EFFECT OF POST-HARVEST HANDLING KNOWLEDGE AND PRACTICES OF SMALL-SCALE MAIZE FARMERS IN TRANS NZOIA COUNTY ON MYCOTOXIN CONTAMINATION OF THE GRAINS

RONALD CHONGE WEKESA

REG. NO A56/10805/2018

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN FOOD SAFETY AND QUALITY

DEPARTMENT OF FOOD SCIENCE, NUTRITION AND TECHNOLOGY

FACULTY OF AGRICULTURE

UNIVERSITY OF NAIROBI

2022

DECLARATION

I, **Ronald Chonge Wekesa,** do declare that this Dissertation is my original work and has not been presented for an award in any other institution.

Signature: Date: 20/08/2022

Department of Food Science, Nutrition and Technology University of Nairobi

This dissertation has been submitted for examination with our approval as University supervisors.

Signature : Date : 20/08/2022

Dr. Lucy G.

Department of Food Science, Nutrition and Technology, University of Nairobi

Signature :

Dr. George Ooko Abong', PhD August 21, 2022

Department of Food Science, Nutrition and Technology, University of Nairobi

UNIVERSITY OF NAIROBI

PLAGIARISM DECLARATION FORM FOR STUDENTS

Name of Student:	RONALD CHONGE WEKESA
Registration Number:	A56/10805/2018)
College:	College of Agriculture and Veterinary Sciences
Faculty/School/Institute:	Agriculture
Department:	Food Science, Nutrition and Technology
Course name:	Master of Science in Food Safety and Quality
Title of the work	**Effect of post-harvest handling knowledge and practices of small-scale maize farmers in Trans Nzoia county on mycotoxin contamination of the grains**

DECLARATION

1. I understand what Plagiarism is and I am aware of the University's policy in this regard

2. I declare that this MSc. DISSERTATION is my original work and has not been submitted elsewhere for examination, award of a degree or publication. Where other people's work or my own work has been used, this has properly been acknowledged and referenced in accordance with the University of Nairobi's requirements.

3. I have not sought or used the services of any professional agencies to produce this work

4. I have not allowed, and shall not allow anyone to copy my work with the intention of passing it off as his/her own work

5. I understand that any false claim in respect of this work shall result in disciplinary action, in accordance with University Plagiarism Policy.

Signature: Date: 20/08/2022

DEDICATION

This Thesis is dedicated to the Almighty God for the success of the research project. It is also dedicated to my beloved family,Margaret Wahu,Hailey Mbone and Hope Zawadi for their prayer, support, encouragement and enduring the hardships during my study period.

ACKNOWLEDGEMENTS

My sincere gratitude to the Almighty God for His love, grace, blessings, protection and guidance during the period of this study. Secondly, to my supervisors Dr. George O. Abong' and Dr. Lucy G. Njue for their commitment, continuous support and insightful guidance towards completion of my research. Additionally, I am grateful to my colleagues, Duke Gekonge Omayio,Judith Katumbi Ndeme and Rhoda Nasambu for their assistance during the research period. This research was funded by the International Committee of Red Cross (ICRC) to whom am grateful for their support.

I thank the University of Nairobi, Faculty of Agriculture, Department Food Science, Nutrition and Technology including the chairman, administrative, technical and other staff for their assistance during my research.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

ELISA – Enzyme Linked Immunosorbent Assays

FCS – Featal calf serum

FFS – Farmers' Field School

MoA – Ministry of Agriculture

KARI – Kenya Agricultural Research Institute

KNBS – Kenya National Bureau of Statistics

PBS – Phosphate Buffered Saline

PDA – Potato Dextrose Agar

SPSS – Statistical Package for Social Scientists

TMB – Tetra Methyl Benzilidine

ICRC- International Committee of Red Cross

GENERAL ABSTRACT

Maize (*Zea mays L.)* is a vital grain that is rich in starch and is considered the staple food of Kenya. The crop is highly productive in ecological zones that have its favorable climate; however, the grain is highly susceptible to mycotoxin contamination which is greatly attributable to poor postharvest handling practices. Little information exists on maize postharvest management especially among the small-scale farmers who are the majority in Kenya. There is lack of standard postharvest, handling, storage procedures for maize grains which contributes to huge postharvest losses due to mycotoxin contamination. The study is aimed at understanding the post-harvest knowledge of the small-scale farmers and the practices employed in their day to day activities and their impact on the aflatoxin levels on the final product. A baseline survey was conducted using semi-structured questionnaire. A total of 200 respondents were interviewed. The current findings indicate that maize farming in Trans Nzoia consisted of male (67%) as compared to female (33%) responents. Male respondents had a higher knowledge score on postharvest practices in comparison to their females counterparts, however, this was not significant ($p > 0.05$). The level of education of respondents was significantly associated (•=37.49^{a}, $p<0.05$) with their knowledge on mycotoxin contamination. More than eight in every ten respondents (83.2%) had knowledge that inadequate drying (high moisture content) of maize and long periods exposes maize to the risk of mycotoxin contamination. Majority of the respondents (49.5%) relied on the casual laborer's as source of human labor during harvesting. Additionally, majority (88.4%) had knowledge that poor ventilation in the storage facility causes fungal contamination, mould growth and the eventual mycotoxin contamination. Moreover, most of the respondents (83%) associated mycotoxins with cause of diseases in humans. Total aflatoxin levels in the initial sample extended from 0.00 to 9.12 µg/kg, with a mean of 1.96 µg/kg. Aflatoxin levels were found to be between 3.69 and 15.43 µg/kg after two months of storage, with a mean of 2.96 µg/kg. Initial total fumonisin concentrations ranged between 0.00 and 1.36 µg/kg, with a mean of 0.44 µg/kg. After two months of storage, fumonisin levels ranged from 0.00 to 1.51 µg /kg, with a mean of 0.60 µg/kg. Only 9.68 percent and 38.71 percent of the samples, respectively, had levels of Aflatoxin and fumonisin above the WHO-recommended levels of 10ppb and 500ug/kg, respectively. The study concludes that mycotoxin contamination of maize pre and postharvest among small-scale farmers was evident in Trans Nzoia and measures should be implimented to reduce the levels of contamination. Trainings of farmers and dispatch of additional extension officers can help improve the knowledge levels of farmers.

CHAPTER ONE: INTRODUCTION

1.1 Background Information

Maize (*Zea mays* L.) is an important grain consumed worldwide either directly or through its derivatives. Maize is widely consumed in the east and southern regions of Africa and is considered as a staple food to about 50% of the total population of Sub-Saharan Africa (IITA, 2007). Maize is high yielding (developed countries 8.6 tons developing countries 1.3 tons) and grows across different climatic zones. Agriculture is the backbone of Kenya as a country. Agriculture sector accounts for approximateley 33% of the gross domestic product (GDP) and 80 percent of the total population is dependent thereupon (NISR, 2015). However, food insecurity and poverty are still a big challenge for the whole country. Through crop intensification program, agricultural production is increasing for many crops including maize, potatoes, beans, cassava, wheat, soybeans, rice and bananas (MINAGRI,2011).The production of Maize in Kenya stood at approximately 4,000000 Tons in 2018 an increase of approximately 35% from 2017. Kenyans are highly dependent on maize and production is rapidly increasing across all the counties.

Trans Nzoia county is considered as the food basket of Kenya. About 90 percent of farmers in this county produce maize for the local market and their family consumption (Njoroge *et al.*, 2019). Trans-Nzoia County is an arable land with conducive climatic condition that supports agricultural activities and enables practice of effective and efficien farming methods. The large scale and Small Scale maize Farmers practice their activities side by side in Trans Nzoia thereby presenting an interesting combination of the modern farming and the traditional farming methods (Njogu, 2019). Maize is one of the crops among cereals, coffee, fruits, cassava and groundnuts which is highly susceptible to growth of toxigenic fungal molds which leads to contamination of the crop by Mycotoxins.Mycotoxins are secondary chemical metabolites of some filamentous fungi which grow in food or agricultural products (Samson *et al.*,2010; Tajkarimi *et al.*,2011). These chemicals are extremely toxic to humans and animals (Wu *et al.*, 2014), contamination of agricultural crops worldwide was projected to be 25% in 2010(Sarah,2011). The toxin producing molds attack different types of food crops at different stages in the food production chain including at the farm before harvesting and during the post harvest handling stages of shelling,drying and storage(Wu *et al.*,2012). Because of the stability of mycotoxins to agents that are used for killing the molds, they may be present in food long after the molds have been rendered unviable.

Although more than 400 types of mycotoxins have been documented, only a few of them have been recognized as important in human health, including agricultural mycotoxins namely aflatoxins (AFs), fumonisins (FUMs), trichothecenes (TCT), ochratoxin (OTA), zearalenone (ZEA) and patulin produced mainly by the mould species *Fusarium, Penicillium* and *Aspergillus*. The toxicity of the mycotoxin is dependent on the species and strains of fungus, composition of matrix and environmental conducive factors such as moisture and temperature (Pitt and Hocking, 2009). Harvesting techniques, Post-harvest handling practices and storage methods can have an influence upon the incidence of mycotoxin contamination in maize hence the need to monitor and control the level of Mycotoxin (Betran *et al*. 2006). This study was aimed at establishing small scale farmers' knowledge on postharvest handling and their practices in Trans Nzoia and contamination of the grains by mycotoxins.

1.2 Statement of the Problem

Maize in Kenya and especially in Trans Nzoia County is grown in climatic conditions that promote fungal growth and development (Kedera *et al*..1999; Okoth *et al*. 2012). Irregular weather patterns have created a suitable environment for fungal contamination and the rapid deterioration of grain and subsequent production of Mycotoxins. The changing weather patterns have altered conditions during maize harvesting period in most parts of Kenya's therefore hindering not only proper grain drying quality, but also provided conditions that are favorable for fungal infestation. There exists a high risk of maize contamination after harvest due to limited knowledge and lack of mechanisms for detection and prevention of mycotoxin contamination in maize grains. Outbreaks of Aflatoxicosis have been reported in Kenya, Eastern areas especially when high rainfall is experienced at maturity satge of maize and during harvesting period or when the storage conditions are inadequate (Daniel *et al*. 2011; Kang'ethe 2011; Nyikal *et al.* 2004).

1.3 Justification

Seventy percentage (70%) of maize produced in Kenya is cultivated by the small-scale farmers who rely on maize for their consumption and economic livelihood (Opiyo *et al.*, 2015).Post-harvest losses in Kenya are estimated to be in the range of 12-20% of the annual product this is as a result of rejection and destruction of contaminated maize (Parliament *et al.*, 2011).The root cause for post harvest losses can be narrowed down to diseases, mechanical injury during harvesting, insect infestation at preharvest and post-harvest stages and slow or improper drying of the Maize. Establishing the post-harvest handling knowledge and practices was intended to give an indication to the government officials and extension officers the areas of emphasis while developing the training programmes. Kenyan government has adopted World Food Programme regulatory limits for mycotoxins. Mycotoxin surveillance at the post-harvest stages is required to avoid contamination and protect the farmers from crop losses therefore averting the health risks that come with it. There has not been a systematic study that has reported on the intake of mycotoxin in Trans Nzoia, yet Maize is the staple food for this region consumed by a clear majority. There is limited information on postharvest handling practices and mycotoxin contamination of maize in Trans Nzoia county. Determination of the level of mycotoxin contamination will inform government planners on the danger lurking in a country where 85% of the population consume maize meal. Mycotoxin contamination of maize results in economic losses and health related complications. The different fungal species have varying serious and chronic mycotoxigenic deleterious effects on both humans and animal consumers (especially monogastric) depending on the degree of vulnerability of a specific animal within a given species. This study will provide information for policy makers to develop appropriate programmes targeted at mitigating these losses. The results from this study will be very beneficial to policy makers, research scientists, academicians, households and consumers, farmers, maize growers, Non-Governmental Organisation (NGOs). Determination of the exposure levels in the maize meal is vital to show the veracity of the situation and help to prepare the required intervention measures and implementing the preventive measure. Limited research work has been carried out on the level of mycotoxin contamination in Trans Nzoia County, which predominantly cultivates Maize Crop both for the market and family consumption. Therefore, this study will go a long way in adding to the information available for the scholars

1.4 Study Objectives

1.4.1 Main objectives

To assess the post-harvest handling knowledge and practices of small-scale maize farmers in Trans nzoia and mycotoxin contamination of the grains.

1.4.2 Specific objectives

i. To establish the post-harvest handling knowledge and practices of small scale maize farmers in Trans Nzoia county.

ii. To establish the contamination and intake levels of mycotoxin during post-harvest storage of maize

1.5 Hypothesis

i. Small-scale maize farmers in Trans Nzoia county have knowledge on postharvest handling and practices of maize
ii. Contamination of maize with mycotoxin is low during the postharvest storage of maize.

CHAPTER TWO: LITERATURE REVIEW

2.1 Maize production and consumption

2.1.1 Maize production

Maize is one of the Crops grown and consumed worldwide. It is Estimated that the maize production is approximately 594,000,000 tons of grains from about 139 million hectares (FAOSTAT, 2000). Maize is grown in varying climatic conditions extending from moderate to tropic during the period when mean daily temperatures are above 18°C and frost-free. Maize is nutritionally rich with approximately 10% protein, 4% fat and 72% starch with approximately 365 Kcal/100 g energy supply. Maize also contains vitamin and other minerals elements like phosphorous, magnesium, zinc, iron, copper, selenium, calcium and potassium. Maize is assumed to have originated from Mexico from where it rapidly spread through the world. The crop was first spread to Latin America and the Caribbean followed by Canada and USA by the indigenous tribes of Central America and Mexico. FAO reported that China, United States and Brazil are the leading maize producing countries in the world with 563 of the 717 million metric tons/year (Ranum *et al*., 2014)

In areas where the crop has been successfully grown its partly due to the research, development and selection of the right varieties for the region so that the weather pattern and the changes in climatic conditions corresponds to the different growth and development stages for the crop. From figure 2.1 below its clear that USA, China and Brazil are the Largest Maize producers. South Africa is the largest producer of maize in Africa (Figure 2.1).

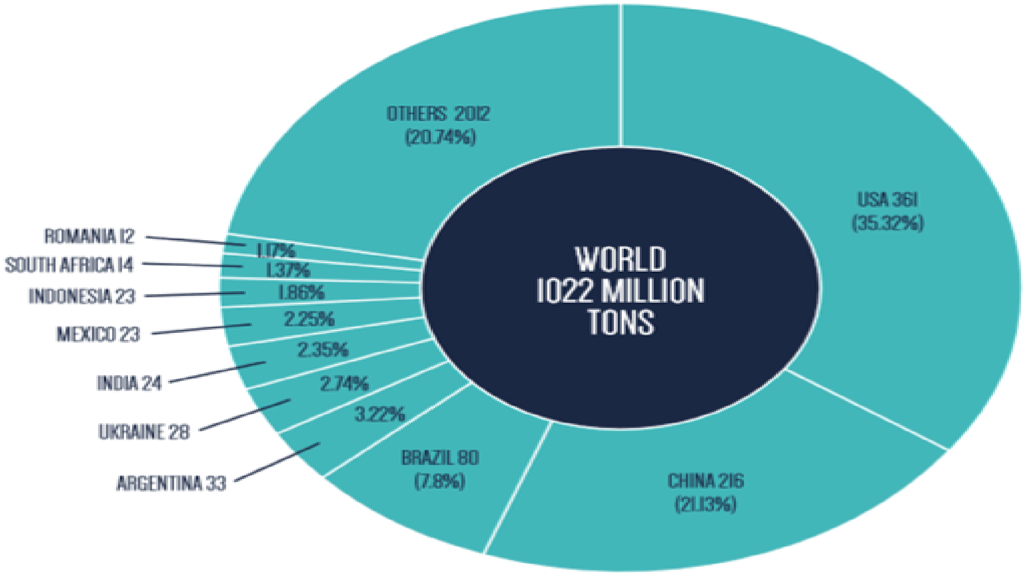

Figure 2.1: Major maize production pattern 2012 (FAOSTAT)

Physical categorization of Maize depends on the nutritional composition, size constitution of the endosperm and the amount of residual sugar. Maize residual sugar is dependent on the maize variety and the level of maturity during harvesting. Another important differentiating characteristic in maize is color. Maize kernels colours range from white maize to yellow maize to red maize to black maize. Yellow maize is widely grown in United states while White maize is mainly preffered in Africa, Central America and the southern United States.

Yellow maize is negatively perceived in Africa as consumed by the poor due to its association with humanitarian organization food•donation programs. Maize quality and quantities in Africa is on high risk due to the effects of factors such as insects, effects of microbial contamination, inadequate post-harvest handling measures and drought and the changing climate patterns. Maize growing regions of Kenya have experienced complete maize fields destroyed in 2018 and therefore affecting the crop yields. Drought and the fluctuating weather patterns has also had an enormous impact on the Maize yield. Crop loss is brought about erratic rain patterns, inadequate mechanization,use of the traditional farming methods and long drought periods can lead to 70-100% crop loss, which affects the population depending on the crop both for consumption and for their economic livelihoods.

2.1.2 Maize consumption patterns

More than 300 million people in Africa are estimated to depend on maize for food. Yellow maize accounts for about 90% of the world's production, However, in Africa white maize is the most common (Outreach, 2017). As much as there is high dependency on maize production in Africa the yields have remained relatively low .The average yield worldwide is estimated to be at 5.5 tons/hectare/year while production in African production has for a long time stagnated at approximately 2 tons/ha/year (Outreach, 2017) (Table 2.1).

Table 2.1: Maize Consumption(• 50g/person/day) for Africa estimates by World Health Organization(WHO)

Country	Maize consumption/day (g/person)	Country	Maize consumption/day (g/person)
Lesotho	328	Ethiopia	94
Malawi	293	Angola	81
Zambia	243	Botswana	78
Zimbabwe	241	Cameroon	75
South Africa	222	Cape Verde	72
Kenya	171	Central Africa Republic	71
Togo	160	Mali	70
Swaziland	152	Seychelles	69
Tanzania	128	Senegal	62
Namibia	127	Nigeria	60
Benin	119	Ghana	53
Mozambique	116	Uganda	52

Consumption of maize above 50 g/person/day indicates that maize is significantly consumed in the region or country (WHO, FAOSTAT 2009). Daily maize consumption in most households in Africa lies between 52 to 328 g/person/day whereas the Mexico recorded the highest daily maize maize consumption in America with approximately 267 g/person. (Ranum *et al*., 2014). It is estimated that the individual maize consumption varies between 98 to 100 kilograms which translates to approximateley 2700 thousand metric tonnes, per year (Nyoro *et al*., 2004). Maize consumption in Kenya is either as Githeri (maize and beans mixed and boiled together) or maize flour through preparation of porridge or Ugali (maize flour cooked in boiling water). Additionally, maize flour can also be used for processing of the traditional alcoholic beverages mainly consumed during traditional ceremonies and rites of passage. Oil extracted from maize embryo can be used for cooking oils, margarine and salad dressings.

2.2 Post-harvest process for small scale farmers

Post-harvest steps refer to the processes undertaken from the time maize crop attains its physiological maturity to the time its consumed or distributed for sale. The steps in Post-harvest process include;

Harvesting: This is carried out after physiological maturity of the crop. It involves the extraction of the maize cobs from the maize stalk

Transportation: This is the process of transportation of the maize to the farmers premises. It can involve use of tractors, Wheel barrows or human carriers on bags.

Temporary Storage: At this stage the maize in cobs is temporarily stored awaiting drying and shelling stages

Drying: This is the stage just before shelling. Its an important stage to reduce breakage of kernel during shelling.

Shelling: Shelling refers to the process of separating the maize from the maize cobs and is done after harvestin the maize from the firm prior to final drying and long term storage.
Drying: This stage reduces moisture content further to keep away maize contamination.

Pest control treatment: This stage involves use of either indigenous methods or chemical treatment to curtail storage insect's infestation of the maize while at the storage area
Bagging: This involve transfer of the maize in bags either polypropylene or sisal bags for storage.
Storage: The maize grain is stored at optimal conditions (temperature and humidity) in different containers and or built storage facilities. The storage duration is mainly dependent on the usage of the usage, short-term storage (4-5 months), season long storage (6-9 months), long term storage (more than 9months)

2.3 Occurance and exposure to mycotoxins

Mycotoxins are naturally occurring toxic secondary metabolic substances produced by fungi. They are found in both the tropical and sub-tropical environments. FAO estimates that 25% of the worldwide crop production is affected by mycotoxins annually (Smith *et al.*, 2016) and their distribution has been enhanced through trade between nations. There are over 300 different mycotoxins that have been identified in the world. These toxins occur as natural contaminants in cereals, nuts, soybeans and other food substances. Mycotoxins from *Fusarium Species*

Aspergillus species and Penicillium species are the most frequent food contaminants (Alshannaq and Yu, 2017).*Aspergillus* and *Penicillium species* are frequently identified at the post-harvest stage of production while the fusarium species are predominantly noted at the pre-harvest stages. Mycotoxins production is highly dependent on temperature and moisture content. Other factors that can affect mycotoxin and fungal Occurance include insect damage, bioavailability of micronutrients(Smith *et al.*, 2016).

