AFLATOXIN ANALYSIS IN STAPLE FOOD CEREALS AND ASSESSMENT OF HOUSEHOLDS' AWARENESS ON ITS MANAGEMENT IN THARAKA-NITHI COUNTY, KENYA

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DECLARATION

This thesis is my original work and has not been presented for degree in any other University. I therefore declare that all the material cited in this write up which are not mine have all been dully acknowledged.

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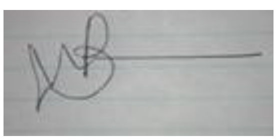
We confirm that that the work reported in this thesis was carried out by the candidate under our supervision.

Signature:  **Date**: 28/09/21

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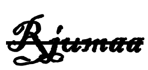
Signature:  **Date:** 28/09/21

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DEDICATION

I wish to dedicate this work to my wife, Amina Mwiti and my children, Ryan Mutwiri and Brian Munene without whose caring support it would not have been possible, to my parents who passed on a love of reading and respect for education, and to my supervisors who unfailingly assisted me.

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It was a team effort!

ABSTRACT

Aflatoxin is a poisonous substance produced by fungi. Crops infestation is inevitable and numerous evolving nations collectively with Kenya do not regularly test their main foods for aflatoxins contamination. Consumption and sale of mycotoxins infested cereals and grains has the risk of contributing to a diversity of severe medical complications in people. Context-specific information on the aflatoxin occurrence in the County makes it possible to document vulnerable staple crops and the level of toxicity in the County. Measurement of exposure using the factors that influence the choice of the food together with the presence of these harmful mycotoxins can be used to demonstrate how this contamination occurs in food, map the aflatoxin hot spots in the County and inform the choice of the most effective control approaches. However, there is lack of local data on aflatoxin contamination in Tharaka-Nithi County to inform interventions chiefly due to lack of local research, testing facilities, and qualified personnel. The main purposes of the research included: to evaluate the levels of aflatoxin in cereals commonly used as staple foods sourced from households and marketplaces, to evaluate households' awareness on suitable conditions for storage of foods regarding aflatoxin contamination, and to identify factors contributing to aflatoxin contamination. Samples were collected from Tharaka-South and Tharaka-North Sub-Counties which had three Wards with a total of 24 Sub-Locations. 3 Households per Sub-Location that had some stock of the crops of interest were randomly chosen from the villages in each Sub-Location. Three major open-air markets were also selected based on size for the collection of the samples. During the collection of the samples, observations were done, and a questionnaire used to determine the study respondents' awareness of aflatoxin contamination and knowledge of the potential causes of contamination. Analysis for aflatoxin levels was conducted using the ELISA Kit. The information collected during household interviews was analyzed using SPSS version 22. The main cereals used as staple foods among households in the County as per the study results included: pearl millet, sorghum, maize, green grams, and cow peas. Overall, aflatoxin contamination in 25.8% of sampled cereals was above the legal threshold of 10ppb Kenyan standards with 17.2% of cereals exceeding the established human tolerance levels of greater than 20ppb. The aflatoxin contamination levels of 44.4% of the market samples was greater than the Kenyan tolerable limits. Based upon the Chi-Square test for association, it was evident that level of aflatoxin was associated with the type of cereals and grains (p-value 0.001, which was less than 0.05 at 95% confidence level). Therefore, cereals and grains levels of contamination differed as they were exposed. Based upon the t-Test for Equality of Means, the difference was not significant (p-value for Maize= 0.89, Sorghum= 0.47 and Pearl Millet=0.64, all of which are greater than 0.05). Thus, there was no difference in mean level of aflatoxin in the cereals and grains in the two study areas. Furthermore, the t-Test for Equality of Means, showed that there was no difference in mean level of aflatoxin in the cereals and grains collected from the markets and households (p-value for Maize=0.294, Sorghum=0.422 and Pearl Millet=0.918, all of which are greater than 0.05). Majority of the farmers (84.7%) were aware of aflatoxin as a dangerous poison found in cereals and grains especially those that are not properly dried to safe moisture content. However, detailed information on the nature, formation, effects, prevention, and control of aflatoxins was scanty and inconsistent. The study provided crucial information on the aflatoxin contamination levels of these major cereals and grains and on households' knowledge on aflatoxin management. This data will be key in bringing issues to light of the presence of these harmful mycotoxins in staple foods and increase the community's knowledge and skills on the use of sustainable, low-cost post-harvest management practices to decrease the contamination. This will enhance the well-being of populations in the County and ultimately the national food security.

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ABBREVIATIONS AND ACRONYMS

AATF	African Agricultural Technology Foundation
CDC	Centers for Disease Control and Prevention.
CGIAR	Consultative Group on International Agricultural Research.
DALY	Disability-Adjusted Life Year.
EAC	East African Community
EIA	Enzyme Immunoassay
ELISA	Enzyme-linked Immunosorbent Assay
FAO	Food and Agriculture Organization
FDA	Food and Drug Administration.
GIS	Geographical Information System
HBM	Health Belief Model
HRP	Horseradish Peroxidase
IARC	International Agency for Research on Cancer.
IITA	International Institute of Tropical Agriculture.
IFPRI	International Food Policy Research Institute
JECFA	Joint FAO/WHO Expert Committee on Food Additives.
KARLO	Kenya Agricultural and Livestock Research Organization.
KEBS	Kenya Bureau of Standards
KNBS	Kenya National Bureau of Statistics.
MoALF	Ministry of Agriculture, Livestock and Fisheries
NACOSTI	National Commission for Science, Technology, and Innovation
NDMA	National Drought Management Authority

PMTDI Provisional Maximum Tolerable Daily Intake.

Ppb Parts per billion.

PT Proficiency Test

USFDA United States Food and Drug Administration.

SERC Scientific and Ethics Review Committee

SPSS Statistical Package for Social Sciences

SRA Short Rains Assessment.

WHO World Health Organization.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

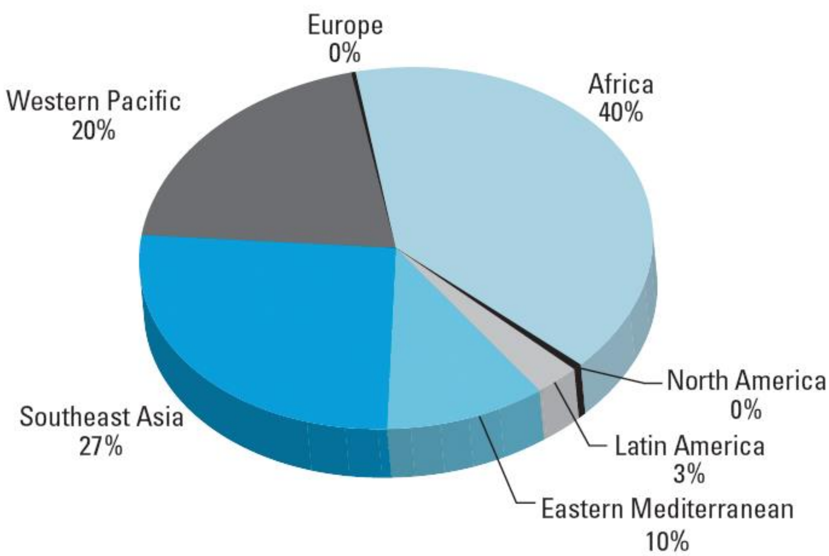
The poisonous substances produced by mycotoxins are recognized to cause many health problems or loss of life in human beings and animals. Examples of mycotoxins are: deoxynivalenol, fumonisins, zearalenone, ergot alkaloids, ochratoxin A, and aflatoxins. These poisonous substances originate from *Aspergillus, Claviceps, Fusarium, and Penicillium* genera (Pitt et al., 2012). In research work (Liu & Wu, 2010) entitled "Global Burden of Hepatocellular Carcinoma Induced by Aflatoxin" with collaboration with the World Health Organization, annual estimates of 5-30% cancer of the liver cases globally are caused by aflatoxin with 40% of these cases being found in Africa as shown in figure 1.1 (Liu & Wu, 2010).

WHO has initiated actions to combat this contamination and emphasized the control of mycotoxins with aflatoxins included. Aflatoxins have been researched by agriculturalists for >40 years because of their extensive poisoning incidences and their noteworthy outcome on crops (Fung & Clark, 2004; Shephard, 2003; Williams et al., 2004). Reports by FAO indicate that aflatoxins contaminate 25% of harvests globally with most cases being reported especially in the tropical areas in the growing nations (Bankole & Mabekoje, 2004). Inadequacy of food and lack of eating a variety of foods drastically make contributions to the vulnerability of humans and communities to aflatoxins. Crops genetic constitution, temperatures, kind of soil, and local weather conditions encourage this contamination (Brown et al., 2001). This infestation is also encouraged by crops stress during production, pests' infestation, early or late harvesting, showers during the harvesting period, and insufficient drying of the crops after removing them from the farm (Hell et al., 2000; Ono et al., 2002; Turner et al., 2005).

CDC and WHO organized a workshop in 2005 to categorize region specific, lasting public health interventions to limit mycotoxins contamination in foods. The workgroup participants recognized gaps in community's knowledge and skills on how to best control this contamination. Globally the responsibility to protect the public health from this contamination is solely on the countries selling food to the other countries due to the enforcement of regulations to curb the contamination.

Figure 1.1

Global Cases of Hepatocellular Carcinoma Caused by Aflatoxin



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As a result, there is confusion due to the fact of monetary factors and foreign bilateral contracts including the safety of crops by means of government subsidies. This leads to varying mycotoxin regulations among nations, from stringent enactments and mitigation measures (Pitt et al., 2012). The safety of the foods being consumed by populations is among the food security challenges globally. States like America has had regulations on allowable aflatoxin levels in foods with established laboratories for the analysis of grains for mycotoxins contamination dating back to 35 years ago. Furthermore, organizations like the WHO and FAO have documented the presence of mycotoxins in foods (Kumar et al., 2017). Codex Alimentarius Commission is in control internationally and is charged with the responsibility of formulating maximum allowable limits for toxins e.g., aflatoxins in foods. These regulations set by codex are adopted and enforced by FAO/WHO countries globally (Gong et al., 2015). In setting the standards for allowable levels of contamination in food, Codex centers its conclusions on scientific data from the Joint FAO/WHO Committee on Food Additives (JECFA). However, there are nations that consider these maximum allowable limits set by Codex to be insufficient for the safety of their populations. The World Trade Organization permits such countries to come up with their own food standards on condition that these standards are scientifically proven. Regional organizations e.g., the European Food Safety Authority carry out independent food analysis and are charged with the responsibility of advising the European Union on matters regarding the maximum allowable limits for food contaminants (Gong et al., 2015).

In many growing nations these toxic compounds contaminate the foods mainly consumed with this contamination being constant and frequently at excessive levels. These are the same areas where crop production and laws to manage this contamination are non-existence. Despite occasional high-profile outbreaks, mycotoxins have not been extensively prioritized to guard the health of populations in these countries. Consideration has only been done to meet the stern international trade laws on mycotoxin poisoning in the first world countries instead of protecting the people farming and utilizing these contaminated foods domestically (Wild & Gong, 2010). The explanations for the absence of efforts to address this contamination in growing nations is multifaceted and partly studied. However, numerous elements can be identified.

First there is the lack of understanding of fungal toxins and their negative health risks. Secondly, in evaluation with other interventions, the alleged importance of interventions to limit this contamination in growing nations is exceedingly low. Third, the most effective simple mitigation measures are complex, needing attention during crop production and post-production. Fourth, the most at-risk populations include the people who grow and consume their individual produce and for that reason governing processes to control the exposure are generally unproductive. Fifth, the mycotoxin contamination is connected to agriculture, well-being, and economics (Wild, 2007). A multi-sectoral approach which is needed to recognize the potential risks of aflatoxin contamination is lacking in the growing countries. Consequently, majority of the global inhabitants have their main foods contaminated by means of recognized toxins with quite minimal organized procedures to fight this contamination at the community level (Wild, 2007).

Crops in tropical areas are extra prone to infection with mycotoxins compared to areas without extreme temperatures. Delayed harvesting and intercropping are agricultural practices associated to mycotoxin contamination. Mycotoxin contamination begins in the farm where the crop is infested. The fungal development will increase after harvesting and at some point of storage conditions. Improper storage, transportation, and processing facilities in negative hygienic stipulations may additionally stimulate fungal growth (Wagacha & Muthoni, 2008). Unfortunately, the occurrence of these fungal toxins in crops is not given the attention it requires in the African continent due to community low awareness about this occurrence, lack of monitoring processes, sale of foods unfit for human consumption, and recurrent lack of meals due to famine, conflicts, political, and financial instability (Wagacha & Muthoni, 2008). As stated in a research Williams et al. (2004) entitled "Human Aflatoxicosis in Developing Countries", aflatoxin causes 60% health concerns recognized by WHO for growing countries, accounting for 43.6 percent overall disease burden. Children are especially vulnerable drastically hindering children's growth and development. Almost all the infants at the age of introduction to other foods were at risk of hazards related to aflatoxin which caused poor development as stated in a research led by CGIAR in Benin and Togo. This fungal toxin severely affects the main foods presenting the greatest danger to people who depend on these foods leading to many people dwelling in growing nations being persistently at risk of this contamination through food consumption.

In the East African region, the central foods contaminated by aflatoxins include maize, groundnuts, and milk. These are also the main foods used as complementary foods putting at risk majority of the infants and young children. In East Africa there is inadequate research on aflatoxin contamination to show aflatoxin prevalence and exposure to the populations living in the region (Gong et al., 2015). Research studies conducted in Uganda during the period 1966 to 2005 show reported cases of aflatoxin contamination above 10ppb. The maximum allowable limits for aflatoxin contamination in Uganda is 10ppb. The Country has however set these limits for baby food at 5ppb. The foods that were mostly contaminated with aflatoxins were groundnuts and their products. The studies also found contamination levels of up to 20ppb in processed infant's food and other foods processed locally (Gong et al., 2015).

Research work conducted in the East African region reveal different levels of contamination depending on the season, crops, and region. Per capita consumption per person per day ranges between 150-500g per day (Kimanya et al., 2014). In Kenya and Tanzania research work conducted reveal regularly high levels of aflatoxin contamination in both countries (Azziz-Baumgartner, 2005 ; Shirima et al., 2013). Majority of communities living in the East African region mainly consume cereals as their staple foods. Unfortunately, these are the foods that are susceptible to the growth of mycotoxins producing fungi which lead to aflatoxin infestation (Gong et al., 2015). There are however countries with more varied dietary consumption patterns e.g., Burundi, Rwanda, and Uganda where plantain, roots, and tubers are the main energy sources. Majority of the populations (60-90%) in the East African region consume their locally produced foods. This situation complicates dietary diversity as an aflatoxin mitigation strategy in the region (Gong et al., 2015).

Best possible incidences of acute toxicity in history have been reported in Kenya which is one part prone to aflatoxins contamination globally. The foremost reported outbreak in 1981 which ensued in 20 casualties and loss of 12 persons was caused by feeding on poisoned maize. Aflatoxin levels up to 12,000ppb was reported in analyzed maize collected from households (Ngindu et al., 1982). The best known severe aflatoxicosis epidemic happened in Eastern Kenya in April 2004 affecting 317 people and loss of 125 people due to adulteration of inappropriately warehoused maize (Azziz-Baumgartner et al., 2005 ; Centers for Disease Control and Prevention [CDC], 2004). Further studies on the patterns and determinants of the outbreaks recognized common features of aflatoxicosis epidemics. Maize was linked to aflatoxin contamination with the season between April and June identified as the period when severe toxicity regularly happened (CDC, 2004; Mwihia et al., 2008; Ngindu et al., 1982). According to Kenya Agricultural and Livestock Research Organization (KALRO), aflatoxin affected and destroyed 10 percent of maize harvested valued at Ksh 89 billion in 2010. This led to a mop of 155,000 90 kg sacks of contaminated maize valued at Ksh 465 million. In Kenya, maize, millet, and sorghum are among the main cereals grown and consumed by people and animals. The cereals are also mainly used to manufacture processed foods. However, with the excessive heat and moisture experienced in some of the regions in the country, these cereals' structure perfect substances for aflatoxin-producing fungi to act on. To mitigate the contamination, Kenya's allowable limits for aflatoxins in cereals used as food are 10ppb. In Kenya, aflatoxin contamination levels up to 1000ppb have been reported in maize sourced from households' during one of the most severe occurrence of aflatoxin contamination (Lewis et al., 2005).

