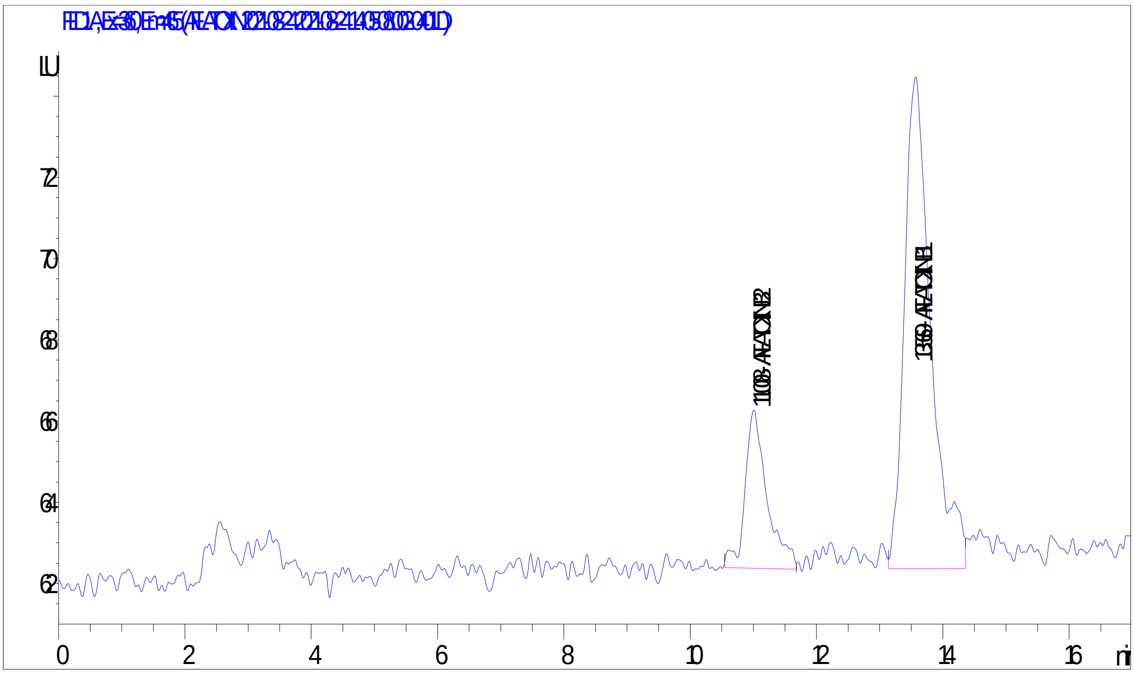
B. Occurrence of molds and aflatoxins contamination in foods (Same as Farmers questions)

C. Cause, Effect of aflatoxins contamination and Health effect associated with consumption contaminated food (Same as Farmers questions)

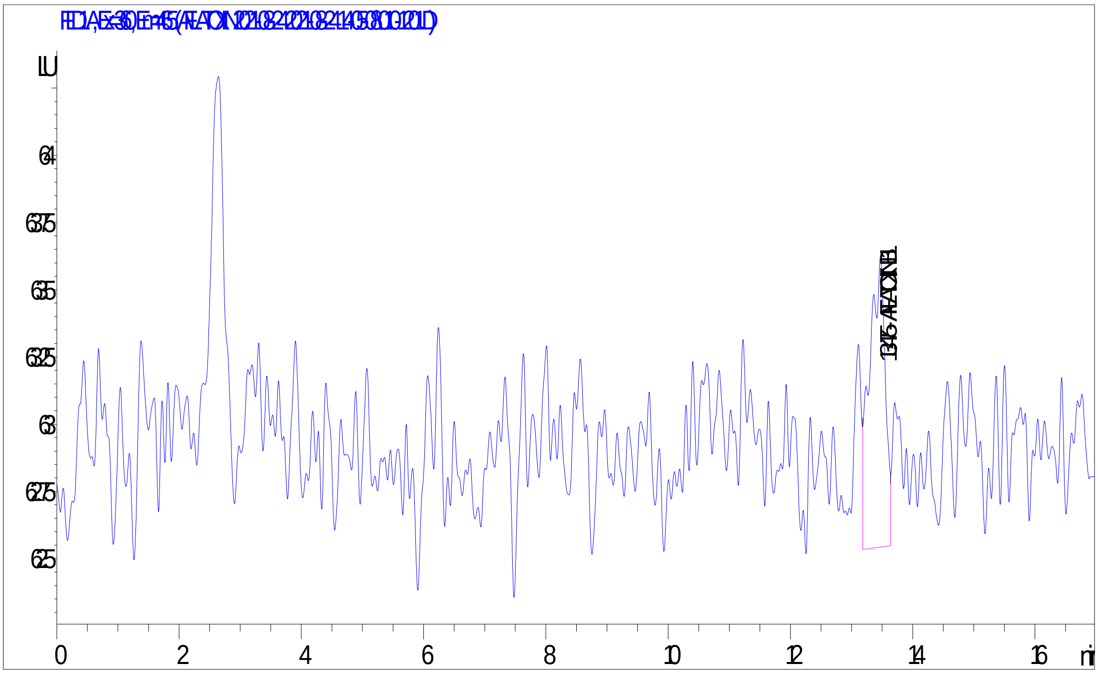
Appendix 2: Chromatograms of different maize sample (showing the positive) and negative detection with HPLC