Mycotoxins are introduced in organism through digestive system or inhalation, as well as absorption through the skin. The various effects produced by mycotoxins on humans and animals depends on the kind of mycotoxin and varies from acute to chronic toxic affecting the liver, digestive system, cardiovascular systems and the central nervous system. The severity of this effects depends on the dose of exposure, gender, affinity towards organs, and age, as well as possibilities of metabolic changes in organism. Mycotoxin contamination occurs at the pre-harvest while the crop is on the farm and at post-harvest when the crop has been harvested and is undergoing the post harvest processes like shelling, drying, storage and distribution of foods. Most crops can be be affected with mold growth if stored in moist conditions with limited aeration over a a prolonged period,however maize is one of the crops most susceptible to mycotoxins contamination due to the climatic regions more favourable to its production (Liu *et al*., 2016). Most of the mycotoxins are thermally stable therefore are not affected by cooking, frying, boiling and pasteurization. They cannot be easily eliminated through heat, physical and chemical treatments. Additionally, mycotoxins carry over from feeds substances manifests in the animal derived products like milk, eggs and meat therefore increasing exposure to mycotoxin contamination. International food regulatory bodies like US Food and Drug Administration (FDA), World Health Organization (WHO), Food Agriculture Organization (FAO), and the European Food Safety Authority (EFSA) have adopted regulations to prevent and control exposure to mycotoxins (Table 2.2).

Table 2.2.: Major mycotoxins and their specifications

Mycotoxin	Fungal Species	Food Item	USFDA (g/kg)	EU (EC 2006) (g/kg)
Aflatoxins B1, B2, G1, G2	*Aspergillus flavus* *Aspergillus parasiticus*	Maize, wheat, rice, peanut, sorghum, pistachio, almond, ground nuts, tree nuts, figs, cottonseed, spices	20 for total	2–12 for B1 4–15 for total
Aflatoxin M1	*Metabolite of aflatoxin*	Milk, milk Products	0.5	0.05 in milk 0.025 in infant formulae and infant milk
Ochratoxin A	*Aspergillus ochraceus* *Penicillium verrucosum* *Aspergillus carbonarius*	Cereals, dried vine fruit, wine, grapes, coffee, cocoa, cheese	Not set	2–10
Fumonisins B1, B2, B3	*Fusarium verticillioides* *Fusarium proliferatum*	Maize, maize, products, sorghum, asparagus	2000–4000	200–1000
Zearalenone	*Fusarium graminearum* *Fusarium Culmorum*	Cereals, cereal products, maize, wheat, barley	Not set	20–100
Deoxynivalenol	*Fusarium graminearum* *Fusarium Culmorum*	Cereals, cereal products	1000	200–50
Patulin	*Penicillium expansum*	Apples, apple juice, and concentrate	50	10–50

Due to limited resources available to the small scale farmers their crops are predisposed to mycotoxin contamination especially during and after harvesting. In Kenya, the value chain of maize which includes the production stages up to consumption has not being adequately streamlined to eliminate the risks to the food safety and quality (Kang 'ethe et al., 2017)Outbreaks of Aflatoxicosis have been reported in Kenya eastern areas especially when rainfall occurs during harvesting, after harvesting and when the crop is in the storage facilities when a bumper crop is stored inadequately (Abass et al., 2018).There exists fumonisns and aflatoxin specifications in East Africa (Table 2.3).

Table 2.3.: Aflatoxin and Fumonisins specifications in accordance with East Africa Standard

S/No.	Mycotoxin	Maximum limit	Test method(EASB901)
1.	Total Aflatoxins (AFB1, AFB2 AFB2) µg/kg	10	Clause 901
2.	Aflatoxins B1 µg/kg	5	
3.	Fumonisins mg/kg	2	Clause 11 or 12

2.4 Prevalence of mycotoxin contamination

Aflatoxin and Fumonisins are the most prevalent mycotoxins in Africa, Asia and South America(Smith *et al*., 2016).The two mycotoxins are more common in the tropical and sub-tropical areas with hot and humid climates. However due to trade between different regions no region of the world can be said to be free from aflatoxin. Trichothecenes and Zearalenone are the more prevalent in temperate and cold regions of Europe and North America.(Smith *et al*., 2016). Figure 2.2 illustrates the distribution pattern of mycotoxin worldwide. African Countries are mainly affected by Aflatoxins (AFs), Fumonisins (Fum), Ochratoxins (OTA) and Zearalenone (ZEA).

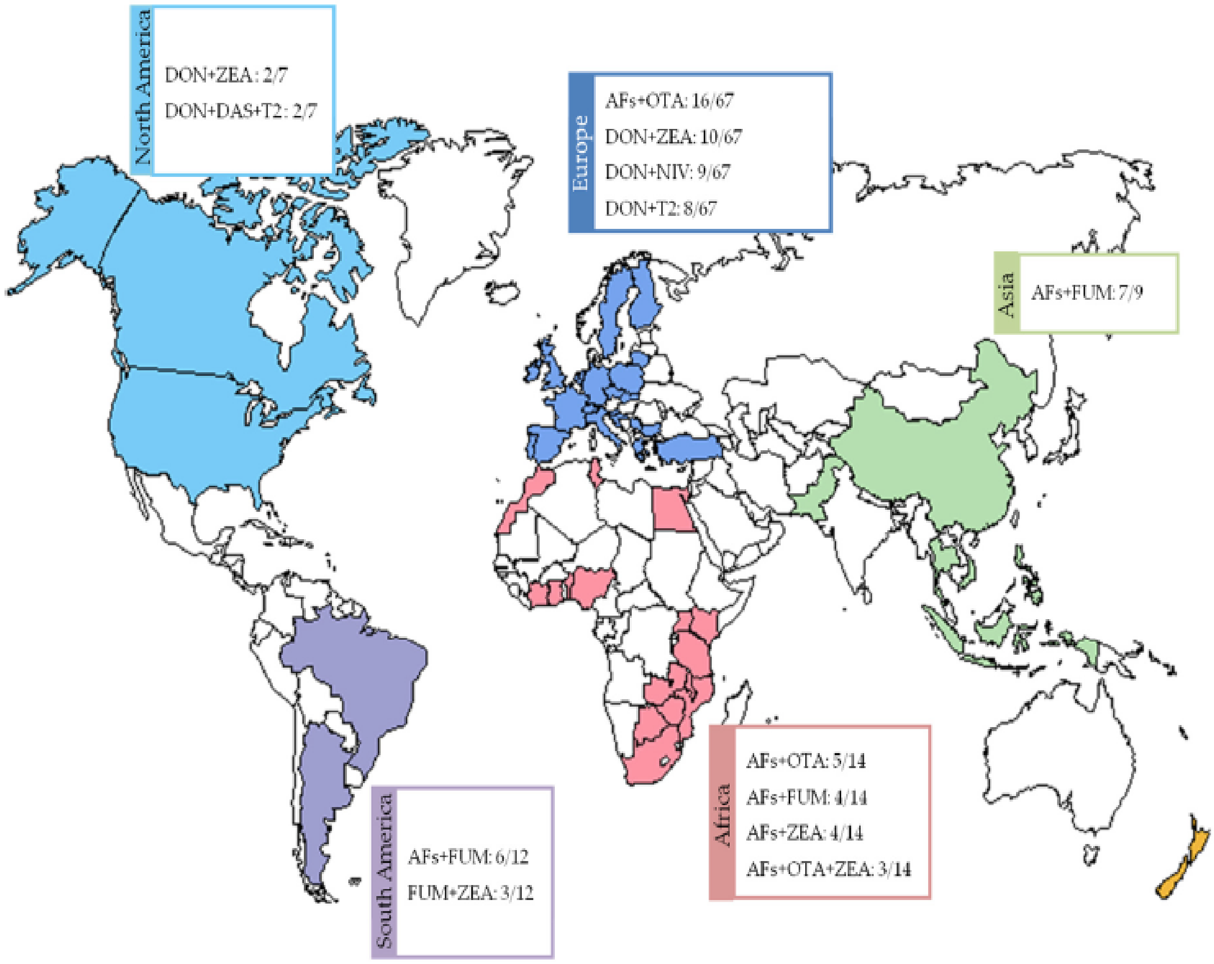

Figure 2.2: World map showing Mycotoxin contamination and distribution around the globe

2.5 Implications of the mycotoxins on human health

The toxic result of mycotoxins on animal and human health is known as mycotoxicosis. Mold metabolites are either classified as Antibiotics e.g. penicillin's which are beneficial in treating disease or mycotoxins which are toxigenic and lead to undesired toxic effects. Severity mycotoxicosis is dependant on the fungal species, toxicity levels of species, affected persons age, the level of exposure and the individual nutritional status. Additionally, the likely interaction of the fungus with the other chemicals an individual is subjected to may have an effect on the severity of the mycotoxicosis. In 1960 Turkey X a feed-related mycotoxicosis was discovered in England creating concerns and making it necessary to research and understand more on the mycotoxins. It was later discovered that the disease is caused by Aflatoxins (Lucic *et al*., 1999). Mycotoxins induce powerfull and dissimilar effects on biological processes as listed below. They are carcinogenic (Ochratoxins, Aflatoxins, Fumonisins), Mutagenic (sterigmatocystin aflatoxins,) , Teratogenic (ochratoxin), Estrogenic (zearalenone) , Hemorhagic (trichothecenes), Immunotoxic, (Ochratoxins and aflatoxins), Nephrotoxic (ochratoxins), Hepatotoxic (Phomopsins and aflatoxins), Dermotoxic (trichothecenes) and neurotoxic (Penitrems, Lolitrems, Ergotoxins and Paxilline).

Toxigenic fungi that produce mycotoxins as their secondary metabolites are widely distributed. The prevalence of the mycotoxin contamination is based on combination of economic, social and environmental conditions combined with optimum temperature and Humidity. Kenya has experienced Aflatoxicosis in the Eastern part in 2004 (Probst et al., 2007) has enforced maximum tolerance levels for aflatoxin B1 to 10ppb in groundnuts, vegetable oil and cereals in Kenya (USAID, 2012.)

2.6 Common methods for mycotoxin detection

International standards bodies such as Official Methods of Analysis of the Association, International organization for Standardization and the European Committee for Standardization have standardized and validated several methods for mycotoxin detection and determination.

2.6.1 Thin layer chromatography (TLC)

TLC is mostly used for qualitative assays and for screening purposes (Semple *et al*.,2002). TLC has is currently used in very limited cases due to the emergency of the HPLC methods which have are more accurate.The disadvantage of using TLC is its Limit of Detection which is concentration above 1µg/kg.

2.6.2 High performance liquid chromatography (HPLC)

HPLC has capacity to detect low levels of mycotoxins.To quantify low levels of aflatoxins by HPLC using fluorescence detection, it is very vital to use pre- or post- column derivatisation due to weak emitter of fluorescent light of aflatoxins. After the excitation at 365nm, the emitted light is detected at 435nm (Kos and krska, 2003a). The method is very fast and accurate but requires high trained staff. However, sample preparation also is very laborious.

2.6.3 Mass spectrometry (MS)

Mass spectoscopy has the advantage of detecting different types of mycotoxins in the same sample extract.The more advanced mass spectroscopy methods are sensitive, selective, accurate while and more confident in quantification (Trombete et al., 2014).

2.6.4 Enzyme linked immunological assay (ELISA)

Immunological assays for mycotoxins have been developed for quantitative analysis to primarily screen out negative samples and identify positive samples. The kits used are user friendly and fast thereby large number of samples are processed at a given time.

2.7 Knowledge gaps

Limited information exists on the existence and prevalence of the mycotoxins contamination in Trans Nzoia County, the region with the highest concentration of maize farmers in the country. There exists limited information on fumonisns and aflatoxin intake by the population in Trans-Nzoia county.

CHAPTER THREE: POSTHARVEST HANDLING KNOWLEDGE AND PRACTICES OF SMALL-SCALE MAIZE FARMERS IN TRANS NZOIA COUNTY

Abstract

Trans-Nzoia County is known to be the breadbasket of Kenya due to the high maize production for both commercial and subsistence purposes. Furthermore, small-scale maize farming is a critical component of the economic and social livelihood of most people in Trans- Nzoia. This study sought to assess postharvest handling knowledge and practices of small-scale farmers in Trans-Nzoia. A cross sectional study was carried out by administering structured questionnaires to 200 respondents identified randomly across the five sub-counties of Trans Nzoia. The results indicated that males formed the bulk of the respondents (67 %) in the study, practicing both animal husbandry and mixed cropping in their land. A very small number of respondents (16%) had good knowledge on postharvest handling and mycotoxin contamination with a score between 60% and 79% while more than half of the respondents (50.5%) had adequate knowledge. More than a third of the respondents (33.5%) had a score of less than 50% indicating poor knowledge on the mycotoxin contamination in postharvest handling practices. However, more than half of the respondents (55.1 %) with 54.6% of them being females, had knowledge on the mycotoxin contamination. Additionally, age groups differed significantly ($p<0.05$) in knowledge with those below 30 years having a higher level of knowledge with a score of 59.3% and were the majority of those who attended tertiary level education compared with those above 30years. Formal training in the tertiary level of education was significantly ($p<0.05$) associated with knowledge of the respondents on mycotoxin. This study concluded that there were poor postharvest handling practices among in Trans-Nzoia especially the small-scale farmers and recommends formulation of standard handling practices and training of farmers. It is recommended that stake holders from the private and the public sectors should develop programs targeting small scale farmers training. Concerned should provide more extension services to the farmers to offer knowledge and tools required to map out risk areas and stages with high risk of mycotoxin growth and development.

3.1 Introduction

Maize originated from originally as a wid grass several centuries ago and has since spread and is consumed in different forms in almost every continent in the world (Ranum et al., 2014). The nutrient composition of maize includes 72% starch, 10% protein, and 4% fat and provides the body with 365 Kcal/100 g (Ranum and Pe, 2014). It is an important grain consumed worldwide either directly or through its derivatives (FAO, 2018). Maize is a vital food crop in the sub-Saharan Africa and is a dominant food to an estimated 50% of the total population of Sub-Saharan Africa (Chauvin *et al*., 2012). Maize is high yielding (developed countries 8.6 tons and developing countries 1.3 tons) and grows across different climatic zones (Ranum and Pe, 2014). Maize contributes 3% of the Kenya's gross domestic product (GDP), 12% of the agricultural GDP and 21% of the entire value of primary agricultural commodities and its production is both small scale and large scale (Groote *et al*., 2005).Large parts of the riftvalley and Western Kenya have a mixed blend of the small and Large scale maize farmers while the central,eastern and Coastal regions have a spread of largely small scale farmers. The country has an estimated maize production capacity of 26 million bags per annum (Kiiru, 2016). Almost 90 % of farmers plant maize for commercial and subsistence purposes.Seventy percent (70%) of maize production in Kenya is by the Small-scale farmers who produce the maize for family consumption and catering for their economic livelihood (Sam Sellers, 2016). The small-scale farmers have less mechanized processes and mainly rely on family labor and the traditional farming methods on their farms.

Maize production in Kenya faces challenges including varying weather patterns,increased cost of production,pest and disease that lead to postharvest losses (Kiiru, 2016). Post harvest losses are approximated to be at 20–30% of the total production from the farm. The huge postharvest losses are attributed to use of the inadequate knowledge on the best practices,Limited or non existent extension services to farmers, unfavorable physical and environmental factors, the existing informal marketing systems and pests and fungal attacks (Koskei *et al*., 2020). The hot and humid conditions experienced in the tropical and the changing weather patterns especially during the harvesting and postharvest seasons predisposes the maize to fungal growth and increased pests and diseases (Kiiru, 2016). Inadequate drying and storage facilities has compelled farmers to rely on the crude methods which has led to substantial fungal attacks,pest damage and rodent attacks (Koskei *et al.*, 2020). This poor postharvest handling practices also contribute to reduced quality of grains and immesurable economic losses to the farmers (Kamala *et al.*, 2016). Maize is vulnerable to fungal infestation specifically those belonging to Aspergillus and

Fusarium species (Mutungi *et al*., 2019). Fungal Infestation takes place from the while the crop is at the farm,during harvesting,during transportation,drying and during storage, which exposes the grains to mycotoxin contamination especially aflatoxins and fumonisins due to fungal growth (Koskei *et al*., 2020). The toxigenic molds produce mycotoxins as secondary chemical metabolites as they grow on the grains (Tajkarimi *et al*., 2011). These mycotoxins are highly toxic to humans and animals and are a health hazard as studies indicate that they are potent carcinogens and causes gastrointestinal illnesses (Suleiman and Rosentrater, 2015). The stability of mycotoxins to agents that are used for killing the molds makes them remain in the food even after the mold has been removed (Harvey *et al*., 2015). The toxicity of the mycotoxin is dependent on the species and strains of fungus, composition of matrix and environmental conducive factors such as moisture and temperature (Pitt and Hocking, 2009).

Harvesting techniques, postharvest handling practices and storage methods have greatly influenced the growth and development of mycotoxin in maize (Kamala *et al*., 2016). Trans Nzoia was selected as the study site due to high maize production and the high postharvest losses reported in the area which was attributed to poor postharvest management and rampant fungal attack on the maize grains. This study purposes to establish post-harvest handling knowledge and practices of small-scale farmers in Trans Nzoia.

3.2 Materials and Methods

3.2.1 Description of study Area

Trans Nzoia County is Situated between Nzoia River and Mount Elgon, 380km Northwest of Nairobi (Figure 3.1). The county borders Bungoma to the west, Uasin-Gishu and Kakamega to the south, Elgeyo-Marakwet to the east, West Pokot to the north and the republic of Uganda to the Northwest. Trans Nzoia covers an area of 2495.5 square kilometers. Trans-Nzoia County is an arable land with tropical climatic conditions therefore making the practice of both small and large-scale agriculture very efficient (Koskei *et al*., 2020). The county is largely agricultural with both large scale and small-scale wheat, maize and dairy farming. Mixed small and large-scale farming activities form the economic back bone of the five sub counties in Trans Nzoia (Kiminini, Endebess, Saboti, Cherangany and Kwanza). About 38,000 small-scale farmers are distributed across the 5 sub-counties sharing similar observable characteristics geographically, climatically and economically (! "Trans Nzoia County Integrated Development Plan, 2013-2017•! i," 2017) (Figure 3.1).

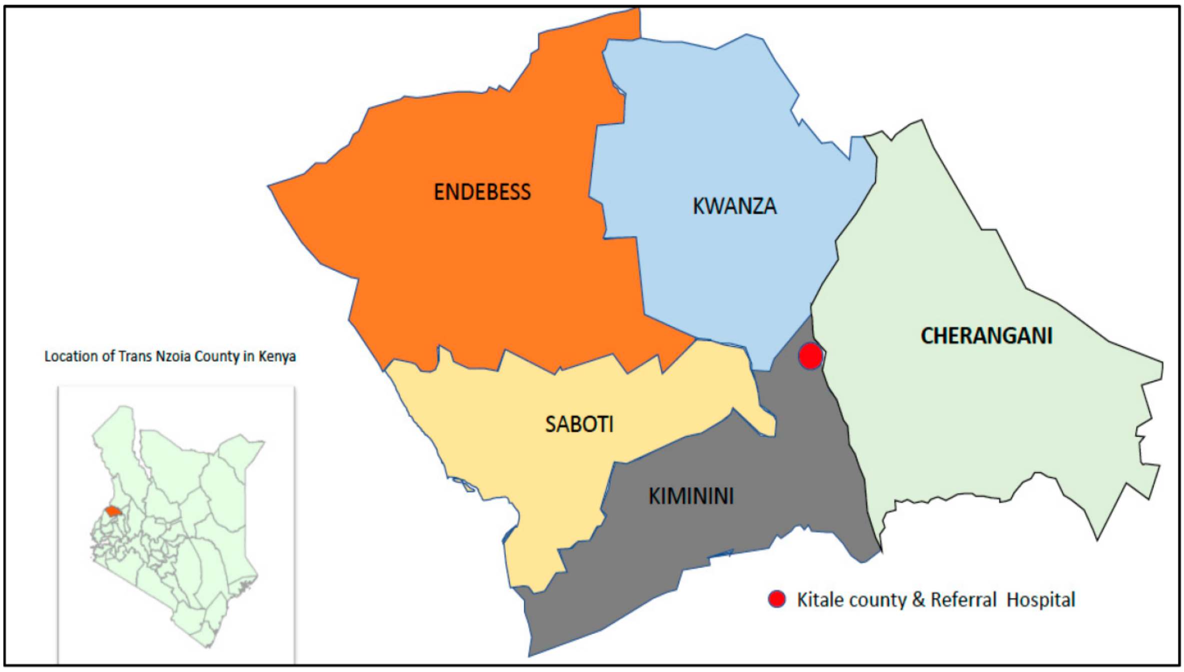

Fig 3.1 : Map of Trans Nzoia County (Mmed *et al*., 2019)

3.2.2 Study design

A cross-sectional study with an analytical element was conducted. The postharvest handling practices and the farmers' knowledge on mycotoxin contamination were assessed using a structured questionnaire (Appendix 1)

3.2.2.1 Sample size determination

Sample size determination was carried out as per the Fischer's formula (Fisher *et al.*, 1991). An average prevalence of 85% (Onono, Wawire, & Ombuki, 2013) was used in the determination of sample size and was used in calculation of the sample size.

$$\bullet = \frac{\bullet^{\cdot}\,\bullet\,\bullet\,\bullet\,\bullet}{\bullet^{\cdot}}$$

n = The desired sample size (when population is >10,000)

z = 1.96 (confidence level at 95%)

p = Prevalence of 85%

q = 1-p (0.15)

d = Level of precision at 0.05%

$$\mathbf{n} = \frac{\bullet.\bullet\bullet^{\bullet}\bullet\bullet.\bullet\bullet\bullet\bullet.\bullet\bullet}{\bullet.\bullet\bullet^{\bullet}}$$

$$= 195.92$$

The number of respondents determined using the calculation was then rounded off to 200 respondents collected randomly from the five sub-counties.