Millet, cowpeas, pigeon peas, green grams, sorghum, and maize are the key crops grown in Tharaka-Nithi County. Cowpeas, maize, and pigeon peas are commonly grown for local consumption. Sorghum and green grams are commonly grown for sale. The rain fed and mixed farming livelihood zones in the County are known for maize production which contributes to 40% of food consumed in homes. The marginal mixed farming zone is known for millet production which accounts for 50% of food (National Drought Management Authority [NDMA], 2018). According to the County Department of Agriculture of Tharaka-Nithi, sorghum and millet are grown on 45% of the cultivated land (approximately 2 million hectares). The daily per capita millet consumption ranges from 120g to 300g. Regrettably, these cereals have the uppermost risk of this mycotoxin's contamination.

Agricultural production in the County is faced by the following challenges: unpredictable weather and climate variations, moisture stress especially when the crops are growing in the farms, heavy rains especially during the harvesting periods, poor roads infrastructure, poor access to the markets, high post-harvest losses, low educational levels among the farmers, absence of good storage structures, lack of value addition facilities, exploitation of farmers by middlemen, lack of awareness on good agricultural practices among the farmers, and low adoption of the modern farming techniques (Ministry of Agriculture, Livestock and Fisheries [MoALF], 2017). The County has high poverty levels (40%) especially in the rural areas. The high prevalence of poverty is linked to unpredictable rainfall received in the area whose main occupation is agriculture (80% of the of the County's population is engaged in agriculture), poor agricultural practices, poor infrastructural support, lack of access to credit facilities, poor marketing systems, recurrent droughts, environmental degradation, and wildlife menace. These poverty levels have negative impacts on the farmers' ability to capitalize on the improved agricultural technologies and limit their ability to access information on the good agricultural practices (MoALF, 2017).

The farmers in the County attribute their inadequate utilization of farm inputs to their low-income levels, high prices of the farm inputs, poor access to the markets, and lack of timely access of the inputs. Erratic and unreliable rainfall received in the County varies the agricultural productivity of the County. Agricultural production is also affected by the increasing temperatures making crops to be more prone to pests and diseases attacks which lead to reduced crop harvests, poor quality yields, and sometimes total crop failure. Notable climate trends in the County in the last decades indicate a moderate rise in temperatures with the future climate forecasts for the period 2021-2065 showing that Tharaka-Nithi County will continue to experience moisture stress because of the increases in temperature (MoALF, 2017). These issues have negative influence on the County's food security thus the need for improved weather forecasting and timely dissemination of this information to the farmers. However, the County has limited capacity to deliver the much-needed extension services to the farmers which is constrained by inadequate funds and limited human resource capacity (MoALF, 2017).

Given the progressively stronger proof that these fungal toxic compounds contribute to a diversity of severe medical complications in people, and the know-how that they are frequently found in cereals used as staple foods, the researcher in this study aimed to analyze contamination of these main foods from two most important grain producing areas of Tharaka-Nithi County. The County is among the major hotspots of aflatoxin contamination in Kenya (Hoffmann et al., 2015). The bulk of food intake (98.7%) of households in the region is provided by cereals and grains (The United States Agency for International Development [USAID], 2018).

Excellent and the most successful pre-harvest, post-harvest, storage applied sciences and food preparation procedures were advocated to enhance the protection of cereals and grains from this contamination. Recognition of these barriers together with the opportunities to prevent and mitigate aflatoxin contaminations from the farm, households and markets, the researcher hoped to improve the health of communities in Tharaka-Nithi County, the financial well-being of households and the national food security. This is because safe food is a requirement for food security and as a matter-of-fact good nutrition and health.

1.2 Statement of the Problem

Main foods consumed by majority of the resource constrained communities globally are contaminated by mycotoxins. Mycotoxins can affect the well-being of people in so many ways even at minimal toxicity. Unfortunately, they are not simply detectable. They contaminate the main diets in many growing nations such that exposure continues for extended periods usually at extreme ranges (Pitt et al., 2012). As stated by Williams et al. (2004) in a study entitled "Human Aflatoxicosis in Developing Countries", aflatoxin is possibly linked to 60% of known health hazards recognized through the WHO for growing countries accounting for 43.6% overall disease burden. Infants continue to be specifically vulnerable impeding their growth and development (Gong et al., 2008). Kenya recorded its first aflatoxicosis epidemic in 1981. Since 2004 a number of these epidemics have been reported resulting to 200 deaths from 500 cases (Azziz-Baumgartner et al., 2005 & CDC, 2004). The contamination was mainly reported in Eastern province of Kenya among the rural dwellers especially those who farm for basic needs and generally linked with eating locally produced maize (Azziz-Baumgartner et al., 2005). Even with occasional high-profile occurrences, mycotoxins have not been broadly given the public health attention they require in growing republics. In nations where efforts have been put to address this situation, a lot of work has been put in favor of the developed countries safe foods guidelines rather than guarding communities growing and consuming these locally produced infested foods (Wild & Gong, 2010). In Eastern Kenya a region prone to aflatoxin toxicity, a growing literature has pointed out an affiliation between aflatoxin toxicity and child development. However, because not any of the research handled the confounding factors, it is not well known if the affiliation was complicated by way of influences including, child illness, dietary consumption, and family socio-economic status (Leroy, 2013). Regulated analysis of mycotoxins contamination in foods in the developed countries ensures that the food is fit for human consumption. However, this regular monitoring and enforcement of regulations is lacking in the developing countries including Kenya. Tharaka-Nithi County is among the hot spots of aflatoxin in Kenya (Hoffmann et al., 2015). Nonetheless, there is lack of local data on aflatoxin contamination in the County to inform interventions chiefly due to lack of local research on aflatoxin contamination, testing facilities, and qualified personnel. Several strategies for preventing this aflatoxin menace have been proposed in the County but the adoption rate for implementation among the farmers is very low.

1.3 Significance of the Study

The cereals selected were staple foods and widely utilized in the County. This study provided crucial information whether these major cereals were contaminated with aflatoxin. On a broader societal level, the results provided important information regarding the households' awareness on suitable conditions for storage of foods, awareness on dangers of aflatoxins in foods and cost-effective and successful post-harvest and storage techniques. The research results were key in elevating cognizance of and attention to innumerable consequences of this contamination besides promoting the utilization of sustainable, affordable storage, and post-harvest practices to control this contamination. With the knowledge generated from the research on the hindrances in addition to chances to avert this menace across the entire value chains which is a serious threat to the food safety and food security, the researcher hoped that food safety in the County will be better and consequently national food security.

1.4 Objectives

1.4.1 General Objective

To analyze cereals used as staple foods among households – sorghum, pearl millet, and maize for aflatoxin contamination in Tharaka-Nithi County, Kenya.

1.4.2 Specific Objectives

i. To analyze the levels of aflatoxin in the cereals used as staple foods among households – sorghum, pearl millet, and maize from two major grain producing areas of Tharaka-Nithi County.
ii. To assess the difference in levels of aflatoxin in cereals sourced from households and marketplaces in Tharaka-Nithi County.
iii. To evaluate households' awareness on suitable conditions for storage of foods regarding aflatoxin contamination.
iv. To identify factors contributing to aflatoxin contamination of cereals used as staple foods among households – sorghum, pearl millet, and maize from two major grain producing areas of Tharaka-Nithi County.

1.5 Research Questions

i. What are the levels of aflatoxin in the cereals used as staple foods among households – sorghum, pearl millet, and maize?
ii. What is the difference in levels of aflatoxin contamination between cereals sourced from households and marketplaces?
iii. What is the level of households' awareness on suitable conditions for storage of foods regarding aflatoxin contamination?
iv. What are the factors contributing to aflatoxin contamination of the cereals used as staple foods among households?

1.6 Research Hypotheses

i. There is no relationship between the types of cereals and grains and the levels of aflatoxin contamination.

ii. There is no difference in mean level of aflatoxin in the cereals and grains collected from the marketplaces and households.

1.7 Operational Definition of Terms

Definition of key concepts used in this study:

Aflatoxicosis – The poisoning that results from ingesting aflatoxins.

Biocontrol – This is the use of living organisms such as insects and pathogens to control pests and plant diseases.

Carcinogenic – Having the potential to cause cancer.

Contamination – The action of making or being made adulterated by poisoning.

DALY – Acronym meaning Disability Adjusted Life Years. It is the number of years of would-be life wasted because of early death or number of years of industrious life wasted as a result of incapacity.

Epidemic – Extensive incidence of transmittable illness in public at a specific period.

Exposure – A case of being subjected to an action or an influence.

Hepatotoxic – Harmful or destructive to the liver cells.

Hotspots – Areas of elevated incidence or prevalence.

Metabolites – A substance formed in or necessary for metabolism.

Mycotoxin – These are naturally produced fungal organic compounds that are recognized as the origin to many health problems or death both in humans and animals.

Mycotoxicology – Study of analyzing and studying toxins produced by fungi known as mycotoxins.

Post-Harvest - Activities on the farm that occur after crops are harvested.

Pre-Harvest - Activities on the farm that occur before crops are harvested.

Putative – Generally considered or reputed to be.

Staple Food - A diet eaten regularly in a given population and in such amounts that it creates a central element of a food consumption pattern.

Stunting – This is a state of compromised growth and development in children as a result of malnutrition, recurrent illnesses and other insufficient social economic factors.

Toxicity – The quality of being toxic or poisonous.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This section analyses associated studies done by other scholars about mycotoxins exposure and their impacts on health. This chapter is organized under the following subheadings: history of aflatoxins, exploring mycotoxins occurrence, human exposure to aflatoxins, conditions for aflatoxins contamination, mycotoxins measurements, acceptable levels of aflatoxins, effects of aflatoxins on child growth, aflatoxins contamination losses, strategies to reduce aflatoxins exposure, alternative uses and disposal of aflatoxin contaminated foods, theoretical framework, and conceptual framework of the study.

2.1 History of Aflatoxins

These mycotoxins were recognized in 1960 after above 100,000 turkey chicks perished in the United Kingdom within a short period from a seemingly new illness that was referred to as "Turkey-X disease (Negash, 2018). Later it was discovered that the deaths emanating from the disease was not only restricted to turkeys. Young pheasants and duck chicks were also prone to the new disease. Careful study of the epidemic was conducted linking the new disease with the animal feed made from groundnuts from Brazil. Several studies were done on the feed made from the groundnuts with the results showing that it was poisonous with similar symptoms of the Turkey-X disease when fed to fowls and ducks (Negash, 2018). *Aspergillus flavus* was associated with the derivation of these mycotoxins as reported in subsequent studies. The contaminants were therefore referred to as "Aflatoxin based on their derivation from A Flavus (Milicevic, 2010). This discovery inspired a lot of research on mycotoxins thus the beginning of the current study of mycotoxins. Researchers conducted a lot of studies on aflatoxins a period which great tasks were accomplished with numerous mycotoxins were discovered (Bennett, 2010). From all the mycotoxins discovered, aflatoxins were considered the most powerful hepatotoxic and carcinogenic fungal metabolites which remain to be given a lot of devotion by researchers to date.

2.2 Mycotoxins Occurrence

Mycotoxins are organic compounds of microfungi that adulterate majority of the recurrently eaten crops globally. Delayed development, inability to fight infections, fatal human diseases, and loss of life are some of the risks associated with mycotoxins (Pitt et al., 2012). Their occurrence in specific areas rely on weather conditions. The main mycotoxins that cause health risks include: zearalenone, deoxynivalenol, ochratoxin A, fumonisins, and aflatoxins. They are produced by the *Fusarium, Penicillium, and Aspergillus* genera. They develop on the produce or attack them after removing them from the farms forming toxic compounds. This contamination is a severe hazard affecting food security in some regions, but the vulnerability of produces varies to a range of fungi that form the toxic compounds. The contamination also depends on a large variety of farming activities and environments (Pitt et al., 2012).

According to FAO, 25% of crops are susceptible to aflatoxin infestation. (Bankole & Mabekoje, 2004). The consequence of prolonged exposure leads to health problems and continual sublethal exposure affects nutrition, resistance to diseases and the danger of cancer. In Gambia 10 percent of men succumbed to cancer of the liver according to research work by Wild (2007) entitled “Aflatoxin exposure in developing countries”.

As stated by Williams et al. (2004) in a research called “Human Aflatoxicosis in Developing Countries”, the cause of 60% of the well-being hazards in growing republics and the cause of 43.6% overall disease burden was aflatoxin. Infants remain especially vulnerable, drastically hindering children’s growth and development. With aflatoxin severely affecting maize and other cereals production, this contamination poses the biggest hazard to communities depending on these cereals and grains as their staple foods. Consequently, masses of humans living in growing nations are persistently unprotected to aflatoxins through diet (Gong et al., 2015).

In Kenya, 125 deaths were witnessed out of 317 persons infected with aflatoxicosis in 2004 which was the worst ever reported in the world (Azziz-Baumgartner et al., 2005). Similar episodes have occurred and have been reported since 1960 to 2010 (Appendix 11). After the 2004 poisoning outbreak there has been intensive efforts by many stakeholders in the Country to mitigate this aflatoxin contamination. However, incidences of this contamination have been reported with laboratory analysis results showing that the contamination in maize and other cereals and grains was still prevalent in the Country (Kang’ethe, 2011). This contamination is a serious hazard to the food security in Kenya with considerable amounts of the farmers’ harvested cereals and grains going to waste. Media exposes on aflatoxin contamination of maize products in Kenya in 2019 caused waves of panic and anxiety in Kenya maize meal supply chain. These revelations came immediately after the Kenya Bureau of Standards (Kebs) put on hold licenses of 5 maize flour millers over the sale of aflatoxin contaminated flour which did not meet the Kenyan market requirements standards (Kabale, 2019). Prior to this, Kebs had suspended seven groundnuts’ products ordering the cessation of production in the manufacturing companies.

The companies were directed to recall back all the products that had already supplied to supermarkets because they were found to have exceeded the maximum aflatoxin content (Mwinzi, 2019). After these exposes, there was heightened testing by Kebs which suspended 17 licenses of maize flour millers authorizing them to remove their products from the supermarkets because their brands contained high levels of aflatoxin. (Nation Reporter, 2020).

Kebs and flour milling companies in Kenya have raised concerns over high levels of aflatoxin contamination in maize. Reports indicate that most of the maize produced in the Country contains very high levels of aflatoxin making it not fit for human consumption. Poor storage facilities and heavy rains have been indicated as the main reasons for this increased contamination. The milling companies reported that the contamination had worsened the acute maize shortage from the previous seasons' 44 million bags to 33 million bags (Bii, 2020). Substantial amounts of maize flour with high aflatoxin levels have been destroyed in the Country. In February 2020, the Government destroyed 36 tonnes of assorted maize flour products from different millers in Nakuru County unfit for human consumption because they contained high aflatoxin levels. Several analysis tests were done for the aflatoxin levels at the Government Chemist with the results indicating aflatoxin levels exceeding the Kenyan maximum allowed limit ten times (Musasia, 2020).

An all-inclusive, harmonized attempts to control this contamination is required in Africa to improve the well-being of populations and trade (Azziz-Baumgartner et al., 2005 ; CDC, 2004). KARLO and Universities in Kenya have conducted many studies though most findings from these studies have never reached the farmers.

KARLO has efficaciously developed Aflasafe which is a natural biological control product to decrease aflatoxin contamination protecting maize in the farms and in the stores (Ogumo, 2019). The Kenyan Government reported to have budgeted Ksh.200 million on Aflasafe for dissemination to the worst hit Counties in the Country with the National Government promising to partner with the Counties to support the small-scale farmers to produce safe food aimed at reducing the escalating costs of cancer treatments in the Country (Murimi, 2019).