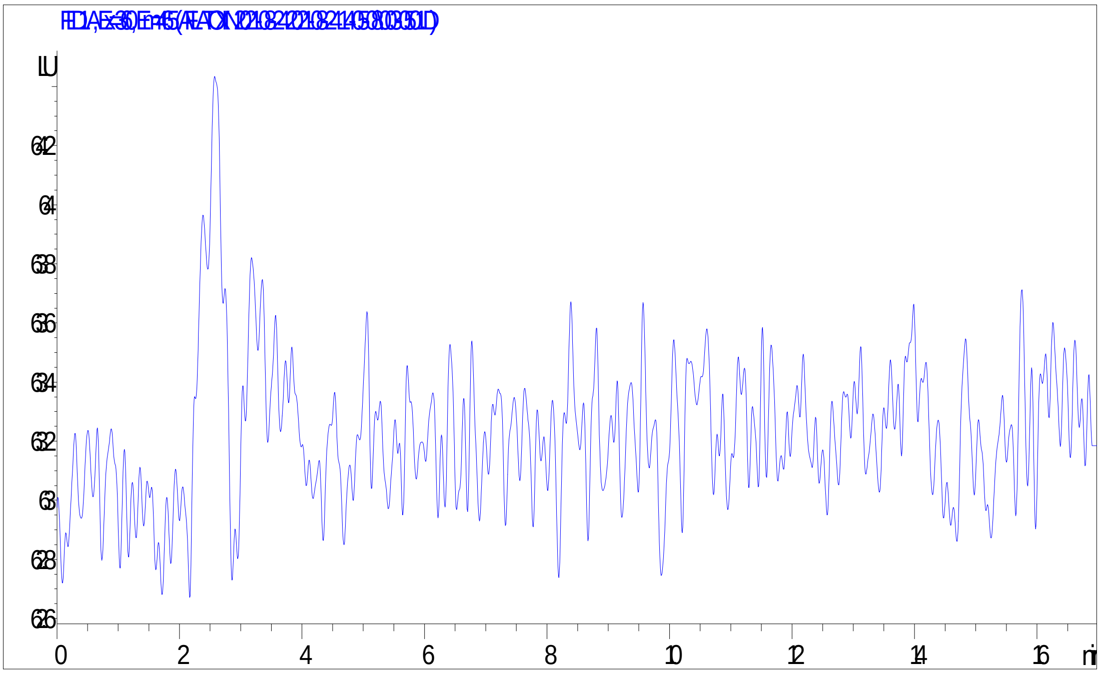
Maize sample (KTC-04) detected with AFB_1, AFB_2, AFG_1 and AFG_2



Maize sample (KB-01) detected with AFB_1 and AFB_2.



Maize sample (CK-20) detected with AF6B_1 only.



Maize sample (CP-018) without contamination by any aflatoxins.