3.2.2.2 Sampling procedure

Trans Nzoia County was purposively chosen because it's a predominantly maize growing region in Kenya and has a high concentration of small-scale maize farmers. The five sub-counties of Trans-Nzoia (Endebess, Saboti, Kaminini, Kwanza and Cherangani) were also purposively sampled. Simple random sampling was used in each sub-county to select 40 households to participate in the survey.Structured questionnaires were used to capture information provided through face-to-face interview with the respondents on the postharvest handling practices and on the farmers' knowledge on Mycotoxin contamination. The questionnaires were prepared, pretested and improved on before being administered. The questionnaires were designed to collectinformation on the demographic characteristics of the respondents, the postharvest handling practices and the small-scale farmer's knowledge on Mycotoxin contamination (Appendix 1). Knowledge of the respondents was assessed using the "True", "False" and "Don't Know" statements while the practice was assessed through the "Yes" and "No" questions and observations. The overall knowledge assessment adopted Blooms cut-off points grade scores of • 59 % as low knowledge, 60 to 79 % as moderate knowledge and 80 to 100 as high knowledge (Nahida., 2007; Abdullahi *et al.*, 2016). The Farmer's social demographics included gender, age, marital status, level of education and socio-economic status like the source of income for the family and Farm size. Knowledge mycotoxin contamination scores of the respondents was evaluated using the True", "False" and "Don't Know" statements while postharvest practices were accessed using "Yes", and "No" statements.

3.2.4 Inclusion criteria

i) Respondents with farm size less than 0.6 Ha and practiced maize farming.

ii) Members of the same family unit were considered as one unit, only one participant per household was selected.

3.2.5 Exclusion Criteria

i.) Respondents under the age of 18 years were not considered.

3.2.6 : Data collection tools

Semi-structured questionnaires were built in the digital open data kit (ODK) application and used to collect data.

3.2.7 Statistical data Analyses

Data collected during the survey was cleaned and analyzed using the Statistical Package for Social Sciences (SPSS) Version 24 and R programming. Descriptive statistics mean, standard deviations, frequencies, charts and tables. T-test and chi-square analyses was done to check for differences in variables of demographic characteristics of respondents. Chi square and regression was used to compare significant differences between the mean scores of demographic characteristics of respondents and their knowledge of toxigenic moulds. The associations of knowledge, practices and demographic characteristics of the food handlers were analysed through Pearson Correlations (Appendix 2). The statistical results were presented in tables and figures for the interpretation.

3.3 Results

3.3.1 Demographic characteristics of the respondents

The male formed the largest percentage of respondents (67%) as compared to females (33%) of the respondents and forty three percent (43%) of the respondents were more than 50 years of age. Close to two thirds (65%) of the farmers interviewed owned less than 3 acres of land. Among the respondents, only 36% had attended school beyond secondary school level, 29.5% had gone beyond primary but stopped at secondary level while slightly more than a third (34.5%) were illiterate (Table 3.1).

Table 3.1: Demographic characteristics of small-scale maize farmers in Trans Nzoia County

Category	Groups	Frequency (n)	Percent (%) N
Sex	Female	66	33.0
	Male	134	67.0
Age group	0-30	31	15.5
	31-40	45	22.5
	41-50	38	19.0
	51-60	56	28.0
	61-100	30	15.0
Farm size in acres	0.1- 0.9	19	9.5
	1 - 1.9	69	34.5
	2 – 2.9	42	21.0
	3 – 3.9	21	10.5
	4 – 5	29	14.5
	5 – 10	20	10.0
Education level	Primary Level and below	69	34.5
	Secondary	59	29.5
	Tertiary level	72	36.0

Key N== Number of respondents

3.3.2 Postharvest handling knowledge of Small-scale farmers on toxigenic molds contamination in maize foods during harvesting and storage

Male respondents had a higher knowledge score compared to females however, this was not significant ($p > 0.05$). Higher knowledge scores were expressed by respondents below 30years. The knowledge difference was statistically significant ($p < 0.05$) among different age groups. Respondents with university/College education had a higher knowledge on mycotoxins followed by those with secondary education and lastly those with primary education. There was a weak association between the respondent's level of education and their knowledge on handling mouldy maize grains ($r=0.114$, $p>0.112$). The respondents who were students had a higher knowledge followed by those who were in formal employment and those in informal employment. There was a significant association (•$=37.49^{a}$, $p<0.05$) the level of education of respondents and their knowledge on mycotoxin contamination. Sixty-seven percent (67%) respondents had a score of less than 59 % indicating poor knowledge of the impacts and effects of post-harvest practices in increase of mycotoxin levels. Majority of the farmers (104 respondents) had a score of between 60%– 79 %. while only 32 respondents had a score of More than 80 %.

3.3.3 Knowledge of the small-scale farmers on causes of mycotoxins during the harvesting and storage stages

Majority (88.4%) of the respondents had knowledge that holding of maize in storage facilities without windows and totally sealed without free movement of air increased the probability of development of toxigenic moulds. Majority of the respondents had knowledge that wet environments during harvesting and in the storage facility and inadequate drying of maize grains increases the risk of toxigenic mould growth. More than half of the respondents (54.5%) had knowledge that dropping of maize on bare grounds in the field during harvesting exposes maize to the risk of mould growth. A third of the respondents (30.7%) had knowledge that mechanically damaging the maize grains (broken kernels) when shelling makes them more susceptible to fungal growth exhibited through the mould growth while only 23.6% had knowledge that Maize grains infested by insects and affected with rodent activity are susceptible to mould growth. More than eight in every ten respondents (83.2%) had knowledge that inadequate drying (high moisture content) of maize and long periods exposes the maize to the risk of mycotoxin contamination. Most of the respondents (88.4%) had knowledge that poor ventilation in the storage facility causes fungal contamination, mould growth and the eventual mycotoxin contamination. Additionally, more than half of the respondents (54.5%) were aware that dropping maize on the farm during harvesting predisposes it to mould growth and mycotoxin contamination. Overall, 56% of the respondents had moderate knowledge on the causes of the toxigenic moulds in maize foods (Figure 3.2).

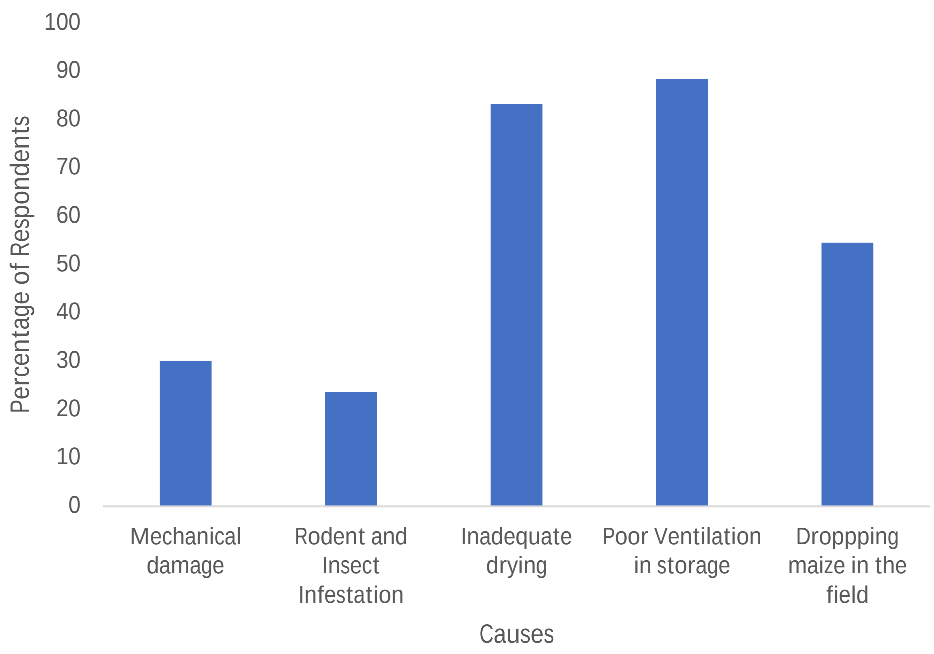

Figure 3.2: Knowledge on the causes of toxigenic moulds during harvesting and storage of maize

A significance difference ($p<0.05$) was observed between the different age groups on knowledge on the causes of toxigenic molds during harvesting and storage of maize. The most knowledgeable group on the causes of moldy toxicity comprised of respondents under 30 years group as compared to the other age groups. The group aged 41-50 years had significantly ($p<0.05$) lower knowledge score than all the other groups. Respondents without and with low formal education displayed significantly ($p< 0.1$) low knowledge compared to those that had attained higher levels of formal education. However, only small proportions of respondents were familiar with the terms. There was a significant difference within levels of education ($P <0.05$) with those who attended higher level of education having higher knowledge on the causes of toxigenic molds as compared to those of lower education level. Higher level of education significantly to higher awareness scores among the participants with those who had tertiary or secondary level of education having higher as compared to those who had attended school to a highest of primary level ($p<0.05$).

3.3.4 Knowledge of the small-scale farmers on health effects of mycotoxins contamination

Majority of the respondents (83%) of the respondents had knowledge that mycotoxins cause diseases in the human population. About 31.3% of the population had knowledge that the mycotoxins are transferrable through animal products when they consume the contaminated maize. Roughly 23% of the respondents had knowledge that the toxigenic moulds are related to the increase in cancer cases in their community while 10.5% of the respondents indicated that it's possible that the high levels of the toxigenic moulds can lead to impaired growth (stunted). Additionally, only 9% of the respondents indicated that high levels of the toxigenic levels could also lead to death. Overall results showed that 47 % of the respondents had moderate knowledge that toxigenic moulds affect human health in general including some acute infections, while 30 % had high knowledge of specific chronic health effects associated with toxigenic moulds. There were significant differences ($p<0.05$) respondents' level of education level of respondents; however, no significant difference was observed by sex and age group. Most respondents considered disease manifestation to be the main health effect of mycotoxins (Figure 3.3).

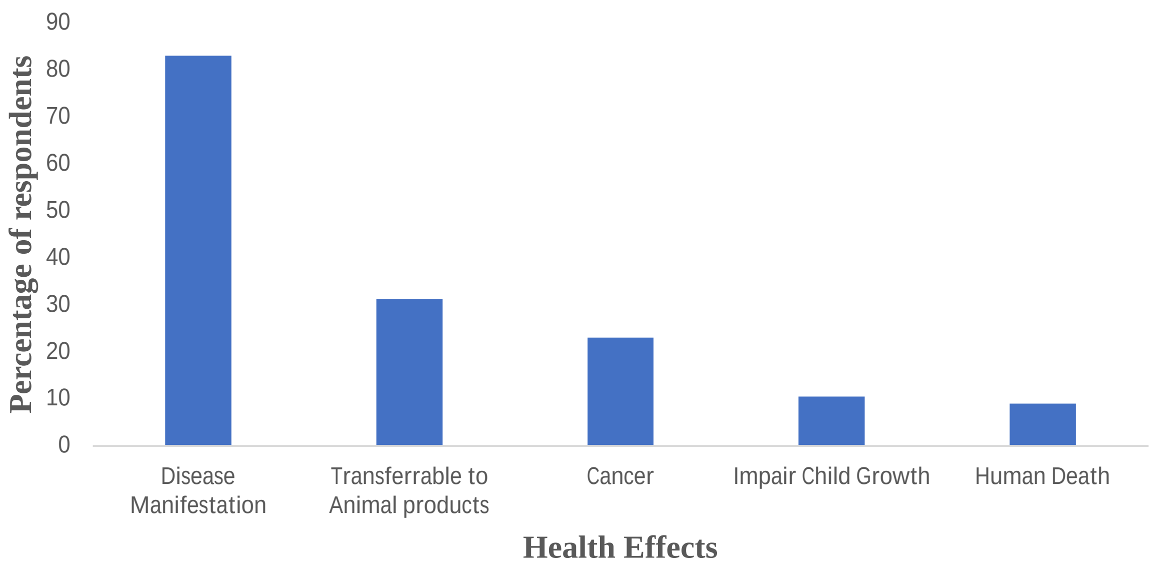

Figure 3.3: Knowledge of the small-scale farmers on health effects of mycotoxins contamination

3.3.5 Knowledge of the small-scale farmers on prevention of post-harvest mycotoxin maize contamination

Majority of the small-scale farmers (82.4 %) had knowledge on the requirement to clean and disinfecting the storage facility before bringing in the new harvest from the farm to protect the maize against the mycotoxin contamination that could possibly be at the storage facility. Only 28% of the respondents had knowledge that disinfection of maize and other measures to protect the maize from rodents and pests significantly protects the maize from mycotoxin contamination

(Figure 3.4). Most of the respondents (56%) had knowledge that sorting and segregation of maize to remove the moldy grains before storage reduces the rate of spread of mycotoxin contamination at the storage facility.

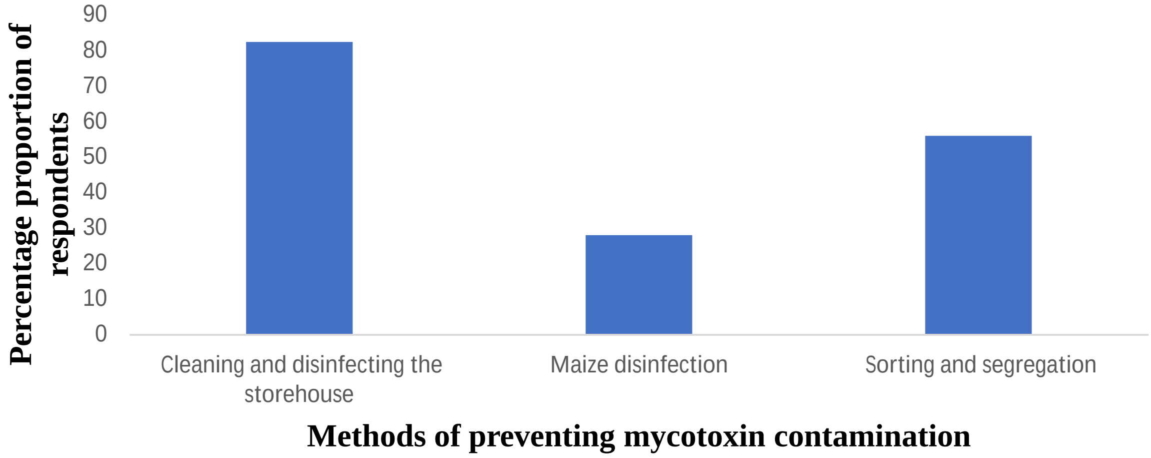

Figure 3.4: Knowledge of the small-scale farmers on prevention of post-harvest mycotoxin maize contamination

3.3.6 Knowledge of the small-scale farmers on control of post-harvest mycotoxin maize contamination

About (51.5%) respondents had knowledge that cooking methods such as boiling, deep frying and roasting cannot reduce mycotoxin contamination from the maize grains. More than four in every ten respondents (44 %) had knowledge that mixing the mould grains with the non-mouldy grains exposed the non-contaminated grains to contamination. More than seven in every ten respondents (78.5%) had knowledge that washing and cleaning away the mould does not remove the toxigenic mycotoxins from the maize grains. Very few farmers (20.1 %) had knowledge on the risks in place by using the contaminated maize as animal feeds either after milling, directly giving the livestock or indirectly by mixing with other animal feeds. About 28.5% of the respondents had knowledge of the efforts put in place to develop chemical treatment methods for dealing with the aflatoxins, with majority mentioning Aflasafe. Overall results showed that 50 % of the respondents had moderate knowledge of the control measures of toxigenic molds in maize foods (Figure 3.5). The only significant difference observed was on the respondents' sex, ($p<0.05$) however, there were no significant differences in knowledge about control measures of toxigenic moulds by the other demographic regions ($p>0.05$).

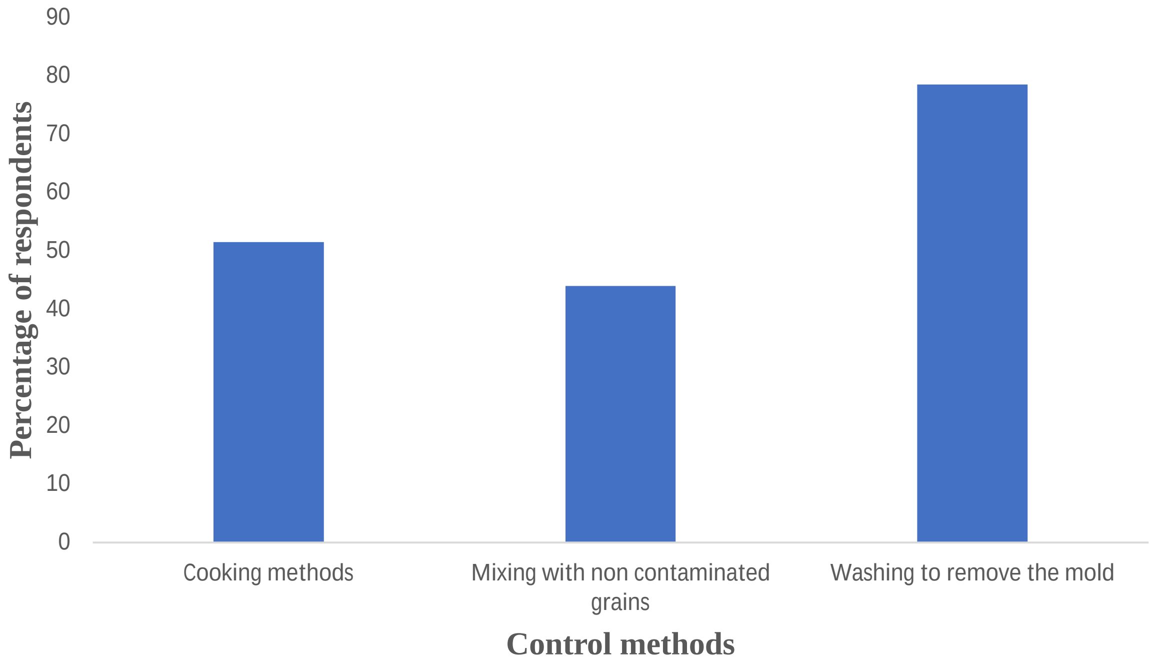

Figure 3.5: Knowledge of the small-scale farmers on control of post-harvest mycotoxin maize contamination

3.3.7 Attendance of respondents to training on postharvest handling of maize foods

It was reported that 18.5 % of respondents had attended training on postharvest handling of maize. The specific topics covered during the trainings included best storage practices for maize, toxigenic moulds affecting maize pests and diseases at the post-harvest stage. There was a significant difference in knowledge or understanding of aflatoxins and fumonisins between respondents that had attended training and those that had not attended training ($p < 0.05$). Overall, the results showed no significant association of knowledge of toxigenic molds with gender ($\bullet^2$ = 20.328, $P > 0.05$), and no correlation between knowledge of toxigenic molds with age of respondent ($r = 0.145$, $P > 0.05$). The correlation though weak was observed between knowledge of toxigenic molds and level of education ($r = -0.310$, $P < 0.001$), where respondents who attended higher level of education had significantly higher knowledge of toxigenic moulds than those who attended low education level ($p < 0.05$).