2.3 Exposure to Aflatoxins

Aflatoxins are invisible, odorless, and bland which complicates populations' perception of their occurrence in foods and feeds (Wu et al., 2011). Ingestion of adulterated animal as well as agricultural products are the main ways people get affected by aflatoxins. Exposure can also occur through inhalation of the toxins through job-related exposure leading to negative impacts. The duration and concentration of the exposure can lead to chronic aflatoxicosis, complicate prevailing medical conditions, or increase the risk of spread of diseases (Wu et al., 2011). Aflatoxin B1, B2, G1, and G2 are the key kinds of aflatoxins. They attack several crops, inclusive of the mainly consumed cereals e.g., maize with aflatoxin B1 recognized to have the greatest toxicity of them all. Aflatoxins AFB1 and AFB2 are produced by *Aspergillus flavus*. All four forms of aflatoxins are produced by *Aspergillus parasiticus*. Aflatoxin M1 is a poisonous cancer-causing breakdown product of aflatoxin B1 present in the milk and urine of animals that have eaten food infested by aflatoxin inclusive of humans (International Agency for Research on Cancer [IARC], 2012). Reports exists of approximations of 0.1-0.4% residues of aflatoxin M1 in human milk (Zarba et al., 1992). Aflatoxin M1 contamination in human breast milk has been reported in growing countries (Magoha et al., 2014; Shephard, 2004; Turner, 2013).

Cases of cancer of the liver in people and animals have been linked with aflatoxin contamination. Aflatoxins are referred to as group 1 human carcinogen by IARC. Aflatoxin contamination and Hepatitis B infection are common in growing countries, and this increases the susceptibility to hepatocellular carcinoma (Wu et al., 2013). Several problems have been found in animals fed on feeds contaminated with Aflatoxin B1. These include digestive, genital, and respiratory problems. The magnitude of the problem in animals depends on the concentration and the period of contact to Aflatoxin B1. Prolonged exposure to concentrations at low levels leads to hepatic cancer while high to medial concentrations are lethal and poisonous respectively (Deshpande, 2002). One fifteenth of ingested aflatoxin B1 is deposited in milk and therefore increased chances of toxic effects occurs when consuming milk contaminated with Aflatoxin M1. The various heat processing methods used in the manufacture of the numerous dairy products do not have the capacity to decrease the levels of contamination in milk (Creppy, 2002).

2.4 Conditions for Aflatoxins Contamination

Fungal mycotoxins growth is determined by the food sources, environmental influences, and specific fungal enzymes (Schmale, 1998). Environments for the growth of moulds and aflatoxin are alike with the development of aflatoxicogenic fungi leading to aflatoxin production. Temperature and the amount of water favor the growth of fungi in stored food. Cereals and grains are harvested from the farms with their moisture content being at higher levels and before storage they are dried to lower this moisture content to required levels. Therefore, deferment of this process increases the risks of the growth of moulds and production of mycotoxins (Chulze, 2010). The contamination of crops with aflatoxin begins before harvest and during storage. Lengthy periods of hot weather conditions and pests' infestation also favor the production of aflatoxin in maturing maize.

Delay in harvesting can lead to contamination which can also be caused by higher moisture contents during storage. Inadequate drying before storing, showers during the harvesting time, and damage to the crops before removing them from the farm encourages the contamination. Production of aflatoxin in grains and cereals occurs in the field or in storage at temperatures between 20 and 40 degrees Celsius, and humidity of 70-90% (Carvajal & Castillo, 2007). Among the storage fungi species Aspergillus flavus has the highest moisture requirements. Therefore, the contamination is worsened by high levels of moisture in cereals and grains.

2.5 Mycotoxins Measurement

Examining the health and financial influences of this contamination requires assessment of mycotoxins occurrence. It is difficult to accurately analyze the contamination levels of one or more mycotoxins in a produce or product because they are diversely spread making it difficult to get a sample that accurately reflects the characteristics of the larger entity (Pitt et al., 2012). Proper attention and preparation are required in sampling and trial preparation for accurate analysis.

Careful attention is required for correct determination of contamination in any mycotoxin analysis for the purposes of well-being outcomes or for monitoring reasons. Getting a sample that accurately reflects the characteristics of the larger entity is a challenge in the context of farmers producing main foods in smaller quantities with sampling techniques required to be context specific (Pitt et al., 2012).

Figure 2.1

How Aflatoxins Get in Our Food, and its Health Effects

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Method of measurement is chosen after a suitable specimen is found and made ready. Many current techniques require distinctly state-of-the-art science and professional specialists. Developed nations have this measurement capacity and ability to deal with high volumes of merchandises. However, this is lacking in the developing republics where lesser quantities of foods are produced, assets inadequate, with fast judgements required on locally eaten foods safety. Currently, technologies e.g., ELISA Kit and validated thin-layer chromatography are effective in solving this problem (Pitt et al., 2012).

2.6 Acceptable Levels of Aflatoxin

Several nations including Kenya have established maximum allowable levels of aflatoxin in foods. These permitted levels are set for regulatory purposes and to decrease harmful effects of aflatoxin contamination. The set permitted levels differ among countries and are subject to the country's climatic conditions, state of development and economic status (Goncalez, 2004). Kenya was among only 5 countries in Africa to set standards on aflatoxin contamination in 2003. Since then, these regulations have been reviewed and limits for aflatoxins in cereals used as food set at 10ppb while in livestock feeds especially the dairy cattle feed set also at 10ppb. Anything above those allowable aflatoxin levels is unacceptable and not fit for consumption. These regionally consistent standards are vital to facilitate the same regulations which guard the health of people and more significantly enhance trade among nations. Once the review of the standards is completed, the acceptable aflatoxin limits in Kenya will be exactly as the East Africa Standards (Gong et al., 2015). Even though communities in Kenya consume a lot of milk, it has not set separate permitted levels of aflatoxin in milk (Sirma et al., 2018). For the set maximum limits of aflatoxin to be effective, there is the need for the private sector to effectively conform to the set standards and the close monitoring of the regulations set by the governments. Exceptionally successful safety control structures exist in the developed nations. This system controls not only the private but also the public areas a scenario which is not possible in the developing countries because of the existent of weak regulatory organizations to impose the set standards and the very common uncontrolled food markets and manufacturing companies. The situation is made worse by the high household consumption of the locally produced foods, casual transaction systems and the risk of eminent economic losses if these regulations are closely monitored (East African Standard, 2018).

2.7 Stunting in Children and Aflatoxins

Stunting in children has been associated with exposure to aflatoxins. This is a state of compromised growth and development in children because of malnutrition, recurrent illnesses, and other insufficient social economic factors. From a public health viewpoint, stunting is significant because it is linked with increased susceptibility to infectious illnesses and cognitive deficiencies that remain past the age of one year (Ricci et al., 2006). Research was conducted involving 680 children living in four different livelihoods regions of Benin and Togo. Supported by the aflatoxin–albumin adducts in serum, the cross-sectional study reported weight-for-age and height-for- age lesser depending on amounts in situations of growing exposures by way of analyzing (Gong et al., 2004). Independently, an evaluation involving two or more changing factors regulating for these elements besides sex and age, AF–alb stages in kids' serum appeared to be substantially related with complementary feeding status: greater aflatoxin exposure was reported in instances of early introduction of complementary foods (Gong et al., 2003). The levels of aflatoxin in flour sourced from homes in Kenya was also linked with wasting in children (Okoth & Ohingo, 2004).

There was a relationship between utero aflatoxin contamination and development faltering in children in a research conducted in Gambia (Turner et al., 2007). For one-year expectant mothers accompanied by their children were followed. Season, sex, placental weight, mother's weight, and pregnancy period were managed, with aflatoxin–albumin measured via enzyme-linked immunosorbent assay. The increase in height and weight of the infants depended on the mother's aflatoxin–albumin (Turner et al., 2007). There was also a reported relationship between low birth weight and mothers' aflatoxin–albumin levels in a research conducted in Ghana (Shuaib et al., 2010).

Low birth weight coupled with reduced length in children was associated with aflatoxin M1 in the mother’s milk in research work conducted in Iran (Mahdavi et al., 2010 ; Sadeghi et al., 2009). Relationships between growth outcomes and aflatoxin contamination have been shown in animal studies (Khlangwiset et al., 2011). No research has identified the linkage between aflatoxin contamination and growth failure. The connection has not been confirmed by all the studies that have been conducted. They have only shown the association between aflatoxin contamination and failure to thrive (Gong et al., 2004). To determine the connection of the affiliation between aflatoxin toxicity and development faltering, as suggested by the research conducted in Benin and Togo is not clear because of the effects of other confounding factors on the child’s nutritional status (Gong et al., 2004). Lack of linkage between aflatoxin contamination and development faltering in the research conducted in Tanzania suggested that there may also be a point where the affiliation between the two factors changes. Taking a broad view of the research results is a challenge due to the fact of their confined geographical distribution and inadequate facts on confounding factors.

To confirm causality of aflatoxin contamination to stunting in humans the following conditions must be achieved: the aflatoxin exposure and the delay in growth must be linked, the exposure to aflatoxins must come before the delay in growth, the resulting effects must be biologically conceivable, and the effects must not be due to confounding factors (Leroy, 2013). The households’ socioeconomic status is difficult to exclude. Infants in households with low socioeconomic status are fed on nutrients deficient diets and are susceptible to infections all which predispose them to delay in growth.

There is a possibility of overrating the association between aflatoxin and failure to thrive when the confounding factors are not effectively managed in research. This underlines the need for researchers to conduct controlled interventions studies to show the causal relationship between aflatoxin exposure and child stunting (Leroy, 2013).

2.8 Aflatoxin Contamination Losses

Aflatoxin contamination in foods is a severe menace to public health, agricultural productivity, food security, food trade and the environment. Several losses emanate from aflatoxin contamination including, economic losses in crop production and in the livestock sector, and medical costs to deal with the toxic effects of the contamination (Negash, 2018). In the aspect of public health deaths, diseases, and even growth retardation in children have resulted from the consumption of aflatoxin contaminated foods. Media exposes in 2019 in Kenya revealed that people in the country for many years have been consuming very hazardous levels of aflatoxin in maize and associated the rising cancer cases in the country to this contamination (Mwinzi, 2019). In agriculture and food security these contaminated foods are unfit for human consumption whereas the destruction of these foods leads to losses. According to FAO, losses amounting to 25% of the globally produced foods are adulterated mainly by aflatoxins among other mycotoxins. Millions of tonnes of food have been destroyed by governments after having been found to be unfit for human consumption. Aflatoxin contaminated maize was destroyed in Kenya both in 2010 and 2014 where 2.3 million bags and 155,000 bags of maize respectively which were not suitable for human and livestock consumption and for sale in the markets were condemned (Ngotho, 2019).
This seriously affects food security and food trade in the country as these foods are condemned and not accepted in the markets locally and across nations.

In the livestock industry there have been reports of illnesses in the animals, compromised ability to fight infections, slow growth, contamination of the animal products, reduced milk production and productivity in animals after the animals are fed with aflatoxin contaminated foods (Negash, 2018). Pollution of the environment occurs during the disposal of these contaminated foods either by incineration and burying or thorough the decontamination methods which are hazardous to the environment. In view of the enormous losses arising from this contamination plus the protection of public health, deterrence, and counteraction of this contamination in foods and animal feeds is critical (Panariti, 2001).

2.9 Strategies to Reduce Aflatoxins Exposure

Developed states have established aflatoxins regulatory set-ups which are challenging to readily apply in the developing nations. Relatively cheap pre- and post-harvest interventions exist which can be easily implemented in the developing countries. Use of more resistant species, interchanging of crops grown between seasons, and the use of living organisms such as insects and pathogens to control pests and plant diseases are some of the interventions used when the crops are in the farm. (USAID, 2012). Currently there has been increased campaigns for farmers to avoid the use of pesticides in their farms especially on food meant for human consumption and because of the pesticide's effects on the environment. Several countries globally have begun the implementation of this ban on pesticide use and some have even gone ahead and banned the use of these toxic chemicals. This has led to the development of more environmentally friendly pest management practices called biocontrols in agriculture. These biocontrols are naturally made from other natural organisms, extracts from plants and from useful insects. These biocontrols are either applied before harvesting or in the farms as the crops grow.

These biocontrols may not be as operative as the use of chemical control however researchers are conducting more studies to find their efficacy in aflatoxin mitigation (Reddy et al., 2009). In Kenya, Aflasafe, which is a natural biocontrol product that decreases aflatoxin contamination in maize has been successfully produced by KARLO. Aflasafe contains four atoxigenic Aspergillus flavus strains that competes and defeats toxigenic strains of Aspergillus flavus when applied 2–3 weeks before the crops flower. Farmers need to apply 4 kilograms to an acre of land. The government of Kenya has also commissioned an Aflasafe production plant at Kalro Katumani Station (Ogumo, 2019). The facility is the only one in East Africa that produces Aflasafe KE01 which is applied to maize three weeks before they flower minimizing the infestation by 70%. However not many people are privy to the information on the new biocontrol product (Ngotho, 2019).

Crop rotation is another pre-harvest intervention that can reduce aflatoxin contamination. Growing of the same crop each season increases the rate of fungal invasion and aflatoxin buildup. Environmental conditions that facilitate aflatoxin contamination of crops include temperatures, spacing of crops, type of soil, water vapor in the air, access to water, and dry spells (Hell & Mutegi, 2011). *Aspergillus flavus* more likely affects crops that are under environmental stress may be because of pest infestation, drought, changes in temperature and humidity. Changing crops grown in the farm between seasons by rotating aflatoxin susceptible crops with the less prone crops in addition to staggering the seasons when crops are grown in the farms allows the farm's environment to be in good health and can help in the reduction of aflatoxin contamination. Despite the efficacy of these pre-harvest techniques in the mitigation of aflatoxin in Africa, the problem remains widespread (Hell & Mutegi, 2011).

There are other post-harvest interventions that are used to mitigate aflatoxin contamination e.g., appropriate storage techniques like drying, maintaining appropriate storage conditions, and processing of the foods. There are some of the processes that reduce the amount of aflatoxin in the foods even though several researches have reported that refinement of food cannot totally eradicate it in foods. Aflatoxin concentration may be in certain parts of the cereals and grains e.g., the husk. Removing this part of the cereal or grain reduces the amount of aflatoxin in the food. Roasting also reduces the amount of aflatoxin levels in nuts by half. The cooking techniques in the homes are inadequate to reduce the aflatoxin levels in the foods (Scudamore, 2008). Another post-harvest technique that can eliminate aflatoxin contamination is drying. Drying the harvested cereals and grains reduces the moisture content in them thus hindering the growth of fungi and moulds. After drying the cereals and grains to the correct moisture content, the storage conditions need to be maintained in the required standards to avoid fluctuations in humidity and temperature (Chulze, 2010). These fluctuations can encourage the growth of fungi and therefore mycotoxins production in the stores. Pest and insect control should also be conducted in the stores to minimize the damage of the stored cereals and grains and to minimize their activity which tends to increase the storage temperatures and therefore increasing the risk of aflatoxin exposure and contamination (Chulze, 2010). Hermetic storage bags have been produced for storage of the dried cereals and grains with up to 66 percent decrease in insect pest losses reported depending on weather conditions during storage (Ng’ang’a et al., 2016 ; Walker et al., 2018).

There are other good agricultural practices that are used as strategies of mycotoxins control. These procedures ensure that the foods produced in the farm for human consumption or for further processing are safe and wholesome. These procedures entail maintaining the farms well and ensuring that the crops are healthy. These practices include: planting crops using ideal spacing which is ideal for the localities, ensuring that the crops are well watered to avoid water stress, controlling of weeds to decrease moisture stress, mulching to reduce weeds and moisture strain, insects and pest control to reduce the damage of cereals and grains which encourages the entrance of mycotoxin producing fungi, application of the right amounts and concentrations of fertilizers to crops, timely harvesting of the crops, and ensuring and controlling appropriate storage conditions (The Food and Agriculture Organization [FAO],2002).