3.3.8 Postharvest handling Practices by small scale farmers

3.3.8.1 Labor source during harvesting

Majority of the respondents (49.5%) relied on the casual laborer's as source of human labor during harvesting. Almost half of the respondents (49%) indicated that the harvesting process was handled by family members. A very small minority (1%) of the respondents could afford machinery during harvesting (Figure 3.6). The small-scale farmers attributed this to mainly the small size of their farms and the limited resources available to the small-scale farmers.

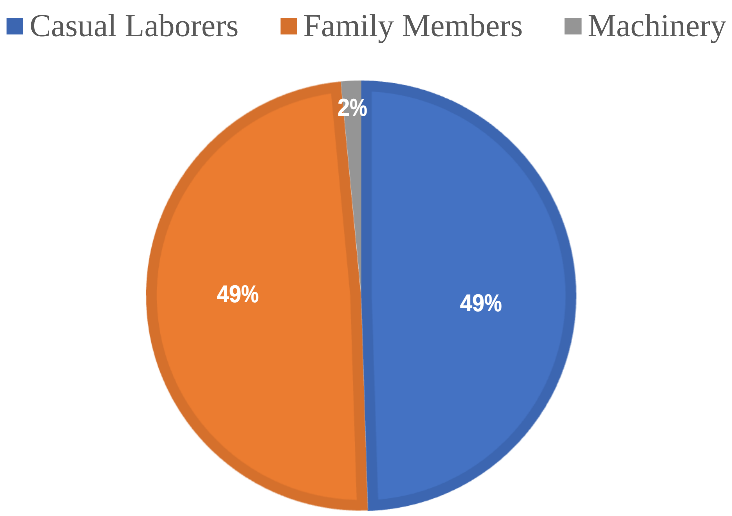

Figure 3.6: Labor source during harvesting

3.3.8.2 Maize transportation from the field to the farm house

About a third of the respondents (31.5%) transported the maize to the farmhouse using human labor loaders while 28% of the respondents transported the Maize using farm animals (donkeys and oxen's). A few of the farmers (24%) afforded tractors, pick-ups and other forms of motor vehicles to transport the crops while 5.5% of the farmers transported the crop using the bicycles and motorcycles (Figure 3.7). The maize was not protected during transportation and therefore exposed to the external environment

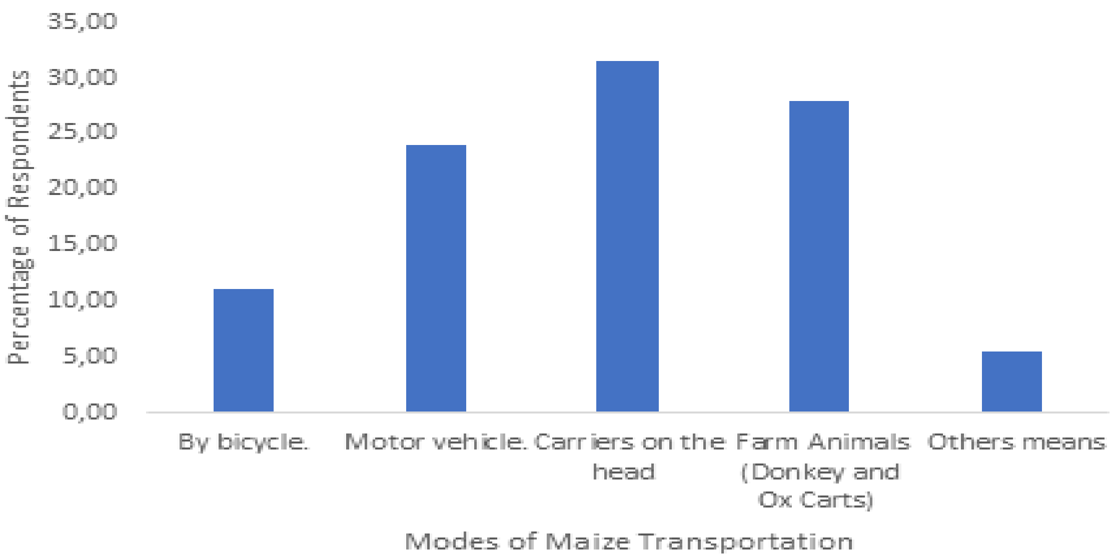

Fig 3.7: Maize transportation from the field to the farm house

3.3.8.3 Post harvest holding duration at the field

Sixty nine percent (69%) of the respondents indicated that after harvesting the maize is held in the farm for 1-3 days as its being slowly transported to the farmhouse or directly shelling was done at the farm. A very small number of farmers (10%) held the maize for 1 – 3 days while 20% of the respondents held the maize in the farm longer than 6 days before moving the product to the storage facility (Figure 3.8). During the holding period the maize is kept bare ground in a cleared area on the farm and is only covered during the nights for safety reasons.

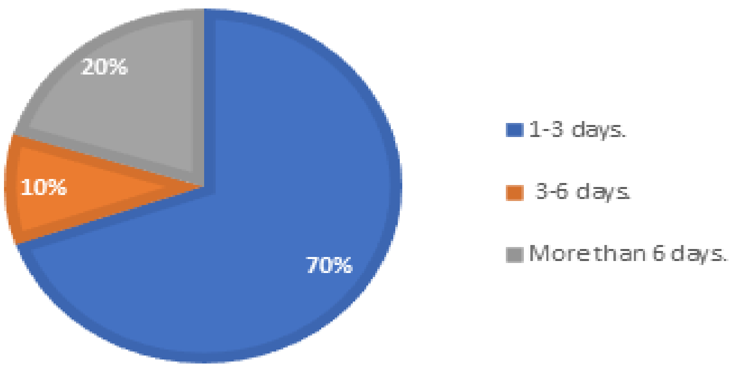

Fig 3.8 : Post harvest holding duration at the field

3.3.8.4 Shelling of maize from the cob

More than seventy percent of respondents (79.5%) shelled the maize using a tractor motored shelling machine to shell the maize while 10% of the respondents hit the maize with a strong wooden plank (Figure 3.9). Shelling and hitting the maize produced a lot of dust and physically damage the maize kernels. About 8.5 % of the respondents used the traditional and much slower method of rubbing the maize with bare hands to remove the maize from the cobs

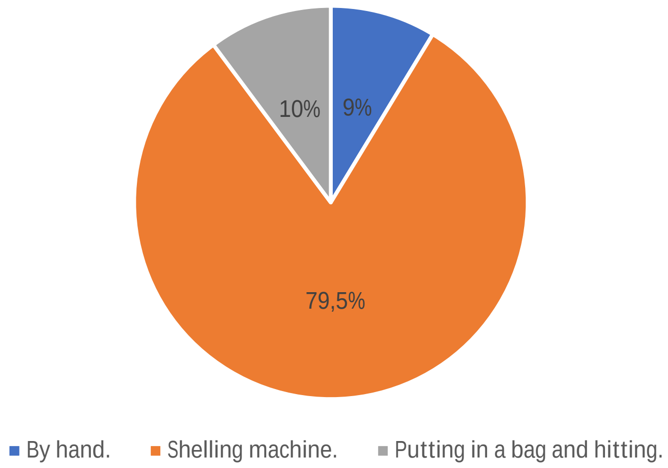

Fig 3.9: Shelling of maize from the cob

3.3.8.5 Cleaning of the shelled maize

More than half of the farmers (55.5%) passed their maize through the sieves after the shelling process to get rid of the dust and the broken particles. Additionally, some farmers (14%) sorted and segregated the maize which were discoloured, broken and with other physical deformities. A low number of respondents (28%) practiced winnowing with the wind blowing off the dust and lighter particles (Figure 3.10). About 1.5% of the respondents did not take their produce through any of the above cleaning procedures and directly transferred their maize to the storage facility. Cumulatively 98.5% of the farmers cleaned their maize after shelling

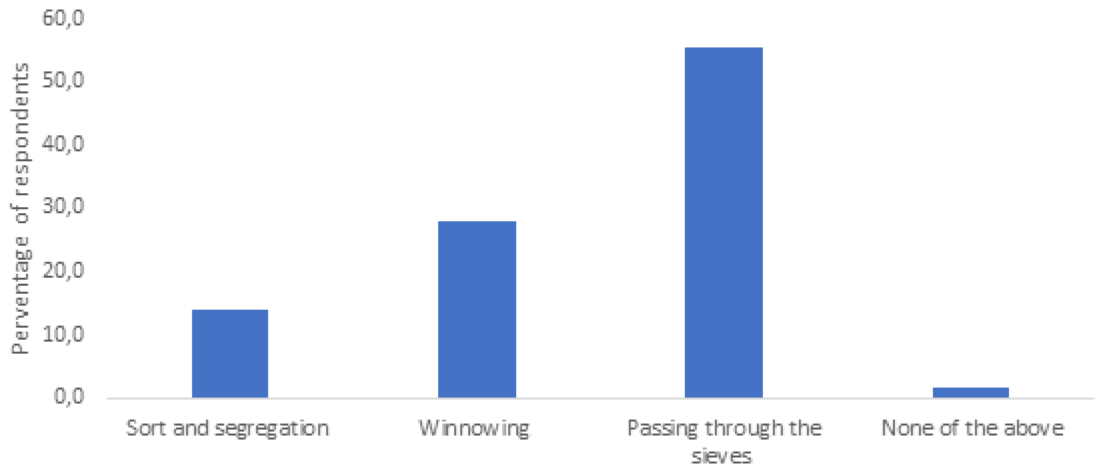

Fig 10: Cleaning of the shelled maize

3.3.8.6 Maize drying practices

All the respondents interviewed dried their maize in some way or the other. Majority of the respondents (87%) dried their maize in the open sun on the bare ground. A low number of respondents (9.5%) placed their crop on a canvas or polypropylene bag during drying while 3% of the farmers could afford the communal solar drier for drying their Maize (Figure 3.11).

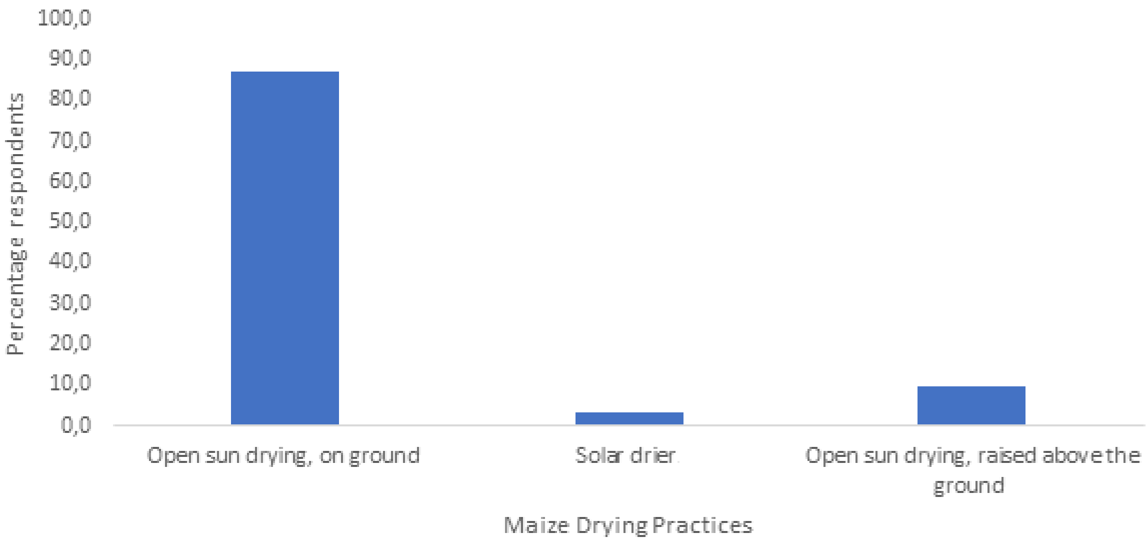

Fig 3.11: Maize drying practices

3.3.8.7 Duration for Maize drying

Duration for maize drying was largely dependent on the availability and intensity of the sun, this is especially because majority of the farmers carried out sun drying. Majority of the respondents (51.5%) took more than 6 days to dry their maize. A low number of farmers (27%) took 1 -3 days of 8 hours of solar a day to dry their maize and have it ready for storage while 20.5% of the farmers took 3-6 days to dry the maize. The maize drying process was intended to reduce the moisture content of the grains to a level considered by the farmer to be optimum for long term storage.

3.3.8.8 Storage facility preparation and cleaning

Most of the farmers (61.5%) cleared the previous year crop from the storage facilities before introduction of the new crop. A number of the farmers (27%) shared the storage facility to store both the previous crop and the current year crop without a physical barrier while 8.5% of the respondents shared the storage facility between the previous year crop and the current year crop with a barrier between the different seasons.

3.3.8.9 Respondents preparation of the storage facility before introducing the crop

Almost half of the respondents (45.5%) only swept the storage facilities without consideration on measures to eradicate the insects infestation from the previous crop while 34.5% of the respondents swept the storage facility, cleaned with soapy water then disinfected the storage facility by dusting with an appropriate disinfectant with notable brand names being Actelic and Nova. A very small percentage of the respondents (17%) only cleaned the storage facility with soapy water and only 3.5% of them only dusted the storage facility with the disinfectants

3.3.8.10 Respondents mode of maize storage

More than a third of respondents (38%) moved the maize from the farm to the storage facility while on cob but after removing the sheath. More than half of the farmers (53%) moved the crop to the storage facility after shelling while 9% of the respondents moved the maize to the farm with the sheath. The sheath for the maize cobs is used as animal feed hence the reason why farmers transferred the sheath with the maize to the storage facility. The sheath increases the duration for maize drying and provides ideal conditions for pests and Insects habitation.

3.3.8.11 Respondents maize storage duration

More than five in every ten respondents (52.5%) indicated that they kept their maize in the storage facility for more than 3 months pending either home consumption or commercialization. About 11.5% of the farmers kept their maize for a period of 2 – 3 months at the storage facility before disposal while 10% of the farmers stored their maize for 1-2 months before utilization or sale (Figure 3.12). The longer the storage period the higher the requirements to have optimum storage conditions that protect the crop from pests and diseases and toxigenic moulds. The respondents stored the maize for the long duration either to enable market prices to stabilize before sale or to provide ford for the family until the next harvest season. Period for storage is attributed to the need to have available food for consumption by their families for as long as possible before the next harvest.

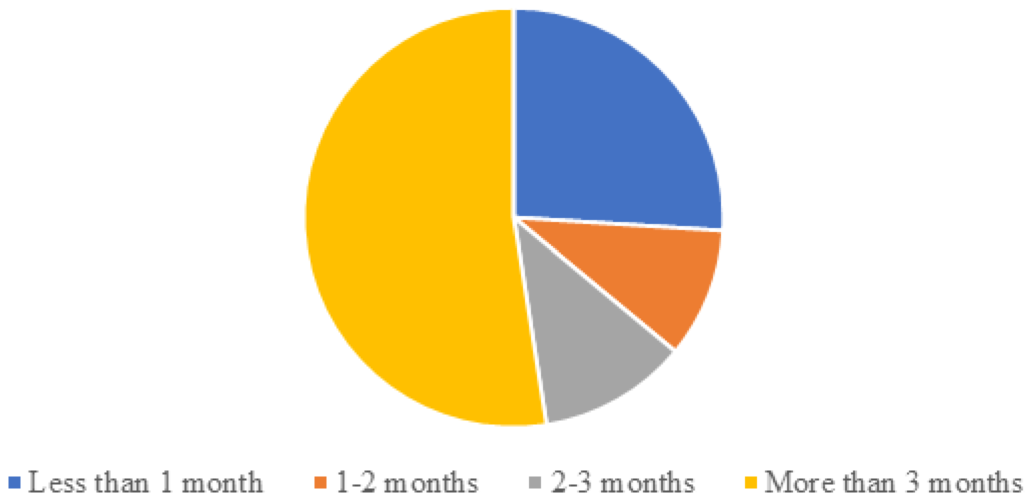

Figure 3.12: Respondents maize Storage duration

3.3.8.12 Respondents utilization of the storage facility

Majority of the respondents (76%) stored the maize in a facility shared with the other crops (Figure 3.13). The main crops grown in the farm included ground nuts, beans and millet. About 24% of the respondents have constructed or rented specific cribs and storage facility. Economic resources dictated the ability of the respondents to have multiple storage facilities for the different crops grown in the farm.

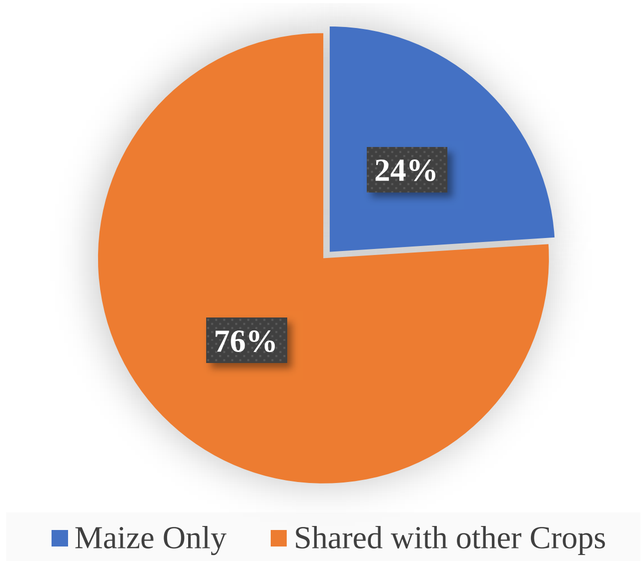

Figure 3.13: Respondents utilization of the storage facility

3.3.8.13 Respondents storage facility ventilation and maize storage structures

More than half of the respondents (53.5%) stored their maize in their living quarters, mostly a room set aside in the house, the maize was reportedly placed on raised wooden planks, stones or spread out pp bags. Some of the respondents (27%) had specialized storage facility either constructed from wooden planks and raised from the surface or utilized traditional cribs constructed from twigs with grass thatched roofs while 19.5% of the respondents rented/leased storage facilities in nearby areas for the storage of their crops

3.3.8.14 Treatment of the storage facility before introducing the crop

Majority of the respondents (82%) used insecticides to dust the storage facilities before bringing in their produce. A few respondents (5.5%) spread dry sand in the storage facility before bringing in the maize crop either after shelling or from the farm while 2% of the respondents smeared cow dung on the floor and walls of their storage facility especially the cribs to ensure the crib remained dry and moisture did not penetrate. A very small percentage of the respondents (0.5%) applied neem on the walls of the storage facility to protect the maize from pests and diseases and 3.3% of the respondents applied other methods like spreading leaves on the floor, putting wooden planks on the floor etc. However, 5.5% of the respondents did not apply any prior preparation before introducing the maize to the storage facility.

3.3.8.15 Maize protection from pests and rodent's infestation

Many respondents (84.5%) indicated that they use of synthetic pesticides to protect the maize from pesticides and diseases. A few respondents (3%) set rodent baits at strategic points in their storage facility to stop the entry of rats into the storage facility while 5% of the respondents applied the use of insecticides and rodents baits for the protection of the maize from damage, pests and contamination (Figure 3.14). However, 7% of the respondents indicated that they applied neither of the methods for the maize protection and more so ensured effective sun drying for the maize.