2.10 Alternative Uses and Disposal of Aflatoxin Contaminated Foods

Since suppression of aflatoxin contamination in foods is not possible at the present time other uses of crops contaminated with aflatoxin should be well thought-out with disposal being the last-ditch effort. There are no recognized and well-designed mechanisms for the disposal of aflatoxin contaminated foods in the East African region (East African Standard, 2018). There are several ways of suitably using the aflatoxin contaminated foods. These include use as livestock feed and in the production of ethanol for energy which is environmentally friendly. The livestock feeds produced from these aflatoxin contaminated foods should be well examined to make sure that they meet the aflatoxin regulatory standards of the country. Currently there has been stepping up of testing food commodities for aflatoxin contamination and when these are found to be contaminated there are directives from the authorities that these foods are unfit for human consumption and for withdrawals from the markets leading to the confinement of these contaminated foods awaiting directives on alternative uses and disposal methods (East African Standard, 2018). The East Africa Community Partner States do not have clear regulations on permitted alternative uses and disposal methods of aflatoxin contaminated foods. However, there are calls for the partner states to come up with a strategy outlining the regulations and guidance on alternative uses and disposal methods of aflatoxin contaminated foods (East African Standard, 2018). The strategy recommends the following possibilities on substitute uses and discarding methods: direct utilization depending on the level of contamination as shown in table 2.1. The health and nutrition status of animals and human beings determine how they react to aflatoxin contamination. Hence the food commodity will be fit for direct consumption if it is within the acceptable levels in a group needing low levels of aflatoxin contamination (Wild & Gong, 2010). The second alternative use could be in the production of energy where maize contaminated with aflatoxins can be used to produce energy in cement companies. The contaminated foods can also offer raw materials to produce glue and industrial alcohol.

Table 2.1

Alternative Uses of Aflatoxin Contaminated Foods

Lot No.	**Total Aflatoxin Contamination(µg per kg**	**Proposal for Use (In the East African Community**
1.	Up to 5	For dog food and direct human consumption
2.	Up to 10	Direct Human Consumption
3.	Up to 20	Feed for mature animals including dairy cows
4.	Up to 100	Feed for mature beef animals excluding dairy animals
5.	More than 100	Reject for all classes or recommend for other alternative use/disposal

Source: East African Community Policy Brief 8. (2018)

The policy proposes the following disposal methods for aflatoxin contaminated foods: Disposal by putting in the ground at the bottom of plants used as food. Many microorganisms found in the soil are capable of mortifying aflatoxin. This can happen within 72 hours in some of the microorganisms (Wu et al., 2009). Aflatoxin has also the ability to bind to some of the clay soils (William et al., 2004). Another disposal method could be by incineration which is the greatest effective method of disposal as it extinguishes the aflatoxin molecules. The incineration can be done in either kilns or in open air. The aflatoxin molecules crumbles at 269 degrees Celsius with the ignition temperatures going up to 500 degrees Celsius (Njapau et al., 2015).

2.11 Theoretical Framework

Based on the concept that food safety risks are multidimensional (Dosman et al., 2001) the researcher used the Health Belief Model to explain Tharaka-Nithi farmers' knowledge and their interpretation of the medical risks resulting from consuming food poisoned by aflatoxin, losses associated with this food adulteration, analysis of the hindrances that avert control of the problem, interpretation of the advantages resulting from controlling this contamination in diets, and indispensable attempts to control this adulteration in staple foods. This structure was preferred to elucidate the existent of the study problem due to the fact of its established ability to efficaciously predict the acceptance of well-being practices and its tacit inclusion of economic and cost-effective motivations of reducing a challenge. Although this structure is ideally an interrelation of social factors and responsible for those factors of conduct that can be described via feelings and behavioral tendencies, it has been effectively used for more than 30 years in a variety of conducts associated with medical care (Harris & Nutbeam, 2004).

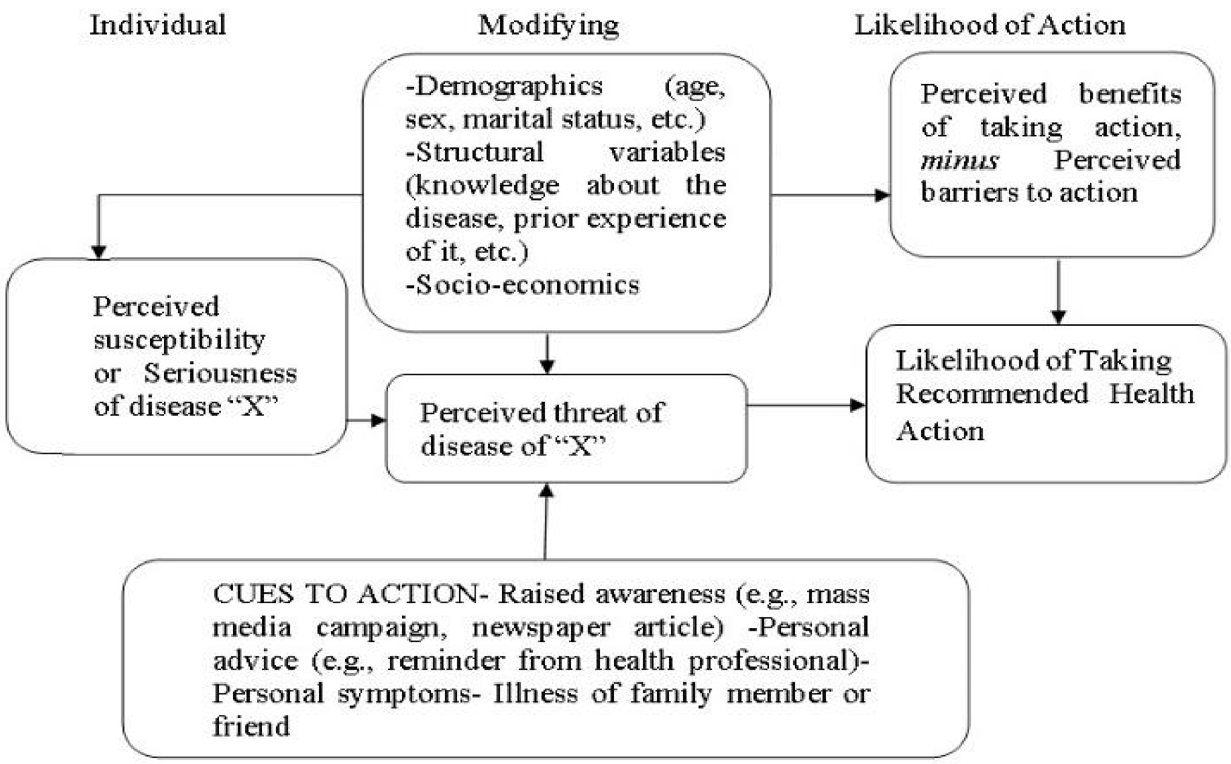
Health Belief Model is grounded on the expectations that, an individual will adopt a medical adopted behaviour if those individual senses that a terrible medical risk can be evaded, with the anticipation that by means of taking an endorsed action, the individual will keep away from the medical risk, and trusts that the individual can effectively take an advocated medical measure.

Health Belief Model recognizes that insights about a disorder and approaches accessible to minimize its prevalence decide medical action taken (Hochbaum, 1958). The structure comprises of four concepts in place of the professed vulnerability - emotions of individual susceptibility that comprises the individual grasp of the danger of acquiring an illness; alleged danger - the apparent danger of acquiring an illness and the result of being maimed by the illness that presents the incentive to modify the actions; apparent rewards - the economic, monetary and medical welfares, and the recognition that attempts gotten hold off to decrease the disorder may be possible and successful; alleged restrictions - the viable terrible elements of particular fitness behaviors that might also turn to be obstacles to accepting suggested social modifications.

Health Belief Model is grounded on the professed dangers linked with consuming infected diets. HBM is ideal since the levels of mycotoxins in many people may not be the origin of observable problems. Increased knowledge of the hazard will empower persons to look for information for a change of action. For that reason, the research aimed to analyze cereals used as staple foods among households to determine their levels of aflatoxin levels and the mitigation of this menace in Tharaka-Nithi County.

Figure 2.2

The Health Belief Model



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2.12 Conceptual Framework

Figure 2.3 illustrates the conceptual framework for the study. It is usually assumed that the initial stage of recognizing plus planning suitable approaches to mitigate a problem is the awareness of its occurrence reasons. Awareness is vital in encouraging farmers to plan suitable approaches for controlling the problem of aflatoxin contamination. Majority of the population are not privy to the information on the dangers of consuming mycotoxins contaminated food. This lack of awareness starts from the farmers producing the food to the consumers utilizing the food.

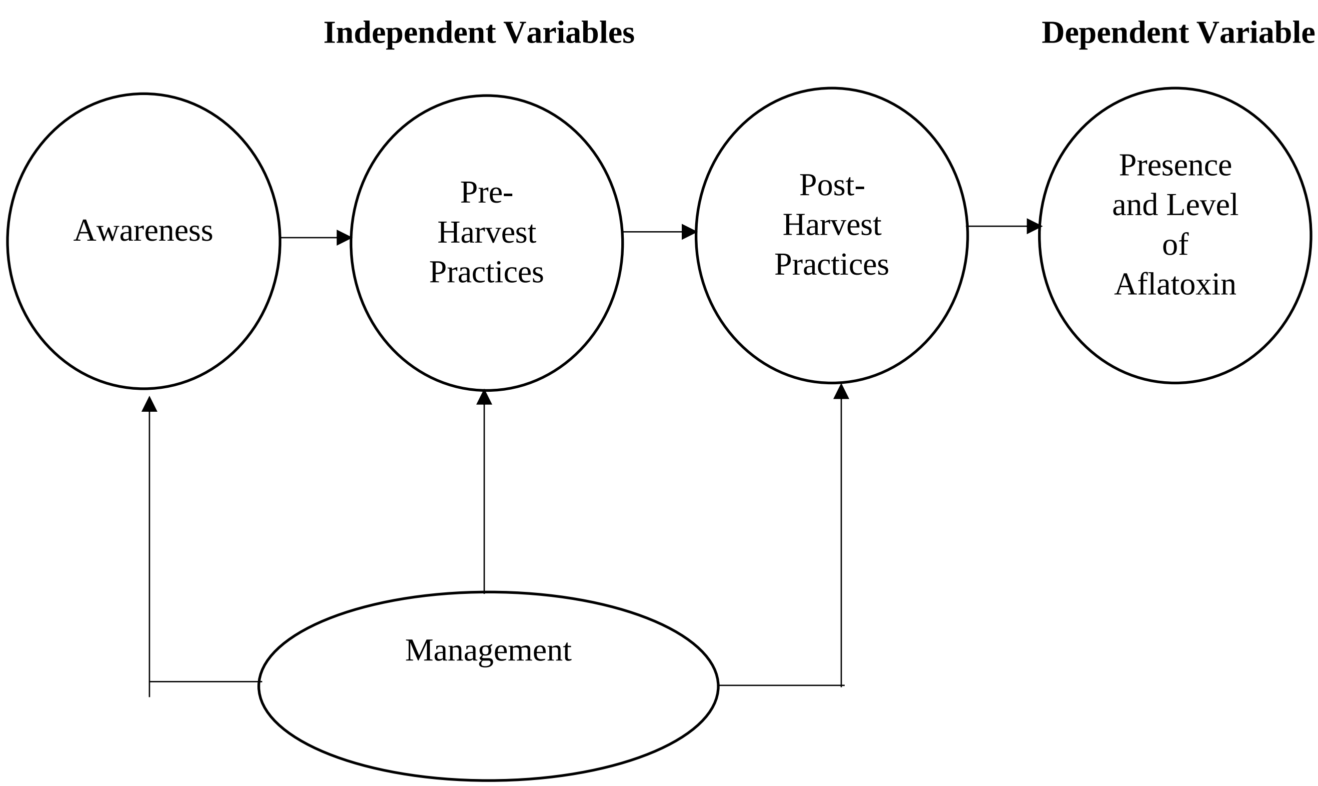
The farmers are not conscious of the consequences that emanate from their management procedures of their crops while in the farm, after the crops are harvested, and during preparations for storage. The farmers' adoption of the good agricultural practices which includes ideal farm and crop management practices to minimize aflatoxin contamination is influenced by the farmers' enhanced awareness. The farmers' management procedures before and after crops are harvested e.g., decisions on farming inputs to use in production, crop management practices in the farm, harvesting time and duration, methods of drying to safe moisture content, weather conditions during the harvesting season, pests' infestation, and sanitation practices in handling the cereals and grains determine the quality and quantity of cereals and grains produced. All these factors influence the contamination of aflatoxins in foods.

Procedures implemented by the farmers to decrease aflatoxin infestation in their crops are cross-cutting with the farmers' management of their farms and crops defining the kinds of practices to use in addition to pre-harvest and post-harvest technologies to apply in their crop production. The magnitude of aflatoxin contamination of the crops depends on the procedures adopted by the farmers noting that contamination can occur across the entire cereals and grains value chains. Given that sorghum, pearl millet and maize are the main cereals used as staple foods among households in the County, thorough evaluation of these mycotoxins statistics was conducted for confirmation. To proof this, the researcher reviewed information from similar studies conducted in the region, information from the relevant County government departments, and information from assessments conducted by organizations operating in the region.

To optimize resources and using the collected evidence that these crops are susceptible to mycotoxins infestation and are the same crops providing a bulk portion of the households' dietary intake, laboratory analysis was conducted to determine the aflatoxin levels in these cereals and grains. Here, the core danger of aflatoxin toxicity in these main foods was determined. The storage duration, kind of storage, temperatures during production and storage, type of soil, moisture, in addition to composition of nutrients in the cereals and grains determine the level of contamination which differs among the different cereals and grains. These factors greatly influence mycotoxins production consequently leading to the presence of these disease-causing agents in the cereals and grains.

Figure 2.3

Conceptual Framework of the Study



CHAPTER THREE

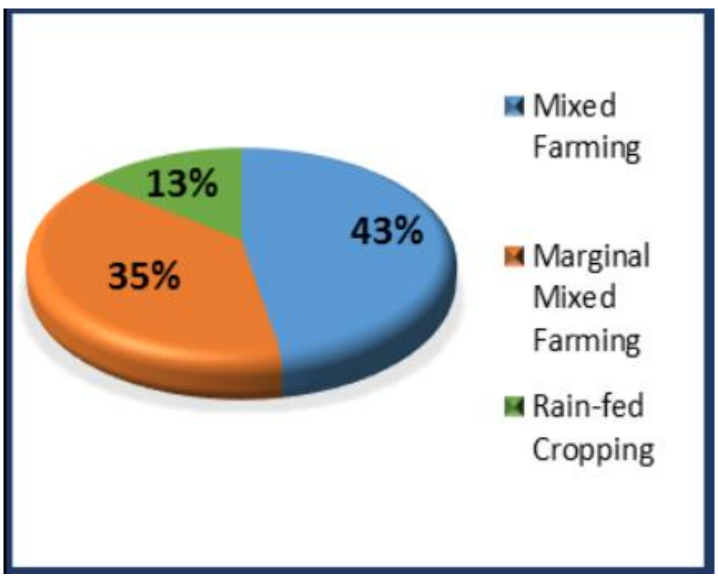
RESEARCH METHODOLOGY

3.1 Field of Study

Tharaka-North and Tharaka-South Sub-Counties of Tharaka-Nithi County constituted the study areas. The size of the two Sub-Counties is 1,569 Km^2 out of a total of 2,409.5 Km^2 which is approximately 65% of the County's geographic area. The estimated number of residents in the two Sub-Counties was 169,748 (KNBS, 2019 Estimates). Rain-Fed Cropping, Marginal Mixed Farming, and Mixed Farming constituted the three main geographical areas. Figure 3.1 illustrates the population distribution.

Figure 3.1

Population by Livelihoods Zones



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The study area was relevant because they are the two-major grain producing areas of Tharaka-Nithi County. Most of the populations living in the County are subsistence farmers growing food for household consumption and for sale. Half of the earning (50%) of the residents living in the mixed farming and rain-fed cropping regions is generated from crop production. Farming gives 25% household income to residents living in the marginal mixed farming zone. Maize, sorghum, millet, pigeon peas, green grams, and cow peas are the main crops grown in Tharaka. Green grams and sorghum are commonly grown for sale. Pigeon peas, cow peas, and maize are commonly grown for household consumption. Farmers in the rain fed and mixed farming regions grow maize which contributes to 40% of the food consumed in the households in the region. Farmers in the marginal mixed farming zone produce millet which contributes 50% to food.

The area has many cereal bulking stores that serve large populations in the County. For example, traders were holding approximately 1031mt of cereal stocks after the short rains season (October to December 2017) which is the most reliable season in Tharaka-Nithi County. When this was compared with the yearly food production in the County, it amounted to just about 64% of it (NDMA, 2018). Table 3.1 illustrates the contribution of cereals and grains in Tharaka-South and Tharaka-North Sub-Counties as reported in the long rains data validation for the year 2015.

Table 3.2

Contribution of Cereals and Grains to Income

Cereals:

Sub-County	**Area (Ha)**	**Quantity (Ton)**	**Value (Kshs)**
Tharaka-North	10,720	11,992.2	469288600
Tharaka-South	31,810	9,693.1	326913000

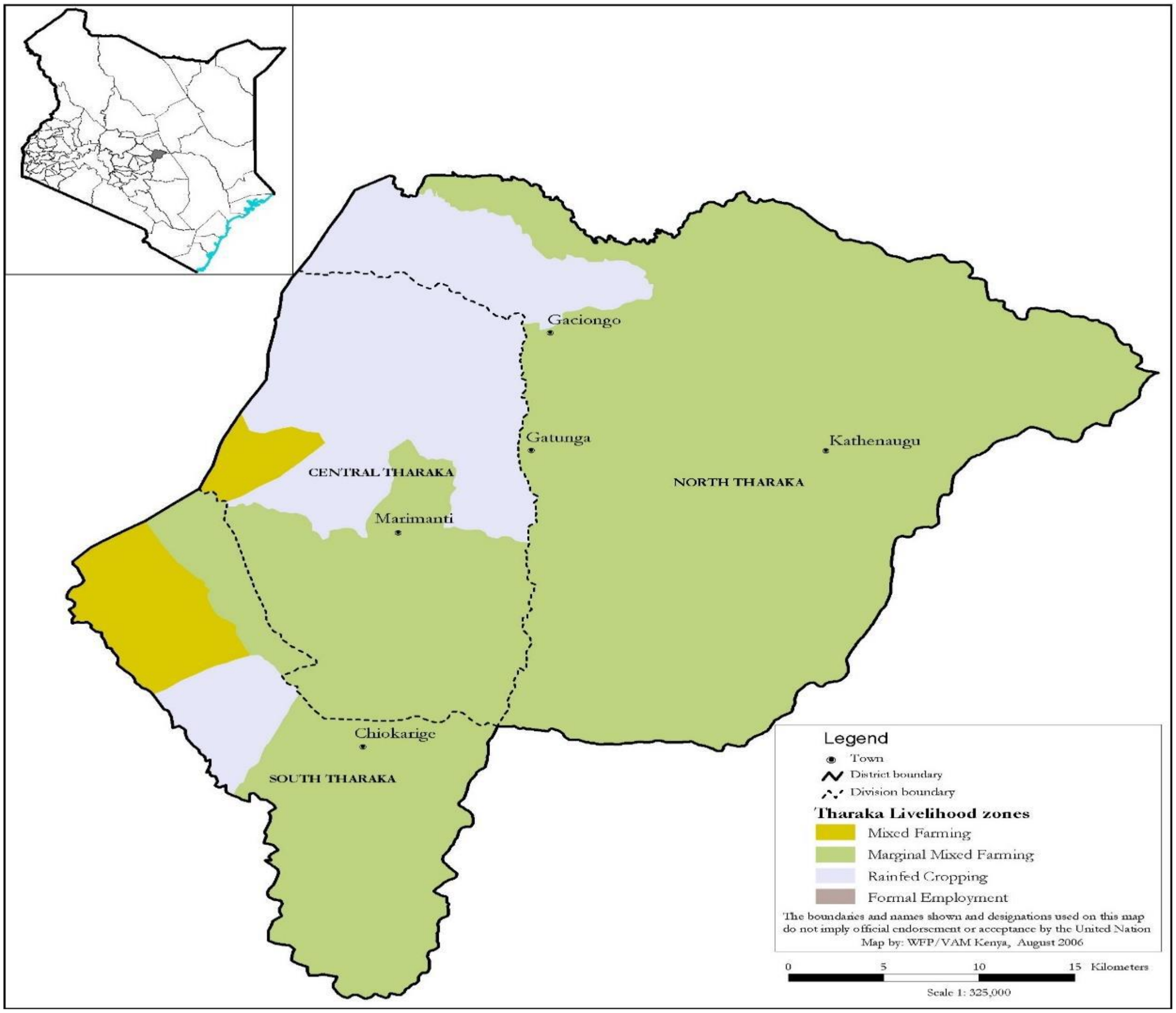
Grains:

Sub-County	**Area (Ha)**	**Quantity (Ton)**	**Value (Kshs)**
Tharaka-North	24,258	91175.2	1318680400
Tharaka-South	28,245	9403.8	611225000

Source: State Department of Agriculture, Tharaka-Nithi County, 2016.

Figure 3.2

Study Area; Tharaka-North and Tharaka-South Sub-Counties



3.2 Study Design

The study was an analytical cross-sectional design in which cereals and grains samples were collected from the study area for aflatoxin analysis. The study design was selected because of its suitability to investigate the association between a putative risk factor and a range of health outcomes. Observations were made to provide insights into the market layout, storage, and post-harvest management practices. The collected facts comprised of the views gathered from discussions at every family on how they handle the grains and cereals after harvesting together with collected samples for laboratory testing.

3.3 Target Population

The total target population for the study area (Tharaka-North and Tharaka-South Sub-Counties) was 169,748. The population living in this area were at the highest risk of consuming foods contaminated with aflatoxins / exposure to aflatoxins. Most of the residents in the County produce crops and livestock on small pieces of land without using advanced and expensive techniques. Most of the main foods are consumed locally. Subsequently, majority of the population utilizes these main diets that are prone to be infected with aflatoxin. The 2019 population census confirmed the following numbers of the most vulnerable populations in all the Sub-Counties of Tharaka-Nithi County as shown in table 3.2:

Table 3.3

Tharaka-Nithi County Demographics

Sub-Counties	Wards	Total Population	Total Number of Households	Pregnant & Lactating Women	Children U2 Years	Children U5 Years (including CU2)
Tharaka-North		65,207	13,585	1761	4108	10,368
	Gatunga	37,404	7793	1012	2356	5957
	Mukothima	27,743	5780	749	1748	4411
Tharaka-South		104,541	21,779	2819	6586	19,853
	Chiakariga	45,248	9427	1220	2851	7194
	Nkondi	20,321	4234	548	1280	3231
	Marimanti	59,293	12,353	1599	3735	9428
Mwimbi		87,310	22,976	2354	5501	11,463
	Mwimbi	27,652	7277	746	1410	3631
	Ganga	21,084	5548	569	1075	2768
	Chogoria	38,574	10,151	1040	1967	5065
Muthambi		41,815	11,004	1127	2133	5,490
	Mitheru	23,358	6147	630	1191	3067
	Muthambi	18,458	4857	498	941	2423
Igambangombe		53,603	12,763	1836	2734	7,038
	Igambangombe	11,641	2772	1086	594	4163
	Mariani	31,711	7550	399	1617	1528
Chuka		102,592	26,306	3515	5232	13,470
	Mugwe	28,903	7411	983	1474	3795
	Magumoni	43,618	11,184	1494	2225	5727
	Karingani	33,543	8601	1149	1711	4404

Source: KNBS 2019 Census Projection.

3.4 Criteria for Inclusion and Exclusion

Criteria for Inclusion:

- Both female and male farmers and households that farmed the cereals the researcher was interested in studying.
- Having lived in the village for over 12 months.
- Chosen households heads and traders who were willing to participate in the research.
- Cereals and grains used as staple foods among households were sampled for analysis.

Exclusion Criteria:

- Non-resident population.
- Non-responders.
- Cereals and grains not commonly used as staple foods.

3.5 Quantitative Analysis of Aflatoxin Levels in Cereals and Grains

3.5.1 Sample Size Determination for the Households

The research aimed to sample cereals and grains used as staple foods among households (sorghum, pearl millet, and maize) for determination of aflatoxin contamination from the two-major grain producing areas of Tharaka-Nithi County. The two study areas included: Tharaka-South and Tharaka-North Sub-Counties which had three Wards (Marimanti, Gatunga, and Mukothima Wards) with a total of 24 Sub-Locations. Households producing the crops the researcher was interested in studying were randomly chosen among all the eligible households which could be sampled based on the study protocols. The list of households which could be sampled was developed by the Area Managers and Field Officers from the Department of Agriculture in Marimanti, Gatunga and Mukothima Wards.

With the guidance of the Crop Officers and Field Extension Workers, villages that cultivated the crops and households that had some stocks of the crops were selected. One village was selected from each Sub-Location. In each village four households were selected. The samples from these households were combined to one sample according to the 'coning and quartering' principle. All four of the samples were put together on a pile and afterwards divided in four equal parts. Two parts that were diametrical towards each other were combined until an average of 1 kg was collected. Thus, the sample of 1 kg represented the composition of the whole village. The researcher assumed homogeneity and hence the idea that Tharaka-South and Tharaka-North Sub-Counties were treated as one homogeneous population. A total of 24 sorghum samples, 24 pearl millet samples, and 24 maize samples were collected from 24 villages located in all the Sub-Locations.

3.5.2 Data Collection Procedure for the Cereals and Grains

Simple random sampling procedure was used to collect cereals and grains samples from households and markets. To ensure collection of a realistic number of samples, sampling was carried out as shortly after the crops were removed from the farm. Households for samples collection were randomly selected from the villages. Caution was exercised while collecting the samples making certain that the households were never told that their crops were not fit for human consumption. Clarifications were done ethnically to the study respondents on the presence of mycotoxins and the hazards associated with them. Three major open-air markets within the two study areas were also selected based on size. These markets were chosen because they served majority of the residents in the region. The smaller marketplaces also get their supplies for sale from these larger markets. Cereals and grain samples were drawn from these markets.

Sample quantities of 1kg of each cereal type were obtained from each market. The researcher therefore had 72 samples from the households and 9 samples of the cereals from the markets.

3.5.3 Sampling the Cereals

Cereals and grains used as staple foods among households (Sorghum, Pearl Millet, and Maize) were sampled for analysis. The researcher sampled at the minimum one cereal or grain sample from each chosen family for laboratory testing. Cereals and grains forming the main diets for families at the time of the research were collected. Since most households and cereals bulking stores stored the cereals in 90-kg bags, the primary unit of sampling was the 90-kilogram bag. More than one sample from diverse parts of one 90-kilogram bag i.e., top, center and backside was collected and combined to produce a sample for laboratory testing that accurately reflects the characteristics of the larger entity. Samples were collected from several randomly selected number of bags to constitute the 1-kilogram sample for laboratory testing from respondents having numerous bags of the cereals and grains.

The sampling plan assumed that contaminants and undesirable materials (mycotoxins, overseas matter, damaged grains, and insects) were heterogeneously distributed, and valuable parameters are homogenously distributed. Simple random sampling was employed to ensure that every member of the population meeting the set criteria was equally likely to be chosen as part of the sample. A representative number of primary units from the stocks was obtained to account for distribution of key quality and safety attributes. To be certain that the irregularly presence of extremely adulterated samples were contained within the collected samples, sufficient samples were gathered from each sampling site.

This collection of sufficient samples also ensured that there was a 95% likelihood of getting no less than one sampling site with samples having aflatoxin levels above the maximum allowable limits. Tools recommended by FAO for samples collection were used to minimize likelihood of contaminating samples from different households and cereal bulking stores. Samples were collected manually using handheld spikes. The spike was used to collect about 500g increment sample per sampling point. The increments were aggregated and homogenized through manual blending so that all contaminants and physical properties were evenly distributed throughout the aggregated sample. Sample reduction was carried out by splitting the homogenized sample into four approximately equal portions (quadrants) from which the representative laboratory sample was collected. The laboratory sample comprising 200g to 250g of the grains and cereals constituted a composite representative sample for grading and milling for aflatoxin analysis. Caution was exercised making certain that the samples were well labeled. Sampling site GIS coordinates, date of collection, and precise sample identifier were included on the sample labels (Appendix 7 and 8). Hermetic sealed paper carriers were used to transport the samples to the laboratory for analysis as soon as they were collected. Collected samples were transported to Equatorial Nut Processors (ENP) Fortified Foods Division factory in Maragua for analysis.

3.6 Data Quality Control

To support the researcher in data and samples collection, the researcher recruited the survey teams from the County. The researcher engaged seven research assistants who had necessary experience in conducting surveys and mastery of the local area dynamics. A one -day training and piloting of the questionnaire (Appendix 2) was conducted in the respective areas of operation. The training focused on the following areas including, study objectives, sampling, data collection tools, how to ask the questions and record the answers, samples collection, and packing procedures.

The two respective Sub-County Public Health Officers attended the research assistants' orientation which was facilitated by the researcher. After the training, the research assistants conducted pilot tests in the proximate purposively selected households which were not selected for the study. Data collected during the pretest was reviewed immediately, feedback shared, and notable gaps addressed sufficiently before proceeding with the study data and samples collection.

The researcher played the key role of coordination and supervision of both study sites. Actual data collection took a maximum of 7 days. The data collection tools were the questionnaires. Sample details, GIS coordinates of the place and date of collection were recorded in the provided templates (Appendix 7 & 8). For every village visited, the survey teams had notebooks to document issues arising and any observations that informed data analysis and interpretation or corrective decision making. Good data quality was paramount for plausible study results. Several measures were employed to ensure quality data. These included: quality design of survey instruments, comprehensive training of the experienced research assistants including pilot tests, field supervision of the survey teams during the samples and data collection, daily meetings with the survey teams and sharing feedback with the teams every morning before proceeding to the field, and real-time samples collection after the day's work for transport to the laboratory for analysis.

3.7 Data Collection Procedure

For coordinated field procedures during the data and samples collection, the study enumerators were all well trained by the researcher. The research assistants were divided into two teams one for each study area. Each team contained two research assistants with a team leader for each team.

The team leader main responsibilities included: to ensure that the visited household was the sampled household, he/she was responsible for conducting the interviews and recording data on the questionnaires, ensure that proper and acceptable methods of samples collection were used, maintain proper care of the collected samples, and manage all aspects of the team. The other research assistant was responsible for making observations at the households, taking notes, collection of the samples, and supporting the lead research assistant with translations if any. After arriving at a village, the research assistants asked to speak with the village leader. Thereafter, the lead research assistant introduced the team, briefed the village leader on the purpose of the study, and confirmed with the leader if the sampled household belonged to his/her village. The lead research assistant also discussed with the village leader how the representative household was sampled by the Area Managers and Field Officers from the Department of Agriculture and asked for the location of the sampled household. If the village leaders had time, they walked with the teams to the sampled households.

Upon arrival at the households, the following procedure was followed: the teams' leaders introduced themselves and others on the team, using their full names and discussed with the household heads the purpose of their visit and study. If the household heads allowed them to collect samples of grains and cereals from their household/store for analysis and agreed to take part in the research, the household heads were given the consent form to sign before the administration of the questionnaire and collection of the samples (Appendix 1). After signing the consent form the household heads were thanked and asked if they have any questions. If they had no questions, they were asked permission to continue and if there was a need for taking any photographs during the exercise, permission was sought from them.

The research assistants then proceeded with the administration of the questionnaires and collected the samples after conducting the interviews. The researcher monitored all the assigned teams to ensure that all the aspects of the data and samples collection were performed correctly. During the monitoring visits, the researcher checked to confirm that the correct households were sampled and visited. The researcher also monitored the lead research assistants to confirm if they: administered the questionnaires and recorded the questionnaire information correctly and consistently from household to household, ensured that the samples were collected and packed appropriately, entered the questionnaire data into the data entry templates for analysis, and managed all the aspects of the study.

3.8 Procedure for Determination of Total Aflatoxin

Laboratory analysis was conducted at the Equatorial Nut Processors (ENP) Fortified Foods Division factory in Maragua. Analysis for Aflatoxin was conducted using the ELISA Kit model STAT FAX 4700 Microstrip reader**.** To determine the accuracy of the results in the laboratory, a reference sample as a control is always analyzed once every two weeks and an in-house reference sample is analyzed every week (Appendix 6).