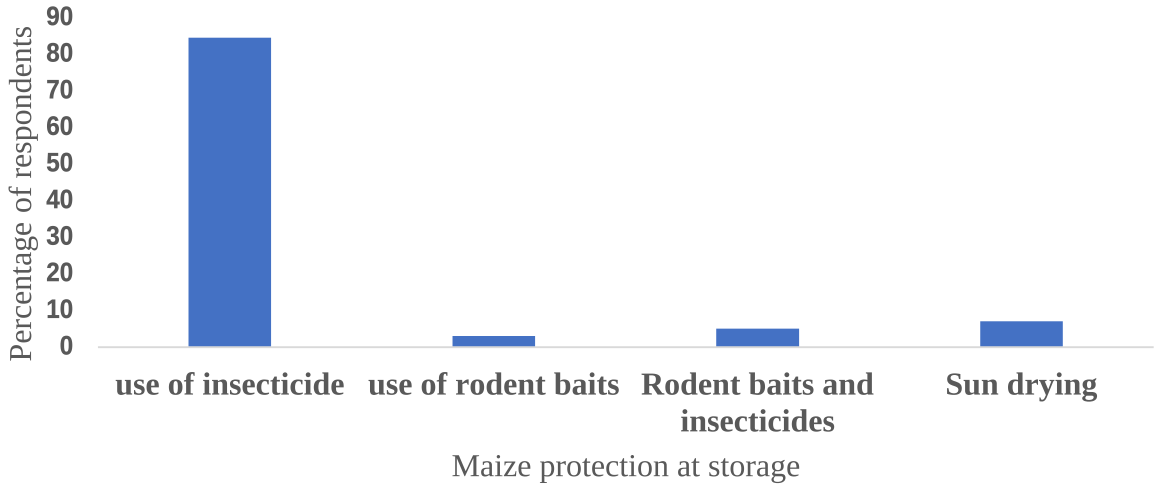

Fig 3.14: Maize protection from pests and rodent's infestation

3.3.8.16 Packaging of the product during storage

Majority of the respondents at 44.5% used polythene bags (not treated) for storage of the maize, 12.5% of the respondents used the pretreated hermetic bags to store their produce.25.5% utilized the sisal bags for storage of the maize while 17% of the respondents used other methods like storage on crates, woven baskets, on top of the open fire in the Kitchen. The respondents indicated that the storage method largely depended on the harvest quantity and the duration which the farmer planned to store the crop. Limited economic resources for the small-scale farmers curtailed their ability to procure the more expensive hermetic bags.

3.3.8.17 Quality Inspection parameters and practices

All the respondents reported that they looked out for the physical and visual characteristics of the maize.25.13% of the respondents focused more on checking the discoloration of the maize, 19.6% of the respondents reported that moulds were one of the key areas that the respondents inspected during the inspection. About 16.06% of the respondents inspected the grains for rodent activities, 24.12% of the respondents inspected the grains size mainly due to the customer preferences at the market. Some farmers (5.4%) inspected the grains for other physical parameters like broken kernels (Figure 3.15). There were no significant differences in the attributes used in determining good quality maize foods across respondents age group, gender and level of education ($p > 0.05$).

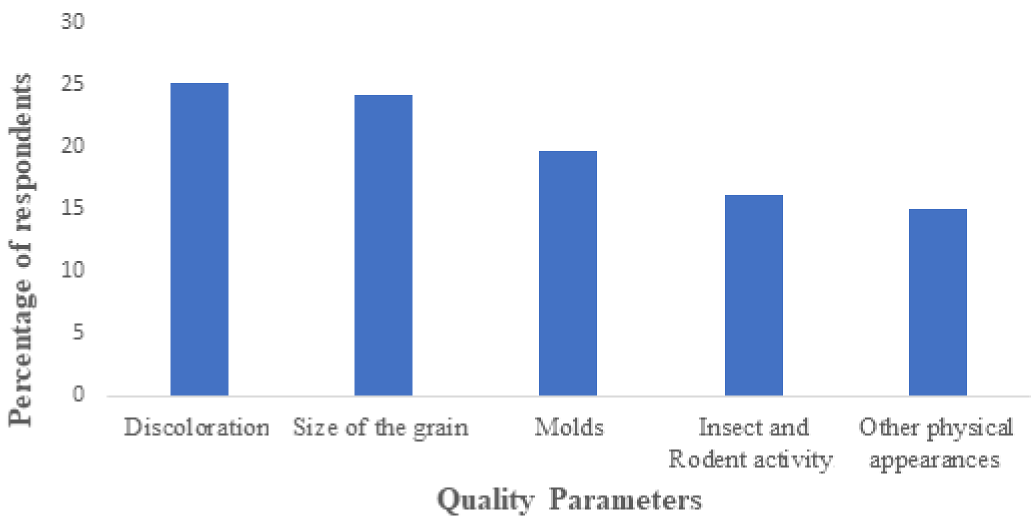

Fig 3.19: Quality Inspection parameters and practices

3.3.8.18 Respondents' moisture content inspection of the grains at the storage facility

Majority of the respondents (91.5%) reported that moisture content is inspected using physical methods.41% of the respondents tested the moisture level of the maize by chewing the grains.30% of the respondents picked a quantity of the grains in their hand and by shaking the grains in their hands and by listening to the sound of the grains make a decision on the dryness of the grains.7% of the respondents observed the colour of the maize grains while 13,5% of the respondents had other methods like a salty glass, pinching it between the fingers etc. If the grain cracks and the kernels, feel hard or make sharp sounds, the grain is dry enough for storage. If the grain is soft, it could mean it is still wet and needs further drying. 8.5% of the respondents confirmed moisture content of their grains sing a moisture metre either procured communally or family-owned moisture metres.

3.3.3.19 Respondents handling of mouldy Maize

More than two thirds of the respondents (66%) had an alternative use of the mouldy maize as animal feed for the livestock and poultry while 15% of the respondents mixed the contaminated maize with the non-contaminated maize. A small number of the respondents (8.5%) disposed the maize in their farms by burying the grains below the ground for utilization by the crops as manure while others (6.5%) of the respondents considered the grains not to be fit for use by human and livestock and therefore burnt the grains in the field. Other ways of disposal by 4% of the respondents included for brewing the traditional alcohol (known as Busaa).

3.3.8.20 Respondents proportion of the grain lost to pests and contamination

More than seven in every ten respondents (73%) estimated their post-harvest losses for every 90kg bag to be between 1.1%-2.2% while 5% of the respondents reported their post-harvest losses at between 3.3% - 4.4% and 7.5% of the respondents reported their post-harvest losses at more than 5.6%. The huge postharvest losses could be attributed to poor maize postharvest practices, informal marketing systems, and unfavorable physical and environmental factors.

3.3.9 Quality measures

At the storage facility it is imperative that farmers ensure that the conditions of storage are satisfactory, and the quality of the produce does not deteriorate. The study findings, however, indicate that at the storage facility the respondents only inspected the maize at the time of drawing the maize for consumption or for the market. Parameters inspected were discoloration and mouldy (25.13%), Moisture (19.6%), rodent and insects' activity (16.06%), grainsize (24.12%) and other parameters like shriveled grains, broken grains, comprising 24.12% of the respondents. About 41% of the respondents tested the moisture level of the maize by chewing the grains. About 30% of the respondents picked a quantity of the grains in their hand and by shaking the grains in their hands and by listening to the sound of the grains make a decision on the dryness of the grains. About 7% of the respondents observed the colour of the maize grains while 13,5% of the respondents had other methods like a salty glass, pinching it between the fingers etc. If the grain cracks and the kernels, feel hard or make sharp sounds, the grain is dry enough for storage. If the grain is soft, it could mean it is still wet and needs further drying. Cumulatively91.5% of the respondents used physical and visual methods for moisture checks.

3.4 Discussion

3.4.1 Demographic characteristics of the respondents

Demographic characteristics showed that men were majority compared to women and this could be linked to the fact that maize production in the area is for commercial purposes hence more interest from men. These findings contradicts previous study by Midega *et al*. (2016) in western Kenya where women constituted majority of the small scale farmers. The study had more women than men, this could be attributed to the Traditional and cultural belief in this region that men are the owners of all materials. The current study compares with previous study by Rapsomanikis (2015a) and the WFP report on Kenya Info *et al*., 2018 where it was noted that 60% of the small scale farms are under management of men, with women providing most of the labor on the farms. Male respondents had a higher knowledge score compared to women due to their attendance and participation in the trainings provided by the NGOs in the region and the government functionaries. The difference in education level between the male and the female respondents was statistically significant ($P<0.05$).This contradicts WFP report on Kenya (2018)and the study by Dallow (1992). This age group also comprised a bigger percentage of those who had attained higher learning education in the tertiary institutions. This current study compares with the study by Rapsomanikis (2015a) and FAO indicating that the level of education can also be linked to the low social capital in the form of knowledge. Education and the formal training opens the opportunity for understanding the new technological advancement in the different fields including agriculture and gives a glimpse to the emerging challenges like mycotoxins in agriculture and the current Good Agricultural Practices. With a clear understanding of the emerging challenges in agriculture and the knowledge from the large volumes of digital data, the younger generation will play a greater role in alleviating their communities from the challenges experienced during farming

3.4.2 Knowledge of the small-scale farmers on causes of mycotoxins during the harvesting and storage stages

Across the different age groups there was significant difference in knowledge between respondents with less than 40 years and respondents with more than 40 years. Gender had a significant influence on respondent's knowledge level. This observation agrees with the findings by Nahida (2007) who reported that there was significant differences in knowledge of mold toxin between female and male respondents ($p < 0.05$) and that male respondents had more knowledge on toxins in food than women. Majority of the respondents (83.2%) had knowledge on the role of moisture in the growth and development of molds. Drying of the maize was considered by most of the respondents as a means of reducing the moisture content to acceptable levels (Alborch *et al.*, 2012). The findings of this study correspond with those of several other researchers who reported that a large population of the small-scale farmers understand the risk of mould development resulting from storage of insufficiently dried maize grains. High moisture levels and poor aeration exacerbate fungal proliferations and mycotoxin production (Harvey *et al.*, 2015)

3.4.3 Knowledge of the respondents on the effect of toxigenic mold consumption at levels above normal to the population

Based on the results obtained majority of the respondents (83%) indicated that consumption of the moldy grains could have negative side effects. There were no significance differences in knowledge across the respondents from the different gender and age. The respondents had limited Knowledge on the specific health effect caused by consumption of contaminated grains. They were not able to correlate the molds to be an indication of mycotoxin contamination of the grains. This observation agrees with the study by Mendoza *et al.* (2017) The results in the present study are consistent with several other reseachers who reported that most rural community households in Southern Africa are less knowledgeable of health implications associated with consuming mouldy contaminated maize foods (Matumba *et al.,* 2015; Mboya and Kolanisi 2014;Mukanga *et al.,* 2011). Consumption of mycotoxins contaminated foods pose serious acute and chronic health implications in consumers (Reddy *et al.,* 2010), which include carcinogenic, mutagenic, teratogenic, hepatotoxic and immunosuppression (Mostrom 2016 ;Liu and Wu, 2010 ; IARC, 2015).

3.4.4 Knowledge of the respondents on the control of toxigenic mold consumption at levels above normal to the population

The trainings organized by the nonprofit making organization (One-acre fund) played a very huge role in ensuring that the small-scale farmers have the knowledge on mycotoxins and how to protect their crop. However, most of the respondents are not aware on the control measures that could be implemented to co protect their harvest. There is limited information on control strategies of mycotoxins contamination in food commodities ((Phokane *et al.,* 2019;Torabi *et al.,* 2016).

3.4.5 Post harvest handling Practices during Maize harvesting

3.4.5.1 Harvesting, Post-harvest holding Duration and Maize Transportation to the farm house

In majority of households, maize production is for household consumption and surplus is sold. This requires a large reduction in costs of labor. Family labor and the largely unskilled casual laborers provide the low-cost labor. Whereas family labor is free and non-conditional, the casual laborers are drawn from the local community with their compensation/wages paid from part of the harvest. The large dependence on the unskilled local community and family limits the pool of knowledge available for the farmer to draw from the highly sort after good agricultural practices. Additionally, the manual harvesting process takes a long time with the crop left on the farm for long periods leading to an increased risk of contamination. The harvested crop is collected in a cleared spot on bare ground with no covering during the day and a light covering during the nights. Transportation increased the cost of production for the small-scale farmers. Given the proximity of the farm to the homesteads for majority of the farmers, human labor or manual transportation was most common mode of transportation in this region, this results contradicts the study by Machekano *et al.* (2018) in Zimbabwe where there was more preference for the carts compared to the human loaders.

The extended harvest duration coupled with the slow transportation process increases the holding period on the farm for the harvested crop. Majority of the farmers of the respondents held the harvested crop in the farm for 1- 3 days prior to transportation to the farm house. These study results agree with an initial survey carried out by Aflastop on farmers in Rift valley and Eastern parts of Kenya. The study by (Koskei *et al.*, 2020) also emphasizes the same point that farmers left the maize in the farm without covering. Longer maize holding period coupled with the humid conditions and light rains during the harvest season exposed the harvest to adverse environmental and weather conditions which increases the risk of fungal contamination as well as Insects infestation.

3.4.5.2 Maize Shelling practices

Use of tractors motored machines for maize shelling was most preferred method by farmers The results obtained from the current study contradict with previous study by Kamala *et al*. (2016) in Tanzania where most of the small scale farmers hit/beat the maize to dissociate the grains from the cobs. Shelling and Hitting the maize creates physical damage to the maize Kernels and generates a lot of dust. Mechanical damage of the maize grains during shelling impacts both on the quantity and quality of the maize grains. Damage to the seed coat increases the susceptibility of the grain to attack by mold and increases the storage hazard for a given combination of temperature and kernel moisture as mentioned by Kalbasi-ashtari, 1980 in his studies .An imperfect seed coat allows for the enhancement of mold growth and allows for easy access by weevils or other injurious insects. The broken kernels and dust generated during shelling is separated from the maize grains by sieving, winnowing, sorting and segregation of the broken and discolored grains.98.5% of the respondents used these methods to clean their maize grains The cleaning removes chaff, weed seeds, broken grains and dust materials which hold water and can lead to product quality deterioration and longer drying period (Golob, 2009).55.5 % of the respondents passed their maize through the sieves after the de-husking/shelling process to get rid of the dust and the broken particles.14 % of the respondents sorted and segregated the maize which were discoloured, broken and with other physical deformities.28% of the respondents practiced winnowing with the wind blowing off the dust and lighter particles. The current study differs from the previous study by Mutungi *et al* (2019) in Tanzania where most of the farmers relied on winnowing during cleaning of shelled maize. This research however, also agrees with the same study on the few number of respondents who did not use any of the methods and relied on the thresher during shelling to blow away the dust.

3.4.5.3 Drying practices

Solar drying of maize was reported as the most preferred by farmers which could be due to its availability and affordability. The results are comparable to the findings by Koskei *et al* (2020) and Kamala *et al.* (2016**)** on maize postharvest storage practices of maize in rift valley and lower eastern regions of Kenya and Tanzania respectively. Sun drying is a low-cost energy and available naturally hence accessible to the small-scale farmers. However, drying the maize directly on the ground predisposes the maize to insects and fungal contamination and is significantly related with aflatoxin and Fumonisin contamination (Kamala *et al*., 2016).Placing the grains or cobs directly on the ground can lead to uptake of fungal spores and also moisture from the ground and therefore making the maize more susceptible to mycotoxin contamination.

Varying weather pattern in the tropical has greatly impacted on the maize drying duration and the effectiveness of the drying process (Koskei *et al*., 2020).Duration for maize drying was largely dependent on the intensity of the sun, this is especially because majority of the farmers carried out solar drying. Majority of the respondents (51.5 %) took more than 6 days to dry their maize while 20.5 % of the farmers took 3-6 days to dry the maize. The findings from this study are similar with the results from a previous study by Koskei *et al* (2020) on the number of days taken for drying of maize in Rift valley and eastern regions of Kenya .Effective drying process reduces the moisture content in the grains and consequently reduces the water activity in the grains. Reducing the water activity leads to a reduced metabolic activity of the microorganism possibly there in therefore increasing the shelf life of the maize. Because maize grains are biologically active high moisture content increases metabolic activity generating a lot of heat and providing the optimum conditions for germination.

The dryness of the grains was largely determined using physical means. 41% of the respondents chewed a part of the grains while 31% of the respondents shook the grains and listened to the sound of the maize. Only 8.5% of the respondents had access to the hand-held moisture meters for accurate moisture measurements. The physical methods cannot be relied on to give accurate results given that they are subjective depending on the strength or listening capabilities of the individuals. In the study by Koskei and Colleagues in rift valley and the Eastern regions of Kenya the farmers chewed/bit part of the grains or listened to the sound of the grains. In Tanzania in the study by Kamala and Colleagues the farmers also applied the same method of chewing/biting the maize and listening to the sounds of the maize in a tin can. Inaccurate detection of moisture content can lead to storage of maize with high moisture content which encourages germination of the grains or even toxigenic fungal growth.

3.4.5.4 Storage Practices

Majority of the small-scale farmers either store their crops in their living quarters (56% or in leased rental houses which have been converted to storage facilities (17%). Limited resources in setting up a specialized maize storage facility and the fear for the safety of their crops are some of the main factors leading to this trend of storage. Living quarters and the leased premises were poorly lit, with a single door and the available windows are mainly closed for safety reasons or inaccessible due to the congestion in the store. Poor aeration of the facility results in buildup of heat and moisture in the storage room providing the optimum conditions for the toxigenic molds to thrive. Temperature above 25 degrees Celsius and relative humidity above 65% provide ideal conditions for these toxigenic molds and also increase the risk of insect infestation (Alshannaq and Yu, 2017).The current study is in agreement with previous study by Kasirayi & Munamato (2016) in Zimbabwe on the knowledge of small scale farmers on storage pests and is also in agreement with a previous survey (Prevention, 2013) by Aflastop sponsored by USAID and Melinda and Bill gates foundation in North Rift and Eastern regions of Kenya on storage practices for the small scale farmers.

The specialized storage facility is well aerated, and the free air movement additionally helps the grains dry to the required moisture levels. Traditional cribs made from twigs and the specialized modern storage facilities raised from the ground were however not equipped with rodent guards which protect against entrance of the rodents**.** The rodents damage the grains and lead to massive losses to the farmers and can also be vectors for myriad of diseases and other pests.

About 76% of the respondents reported used the storage facility for multiple crops. Maize, Beans, Groundnuts and millet form the bulk of the crops harvested and stored for long periods in the farm. Susceptibility of the different crops to toxigenic molds vary from crop to crop, however having the different harvests in the safe facility increases the risks of transfer of pests, Insects and other microbial contamination from the more susceptible crops to the rest of the harvest in the storage facility. Most of the small-scale respondents (53%) store their crop as maize grains after shelling. The ease of storage for the shelled maize and the inadequate space available to the small-scale farmers means most of the farmers gravitate towards this mode.9% of the respondents' favored storage of the maize with the sheath. The sheath is used as animal feed after separation from the maize cob. Shelling/Dehusking provides a larger surface area to volume ratio for drying and shortens the duration for required for maize drying. Additionally, the sheath provides sufficient heat and with the high moisture content of the maize optimum conditions for toxigenic mould growth.

The storage mode for maize is intended to protect the grains against insects, pests and Moisture proliferation. Damage by insects account for the prevalent portion (52-86 %) of grain damage observed in storage treatments (Abass *et al*., 2018). The dominant maize insect pests in Trans Nzoia county are the Large grain borer (LGB), *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) and the maize weevil *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae).44.5% of the respondents used the Woven polypropylene bags for the maize storage which was a mixture of the new and the recycled bags from the previous season. The bags were dusted with the Insecticide on the sides to mitigate against the pests and Insects. Only 12.5% of the respondents had access to the pretreated hermetic bags which are recommended by Kenya Agricultural and Livestock Research Organization (KALRO). The other systems of maize storage including crates, baskets and on top of the fire place which were applied by 17% of the respondents did not necessarily guarantee assured results on the key aspects of insect and pests free produce, fungal free produce and minimal yield drop thought the storage period. The sisal bags are more prone to rodent's infestation and provide ideal hiding areas and food for the insects and pests. The current study compares well with the study in Zimbabwe on post-harvest pest management by Machekano *et al*., 2018 and the previous study by Koskei *et al.*, 2020 on storage bags in se in Eastern and Rift valley regions of Kenya.

All the respondents reported that they cleaned the storage facility before introduction of the crop for the new season. Storage facilities harbor insects and other microbial contaminants for a long period of time due to the availability of food and the conducive climatic conditions. The results from the current study agree with a previous study by Mendoza *et al*., 2017 in Guatemala that cleaning for the storage facility was actually done. 62% of the respondents cleaned the facility by without use of the insecticide.38% of the respondents cleaned their facility with disinfectants.

Dusting of the storage facility with insecticide was widely used by the respondents (82%) to get rid of the insects and pests prior to the introduction of the crop into the store. The other methods applied by the respondents included spreading sand on the floor(5.5%),smearing cow dung on the store(2%),using natural herbs like neem (0.5%) and the other methods like spreading leaves or maize stalks on the facility store(3.3%).The current study is in agreement with the study by Koskei *et al.*, 2020 in Rift valley and Eastern region of Kenya. Storage facilities provide conducive environment for the pests, Insects and even the microbial contaminants that are hazardous to the produce. These insects and pests find hiding places in crevices, wood planks, storage bags and farm implement that might be in the storage facility.