3.8.1 Principle of Analysis

ELISA method of analysis used is centered on direct enzyme-linked immunosorbent assay. This method permits direct ascertainment of the levels of mycotoxins in samples. In this method, the magnitude of contamination is compared to a recognized concentration of a control sample. To extract total aflatoxins from the ground sample, 70% methanol solution is used.

Free aflatoxin and conjugate contest for antibody binding sites when the removed sample and HRP-conjugated aflatoxin are combined and transferred to antibody coated microwells. Substrate is added after a wash step and colour changes because of the presence of the bound conjugate. The levels of aflatoxins in the sample is contrariwise comparative to the resultant color concentration.

3.8.2 Equipment and Reagents

The equipment used included: mixing bottles with screw cap, filter paper, filter funnel, analytical balance, micropipette tips 200ul, micropipette 0-200ul, conical flask 250ml, beakers 100ml, measuring cylinder, gloves, absorbent paper, stopwatch, wash bottle, grinder mixer, spatula, and stat fax machine reader. The reagents used included: Aflatoxin kit, 70% methanol AR Grade, and distilled water. To prepare the 70% extraction solvent, 700ml of methanol was measured using a measuring cylinder into a clean bottle, 300ml of deionized water was added and shook to mix well.

3.8.3 Sample Preparation

A fine powder of the weighed 200g sample was prepared using a grinder mixer. 5g of the ground sample was weighed to the nearest 0.01g and transferred into a 250ml mixing bottle with a screw cap. 25ml of the 70% methanol was added and mixed for at least of 2 minutes. After the mixture settled, 5-10ml of the extract was sieved and the deposits used as samples for testing.

3.8.4 Assay Procedure

Before they were used, all the required reagents for the analysis were allowed to warm to room temperature. For each of the samples to be analyzed, the green marked wells were arranged in the microwell holder.

Similar count of antibody-covered wells were arranged in the microwell holder and well labelled. Before using the reagents, they were mixed by swirling the reagent bottles. 200ul of the conjugate from the green-labeled bottle was transferred using a new pipette tip to each of the green marked wells. The used pipette tip was discarded to avoid reusing it. Using a new pipette tip for each, 100ul of each sample was put in the green well comprising of the conjugate. Using a priming pipettor, mixing was done for a minimum of four times. Using a new pipette tip for each, 100ul from each of the green well was moved to the conforming antibody-covered well. The green well was discarded together with the tip. The green well was kept warm at 20 degrees Celsius for a quarter of an hour in the dark. The microwells were emptied and washed five times. All the residual buffer was removed by turning the wells upside down and vigorously tapping on an absorbent towel. Using a new pipette tip to each well, 100ul of the substrate from the blue-labelled bottle was added and the pipette tip discarded. This was kept warm at 20 degrees Celsius for 5 minutes in the dark. Using a new pipette tip to each well, 100ul of stop solution from a red-labelled bottle was added in a similar order and pace as the substrate reagent was put in.

Power was switched ON after the wells were inserted on the microtiter plate reader ensuring that the instrument displayed stat fax logo as the program loaded. The strip carrier loading and its positioning was checked to ensure that it was okay, well placed on the machine with the two arrows aligned. On the machine, TEST to run was selected and confirmation of the selection done because the printer only prints out the enabled strips found. On the machine display, ACCEPT was pressed on the graph of Absorbance against Concentration in ppb and the number of samples entered by pressing on the # samples on the display and ENTER pressed. ACCEPT on the display of the machine was pressed and the operator waited for the strip carrier to move.

In case it failed to move, start was pressed again, and lump time waited. Quit was pressed and the operator waited for the instrument to print the results until the printer read end of test. Each of the tests was conducted in duplicate. The arithmetic mean of the duplicate results of each of the samples was obtained to get the concentration of aflatoxins in each of the samples if the duplicate results met the repeatability requirement. The results were accepted if the proficiency test control sample was within the limits of the control sample testing, the in-house reference sample was within the set limits and if the duplicate results of the same sample did not exceed ±1ppb. If either the result of the proficiency test control sample or the in-house reference sample is outside the stated limits, the results are considered non-conforming and root cause analysis conducted. The tests are discarded, and repeat tests conducted if the duplicate results differ by more than ±1ppb.

3.9 Statistical Analysis of the Data

Analysis for Aflatoxin levels in the collected cereals and grains samples from the households and the markets was conducted in the laboratory using the ELISA Kit. Descriptive statistics were calculated together with the quantity and fraction of cereals and grains >10ppb which is the maximum allowable limits for aflatoxins in cereals used as food. The data obtained from objective 3 and objective 4 during the household interviews was subjected to statistical analysis using SPSS version 22 which generated analytics majorly frequencies and proportions. To establish the existence of relationship between the types of cereals and grains and the levels of aflatoxin contamination, Chi-square test for association was applied. 95% confidence interval significance was stated. To determine if there was a difference between the mean level of aflatoxin in the cereals and grains sourced from the two study regions, t-Test for Equal Means was used.

3.10 Ethical Approval

The Kenya Methodist University Scientific and Ethics Review Committee (SERC), National Commission for Science, Technology, and Innovation (NACOSTI), and the County Departments of Agriculture, Health and Education provided the required study ethical review and ethical approval. All the research respondents were explained about the value of their participation in the research and approved of their participation by signing the consent form (Appendix 1). All the community entry protocols were applied by the research assistants during the collection of the samples. The research team ensured that all the households well understood the purpose of the study and gave their permission to ensure the study respondents' dignity, privileges, protection, and well-being.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

Principal prerequisite for entry into the food markets globally and even access to the high-value local markets in the growing nations currently is food safety (Ashraf et al., 2009). At the same time mycotoxins exact a substantial health toll in the growing nations especially among the poor populations (Leroy et al., 2015). Globally, tropical, and subtropical regions are more susceptible to mycotoxins contamination. Among these mycotoxins is aflatoxin which is a poisonous substance produced by fungi. This contamination is predominant in Kenya affecting mainly maize which the most consumed food in the country. Consumption of aflatoxin contaminated foods can lead to diseases and loss of life if utilized in bulky amounts. Unfortunately, aflatoxins are not always easily noticeable, and the effects of this contamination can be fatal. Low consumption over extended periods of time can cause cancer and has been associated with children failure to thrive (Strosnider et al., 2006). Poor storage practices increases the chances of contamination which however starts when the crops are in the field. Contamination is inevitable and numerous evolving countries collectively with Kenya, do no longer usually test the main foods for aflatoxins leading to the consumption and sale of mycotoxins infested cereals and grains (The International Food Policy Research Institute [IFPRI], 2011). In Kenya, epidemiologic investigations of the reported outbreaks of aflatoxicosis that have been recorded in Eastern Kenya which is a renowned global aflatoxin hotspot have all been because of consumption of locally produced maize which was poorly stored in homes (Daniel et al., 2011). In the developed states, there are established systems to ensure regular testing of foods which ensure that only allowable levels of aflatoxins are present in the foods. However, in the growing nations there is lack of adequate guidelines and monitoring of aflatoxin contamination (Leroy et al., 2015).

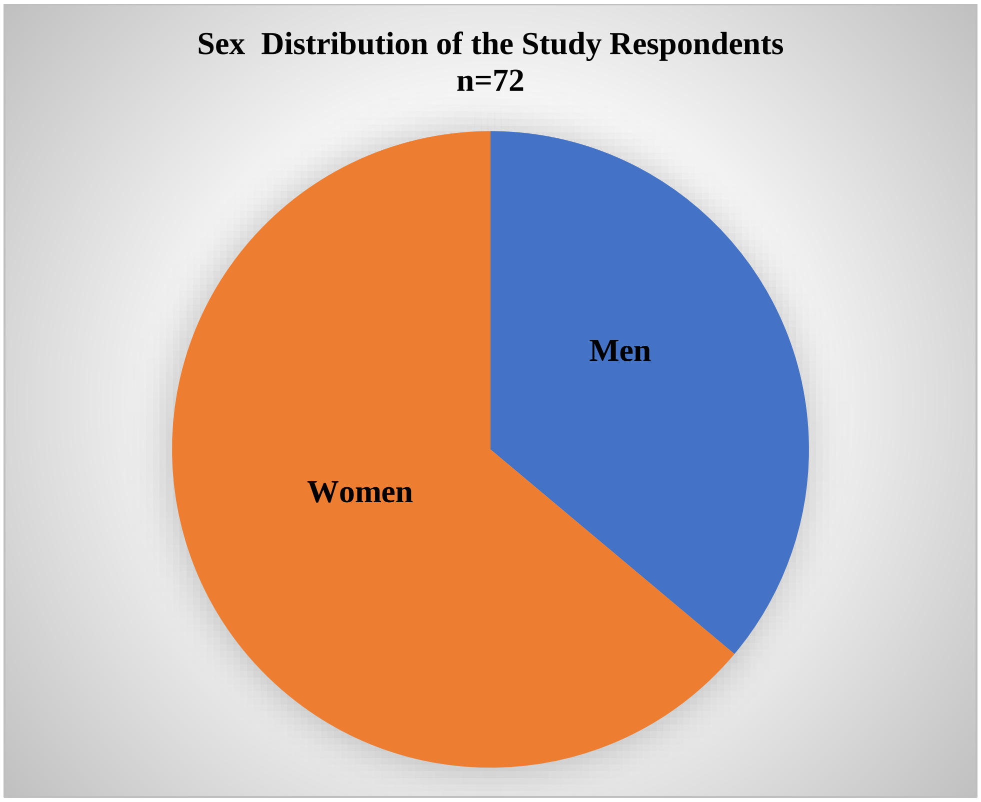
In Tharaka-Nithi County, poor infrastructural support and lack of awareness hamper the analysis and mitigation of aflatoxin contamination. Context-specific information on the aflatoxin occurrence in the County makes it possible to document vulnerable staple crops and the level of toxicity in the County. However, there is lack of local data on aflatoxin contamination in Tharaka-Nithi County to inform interventions chiefly due to lack of local research, testing facilities, and qualified personnel. This justified the need to conduct the study to document the magnitude of this contamination, community awareness of this contamination, and the factors that influence this contamination in Tharaka-Nithi County.

4.2 Social Demographic Factors

The data in figures 4.1 and 4.2 illustrates the socio-demographic characteristics of sex and educational levels of the study respondents. From the descriptive statistics in figure 4.1, it was observed that there were more women (64%) than men (36%) among the study respondents. Greater ratio of women amongst the survey respondents shows the fundamental significance of mother's influence to improved infant and young child feeding. Siblings and their families depend on mothers who mostly act as caregivers. The nutritional status and well-being of children and their mothers are closely associated according to WHO infant and young children nutrition global strategy. Both infants and mothers are part of a biological and social component and share malnutrition complications and ill-health. Therefore, the nutritional status and well-being of mothers is vital for optimal nutritional status of their children (World Health Organization [WHO], 2003).

Figure 4.1

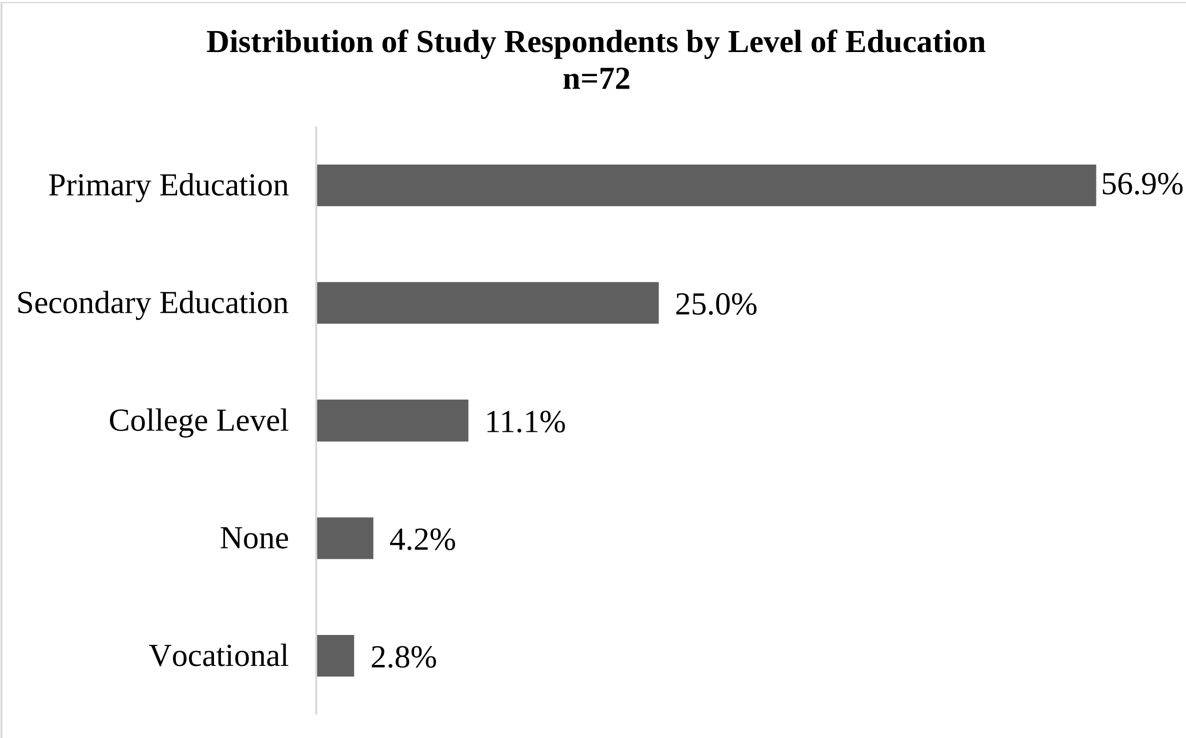
Sex Distribution of the Study Respondents



The educational qualification was added to establish the farmers' knowledge on aflatoxins contamination. Education was assessed in terms of educational level. Attending primary school only was considered as low level of education.

Figure 4.2

Distribution of Study Respondents by Level of Education



The data in figure 4.2 shows that majority of the farmers (56.9%) had low education probably because of the socioeconomic set-up of the region which is resource constrained making it hard for majority to proceed to secondary education. Higher educational level increased the chances of the farmers to have heard about aflatoxins (Table 4.1). This is an indication that educational levels had substantial influence on aflatoxin contamination awareness which could be associated with enhanced cognitive ability amongst well-educated persons. The findings concurs with research results of a study conducted by Marechera and Ndwiga (2014) on farmers from lower Eastern Kenya insights on strategies to control aflatoxins.

Data analysis on the knowledge of aflatoxin contamination among farmers showed that populations with higher educational levels had higher chances of being conversant and more aware of aflatoxin contamination than people with low educational levels (Marechera & Ndwiga, 2014). As stated by Dosman et al. (2001) in a study conducted in Canada, the higher the educational level of an individual, the higher the likelihood that he/she will prioritize the fitness of food than individuals with lower education levels. The findings that several farmers in the study area were not aware of aflatoxins underlines the need for more sensitization meetings with the farmers through the Department of Agriculture.

Table 4.4

Social Demographic Characteristics

Social Demographic Characteristics Influencing Level of Awareness of Aflatoxin Contamination (n=72).

		Have you heard about aflatoxin?			
		Yes		**No**	
Characteristics	**Categories**	**Frequency**	**Percent (%)**	**Frequency**	**Percent (%)**
Sex	Male	25	96.2	1	3.8
	Female	36	78.3	10	21.7
Education Level	Primary Education	33	80.5	8	19.5
	Secondary Education	16	88.9	2	11.1
	College	8	100	0	0
	Vocational	2	100	0	0
	Other	2	66.7	1	33.3

Though poverty was not analyzed in this study as a social demographic characteristic, poverty and ignorance was one of the factors identified to encourage the contamination of maize in Kenya in a study on probable aspects which escalate the growth of fungal toxic compounds in maize (Moturi, 2008). Tharaka-Nithi County has high poverty levels (40%) especially in the rural areas which is recognized to negatively impact on agricultural productivity in the County (MoALF, 2017). Majority of the small-scale farmers and livestock farmers living in the drier parts of Kenya are classified as poor. Poverty is common among the populations living in the rural areas in Kenya. Among these populations, their efforts are geared towards providing food for their families' regardless of the quality of the food. The lower the quality of food, the cheaper it is, and this is what this category of population can comfortably afford for their families.