Shared storage of maize that is harvested in different seasons was a common practice among farmers which compares to the findings in previous study by Kamala *et al*., 2016 in Tanzania. Segregation of the previous year maize from the current year maize or a total clear out of the previous season crop protects the current crop from possible contamination from the old stock. Inadequate storage facility, poor yield and preferable market prices were the major factors that contributed to the short storage period for these farmers. Farmers leasing storage facility recorded shorter holding periods for their maize to minimize on storage expenses. The current study corresponds with those of a study conducted in Guatemala by Mendoza *et al.*, 2017 on the storage period for maize by the small scale farmers. Moisture level of the grains before storage and the storage facility conditions play a critical role in the final produce quality. Pests and Insects, Fungal contamination and rodents are some of the risks associated with long storage periods. Maize grains are hygroscopic in nature and the risk of absorbing moisture from the environment and rewetting is an ever-present risk especially in poorly ventilated stores and in cases where the grains are not uniformly dried. The short rains season between the months of October and November offer a challenge to the farmers with poorly aerated stores and poorly roofed stores.

Majority of the respondents (84.5%) reported use of synthetic pesticides as the primary protection method for the maize and a further 5% combined the two approaches of insecticide and rodent bait stations. The current study finding is in agreement with the study by Koskei *et al*., 2020 however the this findings contradicts with the study in western Kenya by Midega *et al*., 2016 which reported that aeration/Sun drying was the most favored method of protection for the harvest. Sun drying was favored by only 7% with the respondents considering sufficient drying of the maize as adequate protection for their harvest. Limited resources to procure the pesticides, negative perception on use of chemicals and inadequate training and awareness on the safety and sage of the pesticides were cited as the main contributors to shunning of the pesticides. The broad-spectrum Insecticides and pesticides cold be very effective in eliminating the weevils and borers more common in Trans Nzoia county, this cold in effect protect the crop from attack by the toxigenic molds due to the preservation of the maize kernel (Ogendo *et al*., 2004b).However for the toxin produced before produce is harvested it can be argued that the insecticides might have little effect(Kamala *et al*., 2016).3% of the respondents applied the use of the rodents and pests alone.3% of the respondents had rodent baits installed in their facilities. This however cold only be effective against the rodents and therefore very limiting in terms of their protection capability.

Due to the high cost of the moisture meters and the limited extension services support from the Government,one acre fund a non-profit making organisation domiciled in Trans Nzoia county has done a lot in providing community groups with moisture meters for moisture checks, however only 8.5% of the respondents reported having access to these moisture meters. This current study is in agreement with a previous study on appropriate grain and seed storage for small scale farmers. The study also compares with the results finding by Koskei *et al* (2020) in Kenya, Tanzania by Kamala *et al*., 2016,Machekano *et al*., 2018 in Zimbabwe and the study in Guatemala by Mendoza *et al*., 2017 where both studies reported use of biting of the grain by the farmers and listening to the sound of the grains as the most widely used methods for moisture check

3.4.5.5 Disposal of Contaminated Maize

Limited understanding of the mycotoxin significantly influences the safety and food security for the small-scale farmers in Trans Nzoia county. Majority of the respondents used the mouldy maize as animal feed (for the livestock and poultry) or sold the contaminated maize to animal feeds manufacturers. Commercial feeds have been reported to be contaminated with aflatoxin

B1 and milk with aflatoxin M1 (Kang'Ethe *et al.*, 2017).The mycotoxin levels higher than the recommended levels negatively affects the livestock productivity, makes them more susceptibility to infectious disease and lead to stunted growth. Aflatoxin concentration of more than 1mg/kg affects layers performance and causes a reduction in egg weight(Alshannaq and Yu, 2017). The current study compares with a previous study by Koskei *et al.*, 2020 on post-harvest storage practices.15% of the respondents reportedly diluted the contaminated maize with non-contaminated maize. This dilution only spreads the toxigenic molds to the non-contaminated maize. Dilution does not reduce the mycotoxin contamination levels in the grains (Kang'Ethe and Lang'A, 2009).The current study compares with the study in Guatemala by Mendoza *et al*., 2017 where farmers diluted on contaminated maize with diluted maize. Disposal of contaminated maize by burying the grains (8.5%) in the ground and incineration (6.5%) as employed by the respondents are acceptable methods of disposal. However, open-air burning of materials and discharge of untreated toxic waste into the environment including burying in the ground goes against the National Environmental Management Act. Previous studies by (Hariprasad *et al*. 2014); Snigdha *et al*. 2015 have shown that its possible for plants to take up Aflatoxin from the soil. Therefore burying contaminated maize in the ground can be only effective if the grains are buried below the level where uptake by the root system is possible, Burying is only effective if the soil contains microorganisms like *Aspergillus Niger* and *Flavobacterium auranticum* which are thought to degrade the aflatoxins (Wu *et al.*, 2009); and for soils rich in binding calcium aluminosilicates which bind with the Aflatoxin making it less harmful to the soil and the crops(Williams *et al*., 2004)

Incineration is an effective method of breaking down Aflatoxin molecule with temperatures of more than 500°. However, in addition to the environmental concern because of open air burning of the maize grains its highly unlikely to attain the aflatoxin molecule decomposition temperature of 269°C while burning in the open environment (Quadri *et al*. 2010). A small percentage of the respondents (4%) considered the contaminated maize safe for brewing. This current study agrees with the study by Koskei *et al*. (2020) on the different methods the small scale farmers in Rift valley and Eastern regions of Kenya applied. The fermentation process in production of the local brew reduces the aflatoxin levels in Maize. Lactic acid bacteria (*Lactobacillus* strains) involved in natural fermentation reduces the levels of aflatoxin in affected grains by binding with the toxins on their cell wall or by active internalization and accumulation (Adelekan , 2019). The reported postharvest losses are comparable to those stated by Koskei *et al.*, 2020 and Mendoza *et al*., 2017. The high postharvest losses are associated with poor maize postharvest practices, informal marketing systems, and unfavorable physical and environmental factors. Insect damage, Pests and rodents are associated with the losses in the farms.

3.5 Conclusion

The farmers in Trans Nzoia County have moderate knowledge on the best practices in Post-harvest handling practices that protect their maize from the mycotoxin contamination. Economic factors play a critical role in determining the practices by the farmers and the effort to seek for additional knowledge from experts or training institutions on GAP. Concerns such as security has taken precedence over the safety of the crop under storage. Most of the farmers employed physical indicative methods during testing due to limited resources. Majority of the small-scale farmers have adequate knowledge on mycotoxin contamination, crop protection and disposal of contaminated crop.

3.6 Recommendations

It is recommended that stake holders both from the private sector and the public sector should develop programs targeting small scale farmers training. Policy makers should provide more extension services to the farmers to offer knowledge and tools required to map out risk areas and stages with high risk of mycotoxin growth and development.

CHAPTER FOUR: LEVELS OF INTAKE OF AFLATOXIN AND FUMONISIN BY MAIZE CONSUMERS IN TRANZOIA COUNTY, KENYA

Abstract

Small-scale farmers cultivate over 75% of Kenya's maize area, producing more than 65% of the country's annual maize production. However, interest in the level of aflatoxins in maize-based products has increased in Kenya. Aflatoxicosis outbreaks in various parts of Kenya have focused attention on maize farmers, particularly those in Trans Nzoia county, the country's largest maize producing region. The extent to which maize produced and consumed in Trans Nzoia county is contaminated with mycotoxin (Aflatoxin and fumonisins) is unknown. The purpose of this study was to determine the extent of mycotoxin contamination in the county, with an emphasis on the level of Aflatoxin and fumonisin contamination in post-harvest maize, as well as exposure to mycotoxins through contaminated maize consumption. Maize grains were collected from 31 randomly selected small scale farmers in Trans Nzoia. Aflatoxin and fumonisin levels were determined in the samples at the Kenya Bureau of Standards (KEBS) laboratory using ELISA techniques. Total aflatoxin levels in the initial sample ranged from 0.00 to 9.12 µg/kg, with a mean of 1.96 µg/kg. Aflatoxin levels were found to be between 3.69 and 15.43 µg/kg after two months of storage, with a mean of 2.96µg/kg. Initial total fumonisin concentrations ranged between 0.00 and 1.36 µg/kg, with a mean of 0.44 µg/kg. After two months of storage, fumonisin levels ranged from 0.00 µg/kg to 1.51 µg/kg, with a mean of 0.60 µg/kg. However, only 9.68 percent and 38.71 percent of the samples, respectively, had levels of Aflatoxin and fumonisin above 10ppb and 500ug/kg respectively the WHO-recommended levels. The study concluded that Aflatoxin and fumonisin levels were significantly lower at harvest stages compared to the post-harvest storage periods. Further research on a larger population is recommended to ensure that preventive measures are in place to minimize the likelihood of exposure to aflatoxin poisoning by consumers.

4.1 Introduction

Maize arrived on the African coast for the first time in the seventeenth century. It was originally introduced by the Portuguese as they supplied their trading forts, but due to its high energy yield, low labor requirements, and short growing season, the crop was quickly adopted by African farmers (Cherniwchan and Moreno-Cruz, 2019). Maize was heavily promoted and developed in Kenya by white settlers to feed their expanding workforce. Tropical climatic conditions have proven to be favorable for the crop's long-term viability. Maize production in East Africa is rain-fed, with small-scale farmers cultivating more than 75% of the maize area and producing more than 65% of the maize consumed in the country (Agro-ecologies, 2015).

Currently, maize is a staple food for over 90% of Kenya's forty million residents, both rural and urban (Issue and Context, 2015). However, varying weather conditions and insufficient post- and pre-harvest practices pose a serious threat to the maize's quality and safety. Pests and diseases, microbial contamination, including mycotoxins, and post-harvest losses are emerging challenges for the majority of Kenya's small-scale farmers (Agro-ecologies, 2015).

Mycotoxins are chemical metabolites produced by filamentous fungi which grow in food or agricultural products ,these chemicals are extremely toxic to humans and animals(Wu, 2006). Contamination of agricultural crops with mycotoxins worldwide was projected to be 25% in 2010 (Eskola *et al*., 2020). The fungi can attack agricultural crops during pre-harvest and are transmitted throughout the whole post-harvest value chain, including drying, storage and/or processing. Because of the stability of mycotoxins to agents that are used for killing the molds, they may be present in food long after the molds have been rendered unviable. Although more than 300 types of mycotoxins have been documented, only a few of them have been recognized as important in human health, including agricultural mycotoxins namely aflatoxins (AFs), fumonisins (FUMs), trichothecenes (TCT), ochratoxin (OTA), zearalenone (ZEA) and patulin produced mainly by the mould species *Fusarium, Penicillium* and *Aspergillus*(Alshannaq and Yu, 2017).The toxicity of the mycotoxin is dependent on the species and strains of fungus, composition of matrix and environmental conducive factors such as moisture and temperature(Pitt and Hocking, 2009).

Mycotoxins production is highly dependent on temperature and moisture content. Other factors that can affect mycotoxin and fungal Occurrence include insect damage, bioavailability of micronutrients(Smith *et al*., 2016). The most prevalent mycotoxins in Africa, Asia and South America are the Aflatoxins formed by Aspergillus Flavus and Aspergillus Parasiticus (Smith *et al*., 2016). Acute Aflatoxin toxicity is fatal while chronic exposure has been associated with stunted growth in Children, immunosuppression and liver cancer(WHO, 2018a). Consumption of fumonisin has been associated with stunted growth and esophageal cancer (Harvey *et al*., 2015). The two mycotoxins are more common in the tropical and sub-tropical areas with hot and humid climates.

Kenya has experienced Aflatoxicosis in the eastern part in 2004 (Probst *et al*., 2007;Tan, 2020; Mutegi *et al*., 2018). More recently in November 2019 an expose in Kenya shed light on the high levels of Aflatoxin contamination on popular maize flour brands leading to the subsequent withdrawal of these brands from the shelves by the Kenya Bureau of standards (KEBS). Consequently, in 2019 several brands of locally milled maize flour were removed from the market because they had Aflatoxins levels higher than the Internationally and locally acceptable levels. Kenya Bureau of standards has adopted the mycotoxin limits as recommended by WFP with the maximum limit for Aflatoxin at 10 ppb (10• g/kg) and for fumonisin at 1 ppm (1mg/kg).

The aim of this study was to determine the aflatoxins and fumonisins levels in maize-based meals produced by small-scale farmers in Trans Nzoia county, with a particular emphasis on the post-harvest and handling processes, as well as the intake levels of mycotoxins as a result of consuming meals made from the maize.

4.2 Materials and Methods

4.2.1 Study design

The study was designed in a cross-sectional manner, with an analytical component. A pre-tested structured questionnaire was used to interview small-scale farmers in Trans Nzoia county. The demographics of the respondents included gender, age, level of education, source of income, weight and height, and consumption of maize-based meals.

4.2.2 Description of study Area

The study location was as per chapter three

4.2.3 Sample size determination

Sample size was determined as per chapter three above and maize grains were sampled from a total of 196 small scale farmers.

4.2.4 Sampling of the maize for the analysis

The five sub counties' administrative boundaries were used to select sampling sites at random. Thirty-one small-scale farmer households were chosen as potential sampling sites from this group, which were distributed across the five sub-counties. Given that the sub counties are in the same Agro Ecological Zone, the samples drawn in duplicate from the five sub counties were considered to be representative of the maize distribution in the county. Random sampling techniques were used to extract approximately 100g of samples from three 90-kg polypropylene storage bags. The samples were drawn in triplicates at different depths: top, middle, and bottom. The subsamples were thoroughly mixed, and a 100g homogenous sample drawn in duplicate for lab analysis. After a 2-month storage period of maize, storage samples were drawn using the same procedure as the initial sampling. Nonwoven bags were used to transport the samples, which were then placed in airtight plastic containers.

4.2.5 Maize storage

The maize grains were sampled after harvest for mycotoxin analysis. The respondents were requested to store the grains for a period of 2 months. After 2 months, the grains were sampled for post storage mycotoxin storage.

4.2.6 Determination of the mycotoxins in maize samples

4.2.6.1 Assessment of maize intake

A semi-structured questionnaire was used to determine the quantities and frequency of consumption of maize and maize products (Appendix 1)

4.2.6.2 Aflatoxin determination

The Helica Biosystems international protocols were used to analyses total Fumonisin and Aflatoxin using the Enzyme linked Immunosorbent Assays (ELISA) Method according to Harvey *et al*. (2015).

4.2.7 Mycotoxin exposure by maize meal consumers

4.2.7.1 Intake levels of fumonisins and aflatoxins in maize-based porridge

The exposure of respondents to aflatoxins and fumonisins from maize meal consumption was quantified probabilistically using @Risk Top Rank Palisade (UK) software for excel (Palisade, UK) V.8.0, which fitted aflatoxins and fumonisins and consumption levels data to get the best fit distributions. The distribution formulas used are listed in Table 1. The Exposure levels were calculated by combining data on consumption with aflatoxins and fumonisin concentrations in maize samples. The mean and 95th percentile (P95) intake levels were used to estimate the margins of exposure (MoE) using Monte Carlo simulation models with 1,000,000 iterations. Mycotoxins' Estimated Daily Intake (EDI) was compared to their Acceptable Daily Intake (ADI) (WHO, 2005 ; Benford *et al*., 2010). The Tolerable Daily Intake for fumonisins was set at 1000–4000 mg/kg bwt/day mg/child/day, whereas the Tolerable Daily Intake for aflatoxins was set at Fumonisin exposures greater than 0.001 mg/kg bwt/day according to JECFA (JECFA, 2008 ; WHO, 2012).

4.2.8 Formulae used in quantitative risk assessment simulation model for Aflatoxin exposure in maize meal porridge

The maize consumption data were obtained by multiplying the weekly intake of maize meal porridge (kg/person) by the respondents' body weights and then by seven days as per JECFA (2011) to obtain the amount consumed per kg body weight per day. The aflatoxin and fumonisin distributions in maize meal were determined by dividing the mycotoxins levels per kilogram of maize, whereas the intake levels were determined by multiplying the respective mycotoxins and maize consumption to get the amount consumed per kilogram body weight per day (Table 1).

Table 4.1: Distribution functions used in quantitative risk assessment simulation for aflatoxins and fumonisins exposure in maize

Parameter	Distribution	Monte Carlo Function
Aflatoxin		
Maize meal consumption (Kg/Kg bwt/day)	Extent	RiskTriang(0.00090637,0.015385,0.020736,RiskName("Maize meal Consumption (Kg/Kg bwt/day)"))
Aflatoxin levels in maize based porridge (μg/Kg)	Levels	RiskExpon (3.0079, RiskShift (0.048515), Risk Name ("Aflatoxin levels (μg/kg)"))
Aflatoxin intake levels in maize based porridge (μg/Kg bwt/day)	Intake	Aflatoxin distribution in porridge * Maize based porridge consumption (RiskTriang (0.0027263,0.046275,0.062372,RiskName("Aflatoxin exposure (μg/ Kg bwt/day)")))
Fumonisins		
Maize meal consumption (Kg/Kg bw/day)	Extent	RiskTriang(0.00090637,0.015385,0.020736, RiskName("Maize meal Consumption (Kg/Kg bwt/day)"))
Fumonisin levels in maize based porridge (mg/Kg)	Levels	RiskTriang(0,0,1.789,RiskName("Fumonisins levels (μg/kg)"))
Fumonisin intake in maize based porridge (μg/ Kg bwt/day)	Intake	Fumonisin levels in maize meal * Maize meal consumption.(RiskTriang(-0.0022232,0.009128,0.012144,RiskName("Fumonisins exposure (μg/ Kg bwt/day)"))

4.2.9 Data analysis

The obtained data was subjected to Genstat® 20th edition for windows. The One-way analysis of variance (ANOVA) was used to obtain means, standard deviations and compare significant differences of aflatoxins and fumonisins levels among the samples. Tukey Test at 95 % confidence interval was applied to analyze the statistical significance among the samples. The obtained results from aflatoxins and fumonisins analysis were respectively converted from ppb to μg/kg, and ppm to mg/kg for easy interpretation. The consumption and intake levels were analyzed using Microsoft Excel @Risk TopRank Palisade(UK) V8.0.0 AddIn software.

4.3 Results

4.3.1 Levels of aflatoxin and fumonisin in maize grains in Trans Nzoia county

The initial samples drawn after harvesting and before the post-harvest handling process had mean aflatoxin and fumonisin levels of 1.96 µg/kg and 0.44 µg/Kg respectively. About 4 in every 10 (45.16%) of the samples analysed for had detectable levels of aflatoxin with none of the sample above the levels recommended by WHO and KEBs. About 61.29% of the initial samples collected had detectable levels of Fumonisin with 23% of the samples having fumonisin levels above the recommended limits. The samples drawn after the post-harvest handling processes and storage for 2 months had the mean aflatoxin and fumonisin level of 2.96 µg/kg and 0.60µg/Kg respectively.54.84% of the samples had detectable levels of aflatoxins while 9.68% had levels above the allowable limits of 10ppb. About 70.97% of the 31samples analysed had detectable levels of fumonisin and 38.71% had levels of fumonisin above the WHO and KEBs recommended levels (Figure 4.2).

Table 4.2: Aflatoxin and Fumonisin level at harvest and after 2 months storage period in maize samples collected in Trans-Nzoia county

Sampling plan	Aflatoxins (µg/Kg)	Range (µg/Kg)	Fumonisin (µg/Kg)	Range (µg/Kg)
Initial Sample (At harvest)	1.96 ± 2.85	0 – 9.12	0,44 ±0.46	0 -1.36
After 2 months Storage period	2,96 ± 4.74	0 -15.43	0.60 ± 0.58	0 -1.51

4.3.2 Maize meal consumption

The levels of maize consumption, aflatoxin and fumonisin in the maize samples were characterized by triangular distributions ranging from 0 - 0.021 and averaging 0.012±0.005 Kg/Kg bwt/day (Figure 5.1) and an average of 816.6 grams/day of maize based meals. The average quantities consumed in this study might have been slightly higher compared to Jere *et al*. (2020) findings of 0.008-0.082 Kg/Kg bwt/day although the study focused on consumption of maize based porridge in Malawi.