There have been reports of families consuming food that has been declared unfit for human consumption because they do not have any other means to survive. Many of the populations are not aware of the health consequences of consuming mycotoxin contaminated foods. This includes the farmers who produce these crops who are not conversant with the pre- and post-harvest procedures that minimize the contamination, to the consumers who have no information of their rights to safe food free from contaminations. There are instances where populations do not recognize the effects of consuming contaminated foods and continue utilizing these foods even after the relevant authorities have sounded the alarm that the food is unfit for human consumption (Moturi, 2008). This clearly shows that the socio-demographic characteristics of individuals affects their awareness and approach towards aflatoxin contamination.

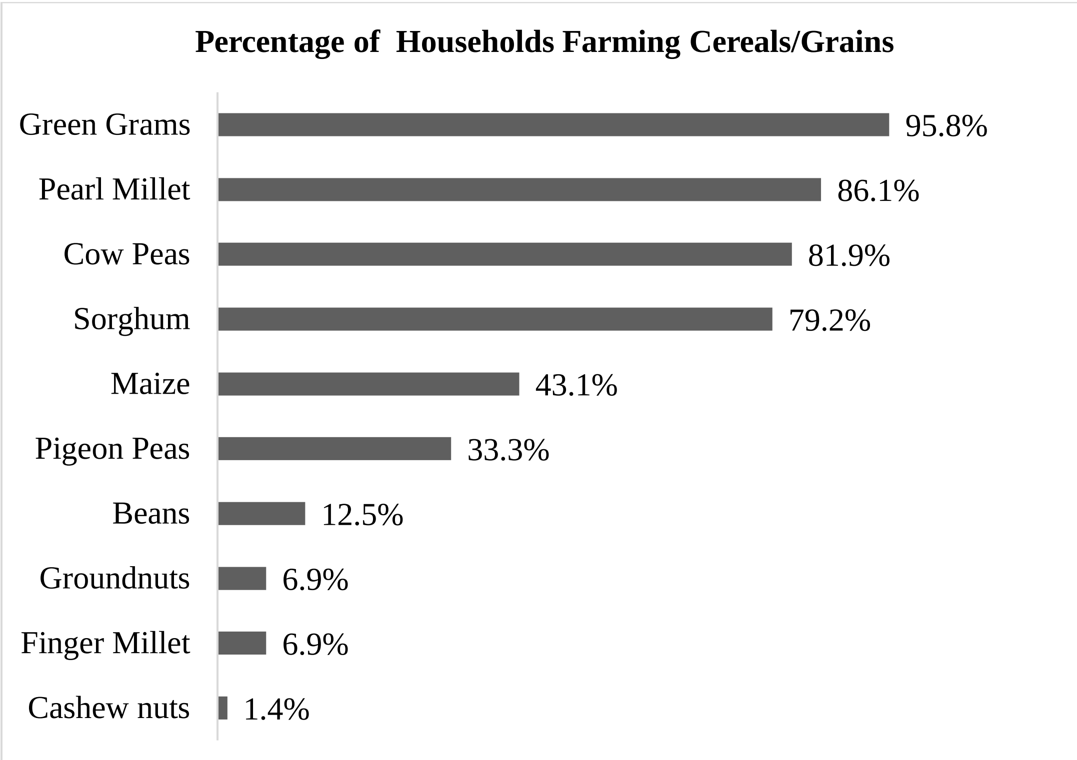
These results also compare with a research conducted in Tharaka-Nithi and Meru Counties by Leroy et al. (2015) to measure the level to which socio-economic characteristics affected the levels of aflatoxin contamination in rural women. Close to 900 rural women participated in the study with their socioeconomic data collected thorough questionnaires and their serum aflatoxin levels as the indicator of their exposure. The socioeconomic data collected was on the women's educational levels, age, food consumption at the household levels, and their access to materials required for farming.

The results of this study found aflatoxin contamination in the blood samples of all the study respondents. There were substantial differences in aflatoxin levels in the blood serum according to the women socioeconomic status. The poorest women exhibited aflatoxin levels equal to five to seven times higher as equated to the least poor women showing a noteworthy association between poverty and exposure to aflatoxins. This finding confirms that the underprivileged populations are most at risk populations to aflatoxin contamination and prioritizing its mitigation among them is key to improving their well-being (Leroy et al., 2015).

Data on type of cereals farmed by the study respondents revealed that green grams (95.8%), pearl millet (86.1%), cow peas (81.9%), and sorghum (79.2%) were the type of cereals and grains commonly farmed in the study area and constitute the main staple foods (Figure 4.3).

Figure 4.3

Type of Cereals and Grains Farmed



During the study period, the survey respondents produced 118.98 tons of these homegrown cereals and grains in their farms. Findings of the household monitoring exercise conducted by USAID in September 2018 in the study area to measure the household dietary diversity confirms these results. The monitoring exercise as illustrated in table 4.2 reported that grains and cereals provided the bulk of households' food consumption in Tharaka-Nithi County contributing 98.7% of all the food groups consumed by households in the region (USAID, 2018). The situation is intensified because a greater number of residents produce, store, and cook their own staple foods locally (USAID, 2018). These results underlines the need for change in the households' feeding habits in the County to avoid over reliance on these foods which are prone to aflatoxin contamination.

Table 4.5

Food Groups Consumed by Children in Tharaka-Nithi County

	Sub-County			Total
Food Types	**Maara (n=93)**	**Tharaka-North (n=51)**	**Tharaka-South (n=65)**	**Tharaka-Nithi (n=209)**
Grains, Roots and Tubers	99%	90%	98%	97%
Legumes and Nuts	39%	82%	78%	62%
Dairy Products	59%	35%	57%	53%
Flesh Foods	9%	6%	6%	7%
Eggs	5%	10%	3%	6%
Vitamin A-rich Fruits and Vegetables	80%	20%	18%	46%
Other Fruits and Vegetables	42%	20%	28%	32%

Source: USAID (2018)

Farmers in the study area reportedly farmed more of pearl millet and sorghum than maize. The farmers preferred planting these cereals (pearl millet and sorghum) because of the following reasons: as part of their traditions, as their main food, ease of production, and because of their ready market. These crops are also drought resistant and give good harvests despite the region receiving low rainfall.

Discussions with the farmers found out that the challenges they face during production of these cereals include low unpredictable rainfall, pests and diseases, high input costs, low market prices, post-harvest losses, and wildlife menace. Analysis of the data for the source of cereals and grains eaten at home revealed that majority of the households (98.6%) were consuming homegrown cereals and grains (Table 4.3), but they were also purchasing other cereals and grains not produced in the study area from the markets for households' consumption.

Table 4.6

Source of Cereals and Grains Eaten at Home

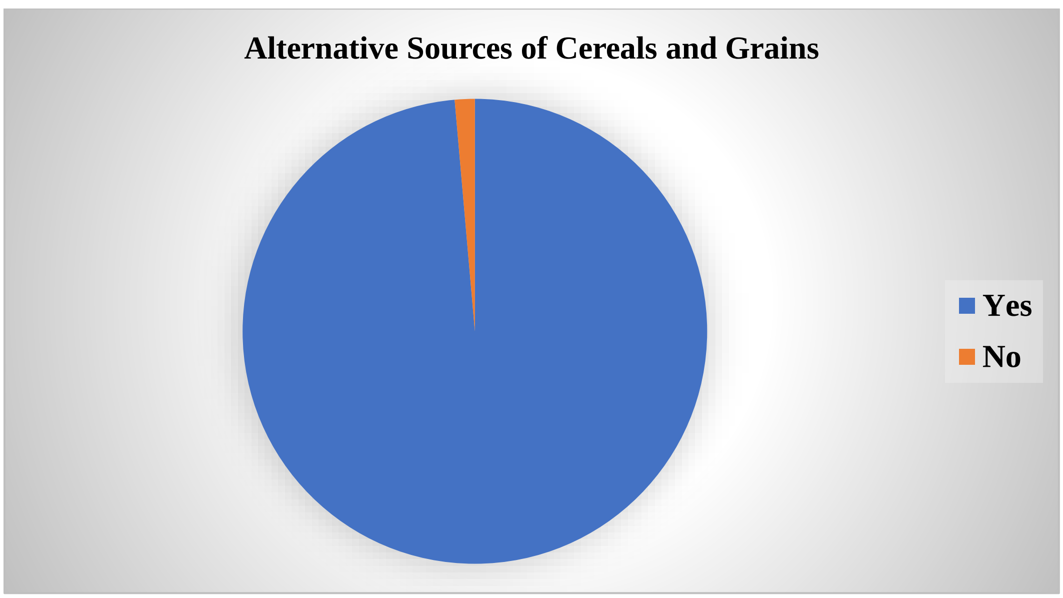
Source of Cereals Eaten at Home	Number of Households	Percent of Households
Homegrown	71	98.6%
Purchased	67	93.1%

This underlies the need for control of cereals and grains trading and marketing channels in the County with mechanisms for traceability of the grains during trading, processing, and marketing to minimize aflatoxin contamination among all the stakeholders in the cereals and grains value chains. A similar study in Nandi and Makueni Counties reported that most of the maize, sorghum and milk eaten by populations in the two Counties was home grown. Homegrown maize was the main food source for majority of households (60-90%) in the two Counties which is a major source of aflatoxin exposure (Kang'ethe et al., 2017).

In Tharaka-Nithi County the main players and stakeholders in the cereals and grains value chains include farmers, farmer groups, community-based organizations, cereals and grain traders, aggregators, transporters, posho millers, consumers (community and institutions) and the government departments (Health, Agriculture and Trade) responsible for enforcing the aflatoxin regulatory standards. Almost all the study respondents (99%) had other alternative sources of cereals and grains as seen in figure 4.4. Most households that mentioned that they have alternative sources for cereals and grains indicated that it was through purchase. The small percentage (1%) of the study respondents reported having received gifts from relatives.

Figure 4.4

Alternative Sources of Cereals and Grains



4.3 The Levels of Aflatoxin in Cereals Used as Staple Foods Among Households

A total of 72 samples were collected from households together with 9 samples from aggregators in the markets (n=81). Analysis to determine the levels of aflatoxin in the cereals collected was conducted using the enzyme-linked immunosorbent assay (ELISA) kit.

Overall, aflatoxin contamination in 25.8% of sampled cereal and grains was above the legal threshold of 10ppb Kenyan standards (Table 4.4). The level of aflatoxin in the sampled grains and cereals ranged from <1ppb to 30.79ppb. The analysis results indicated that 17.2% of cereals and grains exceeded established human tolerance levels of greater than 20ppb that cause symptomatic aflatoxicosis (Table 4.4). The findings indicated that pearl millet and sorghum were least affected by aflatoxin with maize being the most affected. From all the collected maize samples from the households and markets, 59% of the maize was not suitable for human or animal consumption.

This confirms the reports from the results of analyzed maize collected from households during aflatoxicosis epidemics in Kenya where extreme aflatoxin levels were detected. Inappropriately warehoused maize was the cause of the 2004 severe aflatoxicosis epidemic in Eastern and Central Provinces of Kenya. The locally produced maize was found to be stored under damp conditions which encouraged aflatoxin contamination during storage. Aflatoxin B1 levels of >20ppb were reported from half (n=15) of the households' samples (n=31) of maize grain, maize flour, dry maize cobs, sorghum, and millet. (Azziz-Baumgartner et al., 2005 & CDC, 2004). Maize samples (40% and 31%) from Western and Eastern regions of Kenya respectively contained aflatoxin levels above the maximum allowable limits in another study conducted by IFPRI and KARLO (IFPRI, 2011). In August, September, and October 2019 analysis of total aflatoxins contamination and percentage total defective grains conducted on all the maize distributed to families in Tharaka-Nithi County from the Ministry of Interior and Coordination of National Government reported that all the maize distributed to be very poor grade maize with very high percentage of total defective grains and therefore not suitable for human consumption.

From the study, sorghum appeared to be less commonly contaminated than maize and pearl millet with 96% of the sampled sorghum samples containing aflatoxins below the Kenyan tolerable limits (Table 4.4). These results concur with the fact that there are a small number of studies done in the East African region with results indicating millet and sorghum having aflatoxin levels above the allowable limits (Sirma et al., 2016).

Table 4.7

Total Aflatoxin Ranges of Cereals/Grains from Households and Marketplaces

Cereal	**Samples**	**Total Aflatoxin Ranges (ppb)**				
		<1	**1-10**	**10-20**	**21-30**	**>30**
Maize	27	8	3	3	10	3
Sorghum	27	19	7	1	0	0
Pearl Millet	27	10	13	3	0	1
Total	81	37	23	7	10	4
Percentage	**100.0%**	**45.7%**	**28.4%**	**8.6%**	**12.3%**	**4.9%**

To establish whether at all a relationship occurred between the types of cereals and grains and the levels of aflatoxin contamination, the researcher used Chi-Square test for association (Table 4.5). 95% confidence interval significance was stated.

Table 4.8

Chi-Square Test for Association between the Type of Cereals and Aflatoxin Levels

			Level of Aflatoxin (ppb)					
			<1	1-10	10-20	21-30	>30	Total
Sample	**Maize**	**Count**	8	3	3	10	3	27
		Expected Count	12.3	7.7	2.3	3.3	1.3	27.0
	Sorghum	**Count**	19	7	1	0	0	27
		Expected Count	12.3	7.7	2.3	3.3	1.3	27.0
	Pearl Millet	**Count**	10	13	3	0	1	27
		Expected Count	12.3	7.7	2.3	3.3	1.3	27.0
Total		**Count**	37	23	7	10	4	81
		Expected Count	37.0	23.0	7.0	10.0	4.0	81.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	36.819[a]	8	.000
Likelihood Ratio	39.711	8	.000
Linear-by-Linear Association	9.683	1	.002
N of Valid Cases	81		

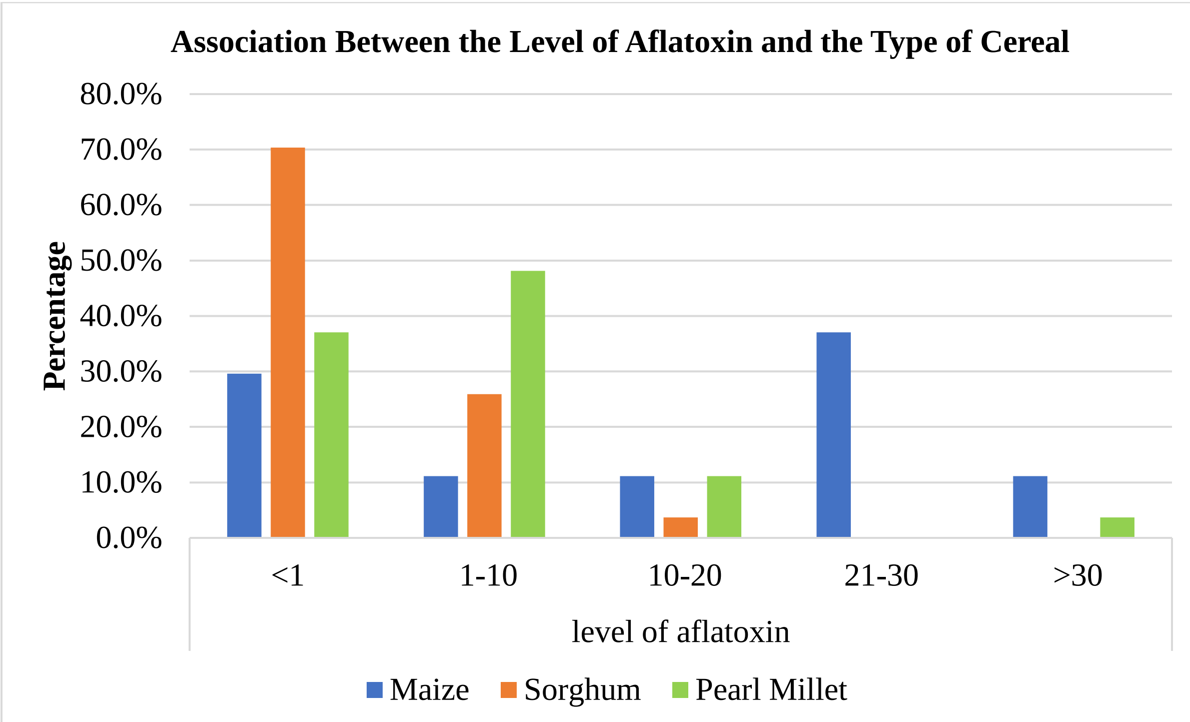
a. 9 cells (60.0%) have expected count less than 5. The minimum expected count is 1.33.