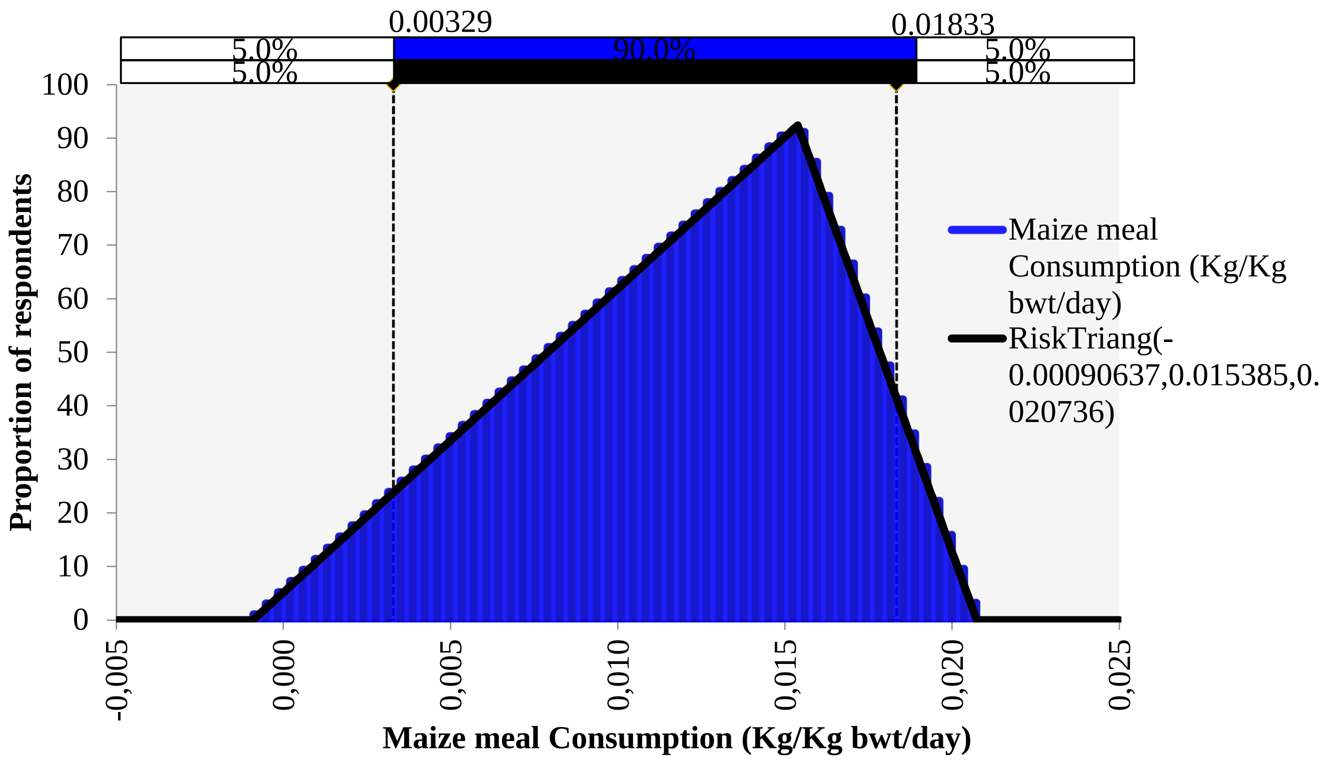

Figure 4.2: Distributions of Maize meal Consumption (Kg/Kg bwt/day) in Comparison with RiskTriang fitting

4.3.3 Exposure to mycotoxins intake through maize meal consumption

The aflatoxin and fumonisins levels for the stored grains averaged 2.96 micrograms and 0.6 milligrams per kg of maize, respectively. Consequently, the exposure was slightly more in the aflatoxin compared to the fumonisins (Table 5.2). The 95th percentiles for the levels and intake for aflatoxins were equally high in the aflatoxin as compared to the fumonisins. The levels of aflatoxins were however within the KEBS standard of 10 µg/Kg at both the mean and the 95th percentile and therefore an indication of the safety of the post harvested maize.

Table 4.3: Levels of mycotoxins intake maize

Mycotoxins	Means	P95	90% Confidence interval	
			Minimum	Maximum
Aflatoxin levels (µg/Kg)"))	2.959±3.008	8.962	0.0	43.563
Aflatoxin exposure (µg/ Kg bwt/day)	0.035±0.014	0.055	0.0	0.062
Fumonisins (µg/kg)	0.596±0.422	1.389	0.0	1.788
Fumonisins exposure (µg/ Kg bwt/day)	0.006±0.003	0.011	0.0	0.012

P95- 95^{th} percentile bwt-body weight

4.4 Discussion

4.4.1 Levels of aflatoxin and fumonisin in maize grains in Trans Nzoia county

Maize in Kenya is grown under Agro Climatic conditions that favor mycotoxin development (Kedera *et al* 1999, Okoth *et al* 2012). The range of detectable Aflatoxin and fumonisin in Trans-nzoia county both at the Initial stage and after 2 months storage was found to be much lower than the levels in eastern parts of the country which has experienced aflatoxicosis more often in the recent Past (Prevention, 2013).The detectable mycotoxin after harvest and before the complete post-harvest handling stages can be linked to the plant stress attributes like soil characteristics and the varying weather conditions. Weather patterns during the pre-flowering stage, during the flowering stage and the grains filling stage play a significant role in the growth and development of the mycotoxins in the crop on the fields. Trans Nzoia county receives rainfall ranging between 1000mm to 1700mm in the year with average maximum temperatures of 28°C and average minimum temperature of 11°C. The high rainfall during the pre-flowering season increases the plant density in the fields therefore favoring fungal growth and development. The low rainfall during the flowering stage and early prefilling is associated with increased aflatoxigenic fungal infection and aflatoxin growth(Morales *et al*., 2016). Most of the small-scale farmers in Trans Nzoia county practiced intercropping using leguminous beans and cow peas therefore providing plant cover and reducing evapotranspiration and providing the much-needed nitrogen to the roots, these consequently reduces plant stress and limiting probability of mycotoxin growth and development.

The increase in Aflatoxin and fumonisin contamination after the post-harvest procedures may be attributed to the heavy rains experienced during the harvesting, post-harvest handling process and during the storage phase. The harvest season falls in the intermediate rain season of June, July and August and the short rains season of October, November and December(Heckman *et al*., 1967,Mbaisi *et al*., 2016).The sub optimal drying process due to the reduced solar intensity and high humidity levels in the environment coupled with poor storage practices have a great impact on the gradual increase in the levels of Mycotoxin. Poor storage facility aeration, Storage facilities filled to capacity, Storage of the grains in concrete (Cemented housings) and storage of the grains on the floor and next to the walls are some of the practices that can be attributed to the increase in mycotoxin.

The percentage of detectable fumonisin in initial samples (61.29%) and after a two-month holding period (70.97%) was found to be greater than the percentage of detectable Aflatoxin in initial samples (45,16%) and after a two-month holding period (54,84%) in Trans-Nzoia county. This finding corroborates prior findings by (Harvey *et al*., 2015; Kedera *et al*., 1999). The higher levels of Fumonisin in the initial sample (22.58%) and the sample after two months (38.71%) could be attributed to the increased health complications such as esophageal cancer reported by Parker and colleagues in 2010 and Wakhisi in 2005 in their studies in Western Kenya. Fumonisins are most prevalent in warm climates and warm tropical areas where maize is grown, which is more typical of storage facilities with restricted air circulation and inadequate aeration.

4.4.2 Maize meal consumption

The high maize consumption levels can be attributed to Transzoia's county’s prominence as a maize producing region. It's however critical to remember, that consuming a lot of maize foods increases the risk of contracting mycotoxins (Alberts *at al.*, 2019). Other research indicates that individuals who consume 400–500 grams of maize-based foods per person/per day have significantly higher levels of mycotoxins biomarkers than the recommended Provisional Maximum Tolerable Intake (PMTDI) (Shephard *et al*., 2007).

Studies have found significantly lower consumption levels, such as 397 grams per day in South Africa and 356 grams per day in Tanzania (Burger *et al.*, 2014), besides exceeding the East African average of 150–500 grams per day (Gong *et al*., 2015).

4.4.3 Exposure to Mycotoxins intake through maize meal consumption

Although the findings in this study were not above the recommended levels, mycotoxin occurrence in Kenya is endemic, and previous studies have found as much as 58,000 g/kg of total aflatoxin in maize, posing serious health concerns among consumers (Obonyo and Salano, 2018). Fumonisins B1 (FB1), B2 (FB2), and B3 (FB3) make up the total fumonisins, with FB1 being the most potent and frequently linked to oesophageal cancers as well as cardiovascular complications, especially in populations who consume large amounts of contaminated maize-based food (Obonyo and Salano, 2018). On the other hand, the commonly occurring aflatoxins Similarly, aflatoxins are classified as B1 (AFB1), B2 (AFB2), G1 (AFG1), and G2 (AFG2), with all of them posing serious health risks, though AFB1 is the most dangerous, according to the International Agency for Research on Cancer (IARC 2002). Kwashiorkor and marasmus incidences in children have been linked to Aflatoxin exposure (Magoha *et al*., 2016). This therefore, requires adequate measures to curb the occurrence of mycotoxins in maize meant for human consumption.

The results of this study indicate a strong correlation amongst the occurrence and prevalence of aflatoxins and fumonisins in maize-based meals consumed by farmer households in the study area, which is a likely scenario in Kenya given the crop's status as a staple crop. This outcome correlates those reported in other similar studies by Jere *et al*., (2020) and Obonyo & Salano, (2018). Pre- and post-harvest handling practices within the maize value chain, in combination with favorable climatic conditions, have resulted in the highest occurrence of mycotoxins in maize produced and stored in tropical regions worldwide, with Kenya being particularly high, according to previous reports. However, the current findings on fumonisins were within the WHO-recommended range, indicating a low food safety risk. According to the World Health Organisation (2018), dietary exposure to total fumonisins from foods should range between 1000 and 4000 µg /Kg body weight/day.

Mycotoxins are highly toxic substances produced by certain types of fungi (molds) found naturally throughout the world; they have the potential to attack food crops and pose a serious health risk to humans and livestock (Schrenk *et al*., 2020). Aflatoxins also have a substantial economic cost, destroying an estimated 25% or more of the world's food crops each year. Two closely related fungi, Aspergillus flavus and Aspergillus parasiticus, produce mycotoxins, particularly aflatoxins. These moulds, which are typically found on dead and decaying vegetation, can infect food crops when conditions are favorable, particularly in tropical and subtropical regions, such as high temperatures and high humidity (FAO/WHO, 2018). The current study established the Estimated Daily intakes (MOE) limits for aflatoxin and fumonisins of 0-620 and 0 - 4.29 mg/person/day, respectively (Table 5.3). The estimated daily intake exposure margins were greatest at the 95th percentile for aflatoxins than for fumonisins (Table 5.3).

Table 4.4: Estimated Daily Intakes (Margins of exposure to mycotoxins)

Mycotoxin Exposure	**Aflatoxins Intake**			**Fumonisins Intake**		
	Min	Mean	P95	Min	Mean	P95
Dietary Exposure (µg/kg bwt/day)	0	2.96	8.96	0	0.60	1.4
MOE (69.21 Kg adult) µg/person/day	0	204.79	620.25	0	41.25	96.9

MOE- Margin of Exposure. The MOE was based on average weight of adults of 69.21 kg obtained in this study.

The levels of fumonisins consumed through the contaminated maize were, however, within the recommended daily intake (ADI) of 1-4 µg /per kg body weight/day as specified by European and USDA standards for fumonisins in foods (Wall-Martínez *et al*., 2019). On the other hand, the current study's aflatoxins intake may have exceeded the FAO/WHO recommendation of 0.0001 µg /per kg body weight/day, which is the lowest level at which certain types of cancer can be caused in the human body. The current study's doses of approximately 3 and 9 µg/per kg body weight/day were higher than the recommended safety levels, posing a risk of mycotoxin poisoning which may be attributed to high consumption of maize meal

4.5 Conclusion

The current study established the presence of aflatoxins in maize stored and sampled by smallholder farmers. Although the levels of the mycotoxins were within the recommended safety limits, there was high intake of aflatoxins attributed to high consumption. There is a need to educate consumers about the importance of diversifying their diets while minimizing maize consumption due to the endemically contaminated local crop.

4.6 Recommendations

Further research on a larger population is recommended to ensure that preventive measures are in place to minimize the likelihood of exposure to aflatoxin poisoning by consumers.

CHAPTER FIVE: GENERAL CONCLUSIONS AND RECOMMENDATIONS

5.1 Postharvest handling knowledge and practices of small-scale maize farmers in trans nzoia county

The farmers in Trans Nzoia County have moderate knowledge on the best practices in Post-harvest handling practices that protect their maize from the mycotoxin contamination. Economic factors play a critical role in determining the practices by the farmers and the effort to seek for additional knowledge from experts or training institutions on GAP. Concerns such as security has taken precedence over the safety of the crop under storage. Most of the farmers employed physical indicative methods during testing due to limited resources. Majority of the small-scale farmers have adequate knowledge on mycotoxin contamination, crop protection and disposal of contaminated crop.

5.2 Levels of intake of aflatoxin and fumonisin by maize consumers in Trans Nzoia county, kenya

The current study established the presence of aflatoxins in maize stored and sampled by smallholder farmers. Although the levels of the mycotoxins were within the recommended safety limits, there was high intake of aflatoxins attributed to high consumption. There is a need to educate consumers about the importance of diversifying their diets while minimizing maize consumption due to the endemically contaminated local crop.

5.3 General Recommendations

§ Information on standard postharvest management practices of maize cobs and grains needs to be disseminated to the farmers and extension officers to reduce the risk of mycotoxin contamination of the grains during storage.

§ There is needed to provide effective maize storage facilities that enhance shelf-life and reduce the growth of toxigenic fungi through enhanced storage.

§ To reduce fungi growth, advanced drying techniques should be introduced to maize farmers to ensure grain for storage attains the required moisture content that reduces the growth of toxigenic fungi hence reducing mycotoxin growth.

§ Training of farmers on postharvest management practices and control of fungi is recommended to lower chances of grain contamination.

- Although the levels of the mycotoxins were within the recommended safety limits, there is a need to sensitize consumers about the importance of diversifying their diets while minimizing maize consumption due to the endemically contaminated local crop.
- The study recommends that the Trans Nzoia county government adopts a policy for controlling and monitoring levels of aflatoxin in maize grains and maize products produced,stored and distributed in the county .

REFERENCES

! Trans Nzoia County Integrated Development Plan, 2013-2017•! i, 2017. 2013–2017.

Abass, A.B., Fischler, M., Schneider, K., Daudi, S., Gaspar, A., Rüst, J., Kabula, E., Ndunguru, G., Madulu, D., Msola, D., 2018. On-farm comparison of different postharvest storage technologies in a maize farming system of Tanzania Central Corridor. J. Stored Prod. Res. 77, 55–65. https://doi.org/10.1016/j.jspr.2018.03.002

Abdullahi, A., Hassan, A., Kadarman, N., Saleh, A., Baraya, Y.S., Lua, P.L., 2016. Food safety knowledge, attitude, and practice toward compliance with abattoir laws among the abattoir workers in Malaysia. Int. J. Gen. Med. 9, 79–87. https://doi.org/10.2147/IJGM.S98436

Agro-ecologies, M., 2015. September 2015 About the Bulletin Maize in Kenya•: Chance for Getting Back to Former Glory•? 4, 1–4.

Alberts, J., Rheeder, J., Gelderblom, W., Shephard, G., Burger, H.M., 2019. Rural subsistence maize farming in South Africa: Risk assessment and intervention models for reduction of exposure to fumonisin mycotoxins. Toxins (Basel). 11, 1–20. https://doi.org/10.3390/toxins11060334

Alborch, L., Bragulat, M.R., Castellá, G., Abarca, M.L., Cabañes, F.J., 2012. Mycobiota and mycotoxin contamination of maize fl ours and popcorn kernels for human consumption commercialized in Spain 32, 97–103. https://doi.org/10.1016/j.fm.2012.04.014

Alshannaq, A., Yu, J.H., 2017. Occurrence, toxicity, and analysis of major mycotoxins in food. Int. J. Environ. Res. Public Health 14. https://doi.org/10.3390/ijerph14060632

Ao, A., Nc, N., 2019. Effect of Fermentation on Aflatoxin Content of Ogi Produced from MouldyMaize (Zea mays). J. Food Process. Technol. 10, 1–3. https://doi.org/10.4172/2157-7110.1000783

Benford, D. Bolger, P. M. Carthew, P., 2010. Application of the margin of exposure (MOE) approach to substances in food that are genotoxic and carcinogenic. Food Chem. Toxicol 48, S2–S24.

Burger, H.-M.; Lombard, M.J.; Shephard, G.S.; Danster-Christians, N.; Gelderblom, W.C.., 2014. Development and evaluation of a sensitive mycotoxin risk assessment model

(MYCORAM). Toxicol. Sci 141, 387–397.

Chauvin, N. D., F. Mulangu, and G.P., 2012. Food production and consumption trends in Sub-Saharan Africa: Prospects for the transformation of the agricultural sector. United Nation Development Programme, working paper on Regional Bureau for Africa. 76.

Cherniwchan, J., Moreno-Cruz, J., 2019. Maize and precolonial Africa. J. Dev. Econ. 136, 137–150. https://doi.org/10.1016/j.jdeveco.2018.10.008

DALLOW, R., 1992. The Role of Women in Agriculture and Rural Settings. Aust. J. Rural Health 1, 3–10. https://doi.org/10.1111/j.1440-1584.1992.tb00056.x

Eskola, M., Kos, G., Elliott, C.T., Hajšlová, J., Mayar, S., Krska, R., 2020. Worldwide contamination of food-crops with mycotoxins: Validity of the widely cited 'FAO estimate' of 25%. Crit. Rev. Food Sci. Nutr. 60, 2773–2789. https://doi.org/10.1080/10408398.2019.1658570

FAO/WHO, 2018. Aflatoxins, Joint FAO/WHO Expert Committee on Food Additives (JECFA).

FAO, 2018. Maize markets in Eastern and Southern Africa (ESA) in the Context of Climate Change, The State of Agricultural Commodity Markets (SOCO) Background Paper.

Fisher Andrew; Laing John; Stoeckel John; Townsend John, 1991. Handbook for family planning operations research design. 2nd ed. TT -, 2nd ed. Population council, New York, USA.

Golob, P., 2009. On-farm post-harvest management of food grains, Food and Agriculture Organization of the United Nations.

Groote, H. De, Owuor, G., Doss, C., Ouma, J., Muhammad, L., Danda, K., 2005. e JADE The Maize Green Revolution in Kenya Revisited 2, 32–49.

Harvey, J.W., Mutiga, S.K., Milgroom, M.G., Hoffmann, V., Nelson, R.J., 2015. Assessment of Aflatoxin and Fumonisin Contamination of Maize in Western Kenya. Phytopathology 105, 1250–1261. https://doi.org/10.1094/phyto-10-14-0269-r

Heckman, J.J., Pinto, R., Savelyev, P.A., 1967. • • No Title No Title No Title. Angew. Chemie Int. Ed. 6(11), 951–952.

IARC, 2015. IARC (International Agency for Research on Cancer) Mycotoxin control in low- and middle income countries. In IARC Working Group Report, ed. C.P. Wild, Miller, D. and J.D. Groopman, Vol 9, pp. 31–42. Lyon, France: IARC Press.

Info, C., Turnbull, P., Annalisa, C., Further, C., 2018. Country Programme Kenya (2014-2018) Standard Project Report 2017 1–31.

Issue, P., Context, E., 2015. Measuring the Demand for Aflatoxin Tested Maize in Kenya 4–6.

JECFA, 2008. Joint food and agriculture organization of the United nations and WHO Evaluation of Certain Food and Contaminants. Sixty-eighth Report of the Joint FAO/WHO Expert Committee on Food Additives (2008).

Jere, G.M., Abong, G.O., Njue, L.G., Masamba, K., Omayio, D.G., 2020. Exposure of school children to aflatoxins and fumonisins through maize-based diets in school meals programme in Salima District, Malawi. Afr. J. Food Agric. Nutr. Dev. 20, 16793–16809. https://doi.org/10.18697/ajfand.94.20110

Kalbasi-ashtari, A., 1980. Effect of internal and external damage on deterioration rate of shelled corn.

Kamala, A., Kimanya, M., Haesaert, G., Tiisekwa, B., Madege, R., Degraeve, S., Cyprian, C., De Meulenaer, B., 2016. Local post-harvest practices associated with aflatoxin and fumonisin contamination of maize in three agro ecological zones of Tanzania. Food Addit. Contam. - Part A Chem. Anal. Control. Expo. Risk Assess. 33, 551–559. https://doi.org/10.1080/19440049.2016.1138546

Kang'Ethe, E.K., Gatwiri, M., Sirma, A.J., Ouko, E.O., Mburugu-Musoti, C.K., Kitala, P.M., Nduhiu, G.J., Nderitu, J.G., Mungatu, J.K., Hietaniemi, V., Joutsjoki, V., Korhonen, H.J., 2017. Exposure of Kenyan population to aflatoxins in foods with special reference to Nandi and Makueni counties. Food Qual. Saf. 1, 131–137. https://doi.org/10.1093/fqsafe/fyx011

Kang'Ethe, E.K., Lang'A, K.A., 2009. Aflatoxin B1 and M1 contamination of animal feeds and milk from urban centers in Kenya. Afr. Health Sci. 9, 218–226.

Kang 'ethe, E.K., Gatwiri, M., Sirma, A.J., Ouko, E.O., Mburugu-Musoti, C.K., Kitala, P.M., Nduhiu, G.J., Nderitu, J.G., Mungatu, J.K., Hietaniemi, V., Joutsjoki, V., Korhonen, H.J., Nairobi, K., Kang, E.K., 2017. Exposure of Kenyan population to aflatoxins in foods with special reference to Nandi and Makueni counties ***Ministry of Agriculture Livestock and Fisheries, Veterinary Laboratories Kabete, Private Bag Kabete. Food Qual. Saf. 1, 131–137. https://doi.org/10.1093/fqs/fyx011

Kasirayi, M., Munamato, M., 2016. Smallholder farmers indigenous knowledge of maize storage pests and pesticidal plant use: The case of Wards 9 and 10 in Bikita District, Masvingo Province, Zimbabwe. African J. Agric. Res. 11, 4831–4839. https://doi.org/10.5897/ajar2016.11516

Kiiru, K.A., 2016. Climate Change Impact on Agriculture: Challenges on Maize Production in Uasin Gishu and Trans-nzoia Counties.

Koskei, P., Bii, C.C., Musotsi, P., Muturi Karanja, S., 2020. Postharvest Storage Practices of Maize in Rift Valley and Lower Eastern Regions of Kenya: A Cross-Sectional Study. Int. J. Microbiol. 2020. https://doi.org/10.1155/2020/6109214

Liu, Y., Wu, F., 2010. Global burden of aflatoxin-induced hepatocellular carcinoma: a risk assessment. Environ. Health Perspect. 118, 818–824.

Liu, Z., Zhang, G., Zhang, Y., Jin, Q., Zhao, J., Li, J., 2016. Factors controlling mycotoxin contamination in maize and food in the Hebei province, China. Agron. Sustain. Dev. 36. https://doi.org/10.1007/s13593-016-0374-x

Lucic, A., Pavlovic, M., Peraica, M., Radic, B., 1999. Toxic effects of mycotoxins in humans. Bull. World Health Organ. 77, 754–766. https://doi.org/10.1038/sj.ejcn.1600519

Machekano, H., Mvumi, B., Richardson-kageler, S.J., 2018. Session 8 Postharvest Pest Management and Extension in Developing 8460. https://doi.org/10.5073/jka.2018.463.192

Magoha, H., Kimanya, M., De Meulenaer, B., Roberfroid, D., Lachat, C., Kolsteren, P., 2016. Risk of dietary exposure to aflatoxins and fumonisins in infants less than 6 months of age in Rombo, Northern Tanzania. Matern. Child Nutr. 12, 516–527. https://doi.org/10.1111/mcn.12155

Matumba, L., Monjerezi, M., Kankwamba, H., Njoroge, S.M.C., Ndilowe, P., Kabuli, H., Kambewa, D., Njapau, H., 2015. Knowledge , attitude , and practices concerning presence of molds in foods among members of the general public in Malawi. https://doi.org/10.1007/s12550-015-0237-3

Mbaisi, C.N., Kipkorir, E.C., Omondi, P., 2016. The Perception of Farmers on Climate Change and Variability Patterns in the Nzoia River Basin, Kenya. J. Nat. Sci. Res. www.iiste.org ISSN 6, 89–97.

Mboya, R.M., Kolanisi, U., 2014. Subsistence farmers' mycotoxin contamination awareness in the SADC region: implications on Millennium Development Goal 1, 4 and 6. J. Hum. Ecol. 46, 21–31.

Mendoza, J.R., Sabillón, L., Martinez, W., Campabadal, C., Hallen-Adams, H.E., Bianchini, A., 2017. Traditional maize post-harvest management practices amongst smallholder farmers in Guatemala. J. Stored Prod. Res. 71, 14–21. https://doi.org/10.1016/j.jspr.2016.12.007

Midega, C.A.O., Murage, A.W., Pittchar, J.O., Khan, Z.R., 2016. Managing storage pests of maize: Farmers' knowledge, perceptions and practices in western Kenya. Crop Prot. 90, 142–149. https://doi.org/10.1016/j.cropro.2016.08.033

Mmed, H.K.R., Macleod, D., Bastawrous, A., Wanjala, E., Gichangi, M., Burton, M.J., 2019. Utilization of Secondary Eye Care Services in Western Kenya. Int. J. Environ. Res. Public Health 16, 3371.

Morales, L., Mutiga, S., Nelson, R.J., 2016. Examining Environmental Drivers of Spatial Variability in. African J. Food, Agric. Nutr. Dev. 16, 11086–11105. https://doi.org/10.18697/ajfand.75.ILRI09

Mostrom, M., 2016. Mycotoxins: Toxicology. Encyclopedia of Food and Health. Fargo, USA: North Dakota State University 43–48.

Mukanga, M., J. Derera, P. Tongoona, and M.D.L., 2011. Farmers' perceptions and management of maize ear rots and their implications for breeding for resistance. African J. Agric. Res. 6, 4544–54.

Mutungi, C., Muthoni, F., Bekunda, M., Gaspar, A., Kabula, E., Abass, A., 2019. Physical quality of maize grain harvested and stored by smallholder farmers in the Northern highlands of Tanzania: Effects of harvesting and pre-storage handling practices in two marginally contrasting agro-locations. J. Stored Prod. Res. 84, 101517. https://doi.org/10.1016/j.jspr.2019.101517

Nahida A., 2007. Knowledge, attitude and practice of dengue fever prevention among the people in male, Maldives, Published Master's Dissertation, Chulalongkorn, University, Thailand.

Njogu, C., 2019. Factors affecting maize production among registered small scale farmers in Trans-Nzoia.

Njoroge, A.W., Baoua, I., Baributsa, D., 2019. Postharvest Management Practices of Grains in the Eastern Region of Kenya. J. Agric. Sci. 11, 33. https://doi.org/10.5539/jas.v11n3p33

Obonyo, M.A., Salano, E.N., 2018. Perennial and seasonal contamination of maize by aflatoxins in eastern kenya. Int. J. Food Contam. 5, 1–5. https://doi.org/10.1186/s40550-018-0069-y

Opiyo, J., Kirimi, L., Kinyumu, N., Brief, J.M.-P., 2015, undefined, 2015. Cost of maize production under different systems in Kenya: The role of policy interventions. Tegemeo.Org.

Outreach, I.P.B., 2017. Maize in Africa. Int. Plant Biotechnol. Outreach 1–55.

Parliament, E., States, M., Podimata, R.A., Ftt, The, Ftt, This, Kong, H., Ftt, A., Eu-wide, P., 2011. Press release Press release 32–33.

Phokane, S., Flett, B.C., Ncube, E., Rheeder, J.P., Rose, L.J., 2019. Agricultural practices and their potential role in mycotoxin contamination of maize and groundnut subsistence farming. S. Afr. J. Sci. 115, 2–7. https://doi.org/10.17159/sajs.2019/6221

Pitt, J., Hocking, A.D., 2009. In Fungi and Food Spoilage, Fungi and Food Spoilage. https://doi.org/10.1007/978-0-387-92207-2_1

Prevention, F.A., 2013. Storage Surveys in Kenya•: North Rift and Eastern AflaSTOP•: Storage and Drying.

Probst, C., Njapau, H., Cotty, P.J., 2007. Outbreak of an acute aflatoxicosis in Kenya in 2004: Identification of the causal agent. Appl. Environ. Microbiol. 73, 2762–2764. https://doi.org/10.1128/AEM.02370-06

Ranum, P., Pe, J.P., 2014. Global maize production, utilization, and consumption.

https://doi.org/10.1111/nyas.12396

Ranum, P., Peña-Rosas, J.P., Garcia-Casal, M.N., 2014. Global maize production, utilization, and consumption. Ann. N. Y. Acad. Sci. 1312, 105–112. https://doi.org/10.1111/nyas.12396

Rapsomanikis, G., 2015. The economic lives of smallholder farmers. Fao 39. https://doi.org/10.5296/rae.v6i4.6320

Reddy, K.R.N., Salleh, B., Saad, B., Abbas, H.K., Abel, C.A., Shier, W.T., 2010. An overview of mycotoxin contamination in foods and its implications for human health. Toxin Rev. 29, 3–26. https://doi.org/10.3109/15569541003598553

Sam Sellers, 2016. Gender and Climate Change• : A Closer Look at Existing Evidence. Glob. Gend. Clim. Alliance 51.

Schrenk, D., Bignami, M., Bodin, L., Chipman, J.K., del Mazo, J., Grasl-Kraupp, B., Hogstrand, C., Hoogenboom, L., Leblanc, J.C., Nebbia, C.S., Nielsen, E., Ntzani, E., Petersen, A., Sand, S., Schwerdtle, T., Vleminckx, C., Marko, D., Oswald, I.P., Piersma, A., Routledge, M., Schlatter, J., Baert, K., Gergelova, P., Wallace, H., 2020. Risk assessment of aflatoxins in food. EFSA J. 18. https://doi.org/10.2903/j.efsa.2020.6040

Shephard, G.S., Marasas, W.F.O., Burger, H.M., Somdyala, N.I.M., Rheeder, J.P., Westhuizen, L. 373 Van der, Gatyeni, P., Van Schalkwyk, D.J., 2007. Exposure assessment for 374 fumonisins in theformer Transkei region of South Africa. Food Addit. Contam 24, 375 621-629.

Smith, M.C., Madec, S., Coton, E., Hymery, N., 2016. Natural Co-occurrence of mycotoxins in foods and feeds and their in vitro combined toxicological effects. Toxins (Basel). 8. https://doi.org/10.3390/toxins8040094

Suleiman, R.A., Rosentrater, K.A., 2015. Current Maize Production , Postharvest Losses and the Risk of Mycotoxins Contamination in Tanzania.

Tan, K., 2020. Aflatoxin and Its Toxic Tragedies in Kenya 38, 10–12. https://doi.org/10.22186/jyi.38.2.10-12

Torabi, M., Drahansky, M., Paridah, M.., Moradbak, A., Mohamed, A.., Owolabi, F. abdulwahab taiwo, Asniza, M., Abdul Khalid, S.H.., 2016. The Socio-Economic Impact of Mycotoxin Contamination in Africa. Intech i, 13. https://doi.org/http://dx.doi.org/10.5772/57353

Trombete, M., Santos, B., Maria, G., Elias, M., 2014. In-house validation of a method for determining.

Wall-Martínez, H.A., Ramírez-Martínez, A., Wesolek, N., Brabet, C., Durand, N., Rodríguez-Jimenes, G.C., García-Alvarado, M.A., Salgado-Cervantes, M.A., Robles-Olvera, V.J., Roudot, A.C., 2019. Risk assessment of exposure to mycotoxins (aflatoxins and fumonisins) through corn tortilla intake in Veracruz City (Mexico). Food Addit. Contam. - Part A Chem. Anal. Control. Expo. Risk Assess. 36, 929–939. https://doi.org/10.1080/19440049.2019.1588997

WHO, 2018a. Aflatoxins 1–5.

WHO, 2018b. Fumonisins 1–5.

WHO, 2012. Food additives series 65. Safety evaluation of certain food additives and contaminant. Prepared by 74th Meeting of Joint FAO/WHO Expert Committee on Food Additives (JECFA): Geneva.

Williams, J.H., Phillips, T.D., Jolly, P.E., Stiles, J.K., Jolly, C.M., Aggarwal, D., 2004. Human aflatoxicosis in developing countries: A review of toxicology, exposure, potential health consequences, and interventions. Am. J. Clin. Nutr. 80, 1106–1122. https://doi.org/10.1093/ajcn/80.5.1106

Wu, F., 2006. Mycotoxin reduction in Bt corn: Potential economic, health, and regulatory impacts. Transgenic Res. 15, 277–289. https://doi.org/10.1007/s11248-005-5237-1

Wu, Q., Jezkova, A., Yuan, Z., Pavlikova, L., Dohnal, V., Kuca, K., 2009. Biological degradation of aflatoxins. Drug Metab. Rev. 41, 1–7. https://doi.org/10.1080/03602530802563850

Yun Yun Gong, Michael Routledge, Martin Epafras Kimanya, Gyavira Musoke, Francesca Nelson, Victor Manyong, Stanley Sonoiya, 2015. Aflatoxin standards for food. Knowledge Platform 2015 Situational Analysis East Africa Region. East African Community.

APPENDICES

APPENDIX I: POST HARVEST HANDLING PRACTICES QUESTIONNAIRE

A. DEMOGRAPHIC INFORMATION

Date of Interview		Name of Interviewer	
Name of Small scale farmer			
Sex:	1 – Male	2 - Female	
Age			
Location /Area			
Size of Farm			
Crops grown on the farm			
Maize variety planted			
Education Level (Tick Correct)	1 - College/University 2 - Completed Secondary 3 - Completed primary 4 - Dropped from primary 5 - In primary 6 - In secondary		

	7 - Literate e.g. Adult Education 8 - Illiterate 9 - Pre-primary 10 - Others (specify)
Occupation(Tick Correct)	1 - Salaried employee 2 - Farmer 3 - Self employment 4 - Casual laborer 5 - Student 6 - Housewife 7 - Unemployed 8 - Others (specify) 9 - N/A
Annual income what do you mean. elaborate	

B. POST HARVEST HANDLING PRACTICES

Sr/No.	POST HARVEST PRACTICES		Comments	Interviewers remark
1.	How do you harvest the maize from the farm?	1 - Casual Laborer's 2 - Family 3 - Machinery		
2.	Are the farm equipments and Machinery cleaned and disinfected before being deployed to the farm?	Yes/No		
3.	For how long do you store the crop after harvesting	1- Less than 3 months 2- 3 - 6 months 3- 6 - 9 months 4- 9 – 12 moths		
4.	When is the Harvested maize stored	1- Directly after harvesting 2- Prestored for few days before being transferred to the main storage facility		

5.	Do you remove old grains from the storage facility before introduction of the new crop?	Yes/No		
6.	Which method do you use to treat the storage facility before the product comes in?	1 - Sand 2 - Insecticide 3 - Smoke 4 - Manure 5 - Neem		
7	Do you store the product together with other crops in the same storage facility?	Yes/No		
8.	Is the storage area disinfected before introducing a new crop? If yes then what do you use for disinfection?	Yes/No		
9.	Do you verify the moisture content of the Maize before, during and after storage and drying	Yes/No		
10.	How do you transport your product home from the farm?	1 - By bicycle, 2 - Motor vehicle, 3 - Carriers on the head		

		4 - donkey, others(Specify)		
11.	How do you dry the product?	1 - Open sun drying, on ground 2 - Solar drier 3 - Open sun drying, raised above ground 4 - Others (specify)		
12.	How long does it take to dry the product?	1 - less than 2 hours 2 - 2 days and over 3 - 2-8 hours 4 - do not dry		
13.	How do you store the product(s)? (Storage conditions)	1- Special room, well ventilated 3 - Anywhere 2 - Special room, poorly ventilated		

		4 - Do not store		
14.	Do you own the structure that you store your grain in?	1- YES 2- NO		
15.	In which form do you store the maize?	1 - On cob without sheath 2 - On cob with sheath 3 - Shelled		
16.	How do you shell the maize?	1 - By hand 2 - Shelling machine, 3 - Putting in a bag and hitting, 4 - Others(specify)		
17.	How do you package the products before storage?	1 - Polythene bags 2 - Crates/woven baskets 3 - Jute bags 4 - not apply		

18.	How long do you keep the products before selling/consuming?	1 - less than one month 2 - 2-3 months 3 - 1-2 months 4 - over 3 months		
19.	What is the quality of the products after storage period?	1 - retained color 2 - big change in color 3 - slight change in color 4 - not apply		
20.	What proportion of the grain did you lose to these pests and contamination?	1 - 1-2 (90 kg bags) 2 - 3-4 (90 kg bags) 3 - > 5 bags (90 kg bags)		

APPENDIX II: POST HARVEST HANDLING KNOWLEDGE QUESTIONNAIRE

A. DEMOGRAPHIC INFORMATION

Date of Interview		Name of Interviewer	
Name of Small scale farmer			
Sex:	1 - Male 2 - Female		
Age			
Location /Area			
Size of Farm			
Crops grown on the farm			
Maize variety planted			
Education Level (Tick Correct)	1 - College/University 2 - Completed Secondary 3 - Completed primary 4 - Dropped from primary 5 - In primary 6 - In secondary 7 - Literate e.g. Adult Education		

	8 - Illiterate 9 - Pre-primary 10 - Others (specify)
Occupation(Tick Correct)	1 - Salaried employee 2 - Farmer 3 - Self employment 4 - Casual laborer 5 - Student 6 - Housewife 7 - Unemployed 8 - Others (specify) 9 - N/A

B. POST HARVEST HANDLING KNOWLEDGE QUESTIONNAIRE

	TICK APPROPRIATELY	Feedback	Remarks
1.	Do you collect the maize in bag or tarpaulin during harvesting?	**Yes**	
		No	
2.	Do you remove the old crop from the storehouse before bringing in the new crop	**Yes**	
		No	
3.	Do you segregate the moldy/discoloured maize from the good crop after harvesting	**Yes**	
		No	
4.	Do you have in place any precautionary measure(treatment/disinfection) to protect the maize from mold contamination?	**Yes**	
		No	
5.	Do you cleaned and disinfected the storage house before introducing the new crop	**Yes**	
		No	
6.	Is the storage facility protected from moisture permeation?	**Yes**	
		No	
7.	Have you ever heard of mycotoxin, Aflatoxin and Fumonisin contamination before?	**Yes**	

		No	
8.	Are you aware of the risks associated with consumption of molded maize?	**Yes**	
		No	
9.	Do you involve in selling and or buying of molded maize for consumption purposes and for livestock feeds production	**Yes**	
		No	
10.	Do you have a procedure in place for disposal of molded and discoloured maize?	**Yes**	
		No	

APPENDIX III: CONSUMPTION PATTERN FOR MAIZE MEAL QUESTIONNAIRE

A. DEMOGRAPHIC INFORMATION

<table>
<tr><td>Name of Interviewer</td><td></td><td>Date of Interview</td><td></td></tr>
<tr><td colspan="2">Name of Respondent</td><td colspan="2"></td></tr>
<tr><td colspan="2">Name of House hold head</td><td colspan="2"></td></tr>
<tr><td colspan="2">Relationship of Respondent to Household head</td><td colspan="2"></td></tr>
<tr><td colspan="2">Area/Location</td><td colspan="2"></td></tr>
<tr><td colspan="2">Sex: (Tick correct) applicable to all</td><td colspan="2">Male=1
Female=2</td></tr>
<tr><td colspan="2">Age</td><td colspan="2">Below 18 years
1 = 18- 30 years   2 = 31-40 years
3 = 41 -50 years   4 = 51 -65 years
5 = Above 65 years</td></tr>
<tr><td colspan="2">Education</td><td colspan="2">1=College/University
2=Completed Secondary
3=Completed primary
4=Dropped from primary</td></tr>
</table>

	5=In primary 6=In secondary 7=Literate e.g. Adult Education 8=Illiterate 9=Pre-primary 10= Others (specify)
Estimated body weight(kg)	
Amount consumed/day/week	
Estimated height(m)	
Marital status	1=Married 2=Separated 3=Widowed 4=Single 5=Divorced 6=N/A
Main occupation	1=Salaried employee 2=Farmer 3=Self-employment 4=Casual laborer 5=Student 6=Housewife 7=Unemployed 8=Others (specify) 9=N/A
Annual income in ksh	

B. CONSUMER STUDY

Sr/No.	TICK APPROPRIATELY			
1.	Do you consume maize meal?	Yes No		
2.	What is the source of maize consumed?	1 - Small scale farm 2 - Posho mill 3 - Retailers/ Supermarket		
3.	When did you last take Maize Meal?	1 – Home 2- Hotel/ Restaurant 3 – Others (Specify)		
4.	How is the maize prepared before consumption?	1 - Milled maize(floor) 2 – Whole grains		
5.	In which form is the maize meal prepared?	1 - Pre-cooked/Boiled 2 – Roasted 3 -Slurry (preparation with cold water		
6.	Do you sort the molded and damaged maize before milling or cooking?	1 – Yes 2 - No		

7.	Do you clean the maize before preparing for consumption?	1 - Yes 2 - No		
8.	How many times in a week do you consume Maize?	1- Once 2- Twice 3- Thrice		
9.	What unit quantity do you consume per day?	1- 100g 2- 250g 3- 500g 4- 1kg 5- >1kg		
10.	Do you clean the maize before preparing for consumption?	1 - Yes 2 - No		