Based upon Chi-Square test for association, the value of the Chi-Square statistic is 36.819, with the p-value less than 0.001 which is less than 0.05 at 95% confidence level. Therefore, the result is significant. And thus, we reject the null hypotheses that there is no association between the type of cereals and the level of aflatoxin and conclude that the level of aflatoxin was associated with the type of cereals and grains. Both the likelihood ratio (39.711, p-value< 0.001) and linear by linear association statistic (9.683, p-value=0.002), further corroborate that there is a significant association between the two variables in the study. Therefore, cereals and grains levels of contamination differed as they were exposed.

The storage duration, kind of storage, temperatures during production and storage, type of soil, moisture, in addition to composition of nutrients in the cereals and grains determine the level of contamination which differs among the different cereals and grains. Based on the analysis examining the pattern of numbers, it is noted that the level of aflatoxin in maize in the category of 10-20ppb, 21-30ppb and >30ppb is more than expected. The level of aflatoxin in sorghum in the category of <1ppb is more than expected. While level of aflatoxin in pearl millet in the category of 1-10ppb and 10-20ppb is more than expected. The level of aflatoxin is higher in maize as compared to the other cereals. Figure 4.5 illustrates the patterns of the responses based on the aflatoxin levels of the cereals.

Figure 4.5

Association between the Level of Aflatoxin and the Type of Cereal



4.4 The Difference in Levels of Aflatoxin in Cereals from Households and Marketplaces

The analysis results showed that overall, aflatoxin contamination in 23.6% and 44.4% of sampled cereals and grains from the households and markets respectively was above the legal threshold of 10ppb Kenyan standards (Table 4.6 and Table 4.7). The aflatoxin contamination levels of almost half (44.4%) of the market samples was greater than the Kenyan tolerable limits. A few samples (5.6%) collected from the households had aflatoxin levels greater than >30ppb. Majority of these samples was maize (n=3) and pearl millet (n=1). All the maize samples (n=3) collected from the markets had aflatoxin levels above the maximum allowable Kenyan limits of 10ppb. This is a great concern in the region because majority of the maize consumed by households is sourced from the markets. The maize is milled, and the flour used to prepare porridge and ugali.

Another common traditional dish in the region cooked with maize is githeri which is a combination of maize and beans prepared whole. Sorghum appeared to be less commonly contaminated than maize and pearl millet both at the households and markets levels.

Analysis of the aflatoxin levels in maize both at the households and market levels confirms previous work done in Kenya and in the County where the Eastern region of Kenya has been dubbed a region of high aflatoxin prevalence. A previous study by Lewis et al. (2005) in Eastern and Central Kenya to evaluate the aflatoxin contamination of maize products found in markets after the acute aflatoxicosis outbreak revealed that majority of the procured maize contained aflatoxin amounts greater than the Kenyan standards. The study also analyzed the origin of the maize found in the markets and the results revealed that the harvested maize was possibly not stored by the farmers but sold to the aggregators in the market with the farmers buying it back when the need arose. This clearly shows that the market activities and the circulation of the adulterated homegrown maize may contribute to the spread of the contamination in the community (Lewis et al., 2005).

Similar research by Sirma et al. (2016) in Tharaka-Nithi and its neighboring County Isiolo revealed that the maize samples collected in Isiolo during the rainy season contained twice aflatoxin contamination in the maize samples from Tharaka-Nithi County which supplies Isiolo County with the maize. This clearly shows that a problem with food from one region could cause problems in other regions. The result of this study underlies the need for the authorities both at the National and County levels to enforce the regulations on testing of grains and cereals before they are sold to other parts of the Country that do not produce the same.

Additionally, all the main actors in the cereals and grains value chains need to be trained on appropriate storage practices irrespective of whether they are growing the crop in their regions or not because the contamination could occur during the marketing process (Sirma et al., 2016).

A similar research by CDC in Kitui, Machakos, Makueni and Thika after the 2004 aflatoxicosis outbreak revealed high level aflatoxin contamination of maize. Out of the 342 samples collected, 182 had aflatoxin levels > 20ppb (CDC, 2004). A recent study conducted in Eastern and Western Kenya revealed that 30% and 60% of maize sourced from the farmers' stores in the two regions respectively contained aflatoxin levels exceeding 10ppb. The study also found out that there is minimal assessment or sometimes none for aflatoxin contamination of cereals and grains sold in markets in Kenya (IFPRI, 2011).

Table 4.9

The Levels of Aflatoxin in Cereals and Grains Sourced from Households

Cereals	**Households Samples**	**Total Aflatoxin Ranges (ppb)**				
		<1	**1-10**	**10-20**	**21-30**	**>30**
Maize	24	8	3	2	8	3
Sorghum	24	16	7	1	0	0
Pearl Millet	24	9	12	2	0	1
Total	**72**	**33**	**22**	**5**	**8**	**4**
Percentage	**100.0%**	**45.8%**	**30.6%**	**6.9%**	**11.1%**	**5.6%**

Figure 4.6

The Levels of Aflatoxin in Cereals and Grains Sourced from Households

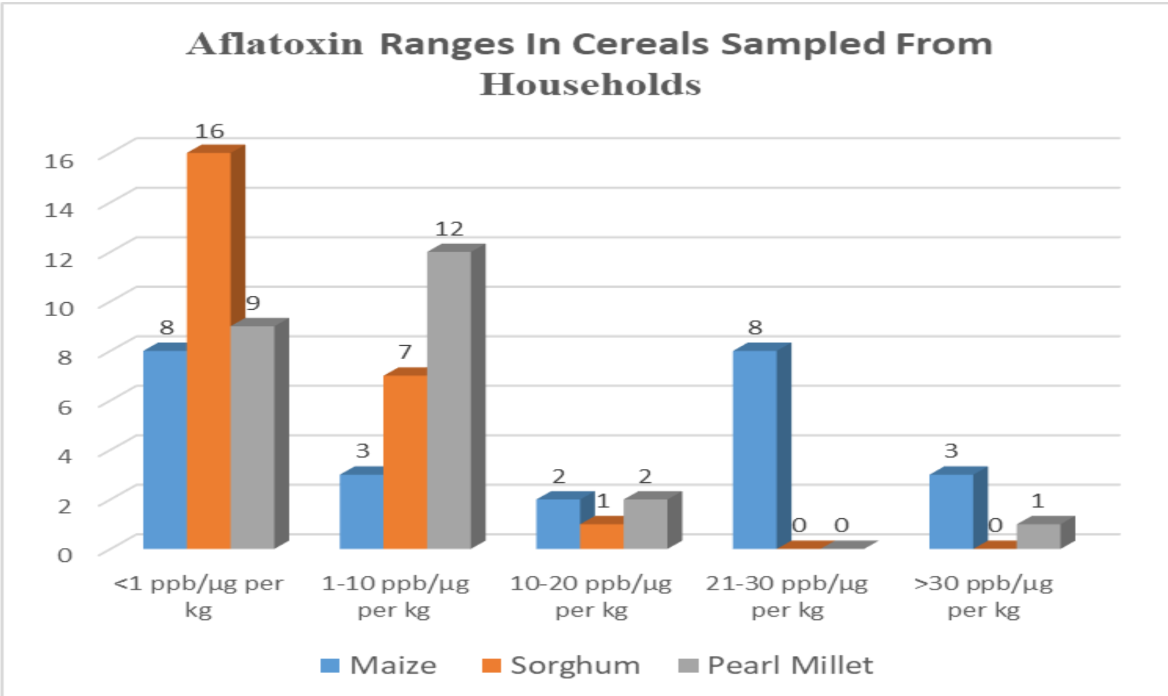


Table 4.10

The Levels of Aflatoxin in Cereals and Grains Sourced from Marketplaces

Cereals	**Market Samples**	**Total Aflatoxin Ranges (ppb)**			
		<1	**1-10**	**10-20**	**21-30**
Maize	3	0	0	1	2
Sorghum	3	3	0	0	0
Pearl Millet	3	1	1	1	0
Total	**9**	**4**	**1**	**2**	**2**
Percentage	**100.0%**	**44.4%**	**11.1%**	**22.2%**	**22.2%**

Figure 4.7

The Levels of Aflatoxin in Cereals and Grains Sourced from Marketplaces

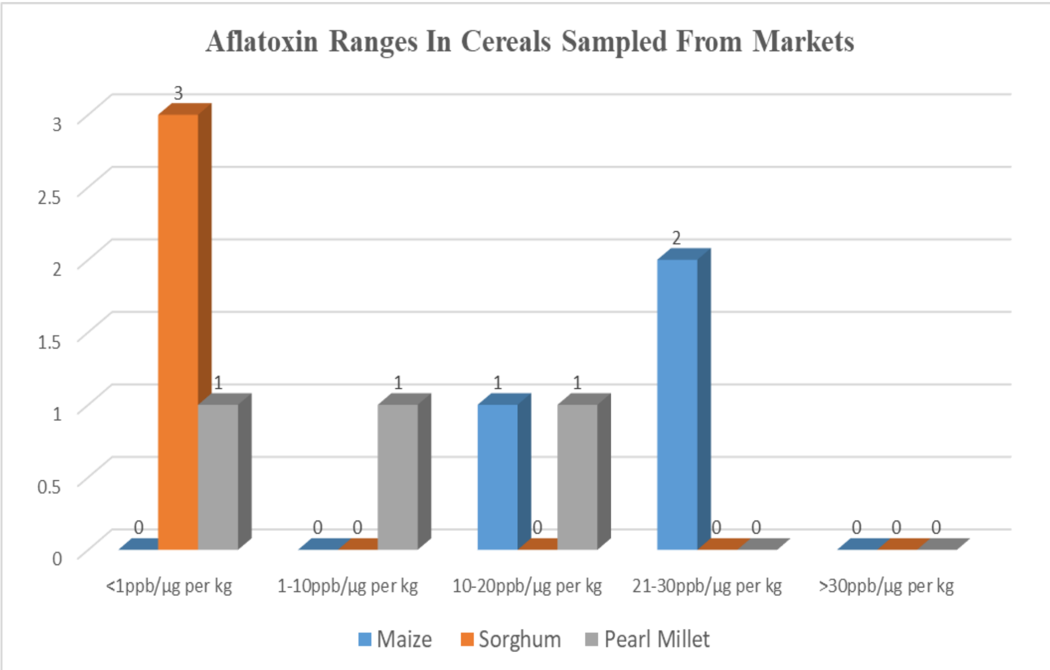


Table 4.8 shows that, as per Levene's Test for Equality of Variances, there is no statistically significant difference between the variability of conditions in sorghum and pearl millet collected in the households and those from the marketplaces (p-value for Sorghum=0.157 and Pearl Millet=0.893) and the means are likely due to chance and not likely due to the place where the samples were collected. However, for maize, the analysis shows that there is a statistical significance (0.02) in the variability on the mean of aflatoxin levels of samples collected from the two places (households and marketplaces). Furthermore, the t-Test for Equality of Means, shows that the difference between the means of the level of aflatoxin in the cereals in the two places of collection (households and marketplaces) was not statistically significant (p-value for Maize=0.294, Sorghum=0.422 and Pearl Millet=0.918, all of which are greater than 0.05).

Hypotheses was accepted; there was no difference in mean level of aflatoxin in the cereals and grains collected from the marketplaces and households.

Taking into consideration, the mean of level aflatoxin of cereals and grains sourced from the households and those from marketplaces, the mean level of aflatoxin for maize sourced from marketplaces was higher (mean difference is negative, given market as the reference category) as compared to those sourced from households. While the mean level of aflatoxin in sorghum and pearl millet sourced from marketplaces was lower (mean differences is positive, given market as the reference category) as compared to the ones sourced from households.

Table 4.11

T-Test for Equality of Means for the Aflatoxin Levels

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
Cereal		**F**	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference*** **	**Std. Error Difference**	**Lower**	**Upper**
Maize	**Equal Variances Assumed**	6.222	.020	-1.071	25	.294	-8.86167	8.27332	-25.90088	8.17755
	Equal Variances Not Assumed			-1.286	2.858	.293	-8.86167	6.89289	-31.42649	13.70316
Sorghum	**Equal Variances Assumed**	2.131	.157	.816	25	.422	1.45250	1.77961	-2.21268	5.11768
	Equal Variances Not Assumed			2.349	23.000	.028	1.45250	.61846	.17312	2.73188
Pearl Millet	**Equal Variances Assumed**	.019	.893	.103	25	.918	.46042	4.45069	-8.70594	9.62678
	Equal Variances Not Assumed			.130	2.966	.905	.46042	3.55289	-10.91938	11.84021

****Reference Category is the Market Place*

Table 4.12

T-Test for Equality of Means for the Aflatoxin Levels in the two Sub-Counties

Cereal	Variance	Levene's Test for Equality of Variances		t-Test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference***	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Maize	Equal Variances Assumed	2.976	0.099	-0.142	22	0.888	-0.815	5.72153	-12.68073	11.05073
	Equal Variances Not Assumed			-0.142	21.705	0.888	-0.815	5.72153	-12.6901	11.0601
Sorghum	Equal Variances Assumed	2.21	0.151	-0.743	22	0.465	-0.92833	1.24913	-3.51888	1.66221
	Equal Variances Not Assumed			-0.743	16.71	0.468	-0.92833	1.24913	-3.56726	1.7106
Pearl Millet	Equal Variances Assumed	0	0.983	-0.472	22	0.641	-1.45083	3.07222	-7.82222	4.92056
	Equal Variances Not Assumed			-0.472	20.294	0.642	-1.45083	3.07222	-7.85342	4.95176

****Reference Category is Tharaka-North Sub-County*

Table 4.9 shows that, as per Levene's Test for Equality of Variances, there is no statistically significant difference between the variability of conditions in the two Sub-Counties (p-value for Maize=0.099, Sorghum= 0.151 and Pearl Millet=0.983) and the means are likely due to chance and not likely due to the ecological differences in the two conditions. Furthermore, the t-Test for Equality of Means, shows that the difference between the means of the level of aflatoxin in the cereals in the two ecological zones was not statistically significant (p-value for Maize= 0.89, Sorghum= 0.47 and Pearl Millet=0.64, all of which are greater than 0.05).

Thus, there was no difference in mean level of aflatoxin in the cereals and grains in Tharaka-South and Tharaka-North Sub-Counties. This confirms researcher's assumption on the homogeneity of the two study regions which were treated as one homogeneous population during the sample size determination for the households. Taking into consideration, the mean of aflatoxin levels of cereals and grains sourced from the households in the two study areas, the mean level of aflatoxin in all cereals and grains sourced from Tharaka-North Sub-County was slightly higher (mean differences are all negative, given Tharaka-North Sub-County as the reference category) as compared to the ones sourced from Tharaka-South Sub-County.

4.5 Households' Awareness on Suitable Conditions for Storage of Foods

Majority of the study respondents (84.7%) had previous awareness of aflatoxins. This is an indication of the presence of aflatoxins in the area and a pointer of its seriousness in the region where it occurs regularly. In depth information on what aflatoxins are and the effects of their contamination was scanty and inconsistent. Strengthening the recognition of the farmers on the graveness of this issue provides a platform for the adoption of management practices that reduces aflatoxin contamination, in this regard 26.8 % of the study respondents had training related to storage and safe handling of foods. There is need for ongoing farmers' sensitizations thorough the Department of Agriculture to reach to the few farmers not aware of the contamination. However there needs to be a change in the current perception of the government policy that indicates that the farmers need to request for the extension services from the agricultural officers only when there is need. This could be attributed to the low numbers of farmers reached with aflatoxin mitigation messages and because of the very few field extension workers covering the two Sub-Counties who cannot effectively reach all the farmers with the messages. Awareness creation and sensitizations to all the stakeholders in the cereals and grains value chains is needed to manage the contamination problem and increase the adoption of the recommended practices to improve the quality of food at home and in the markets.

Table 4.13

Knowledge on Aflatoxins

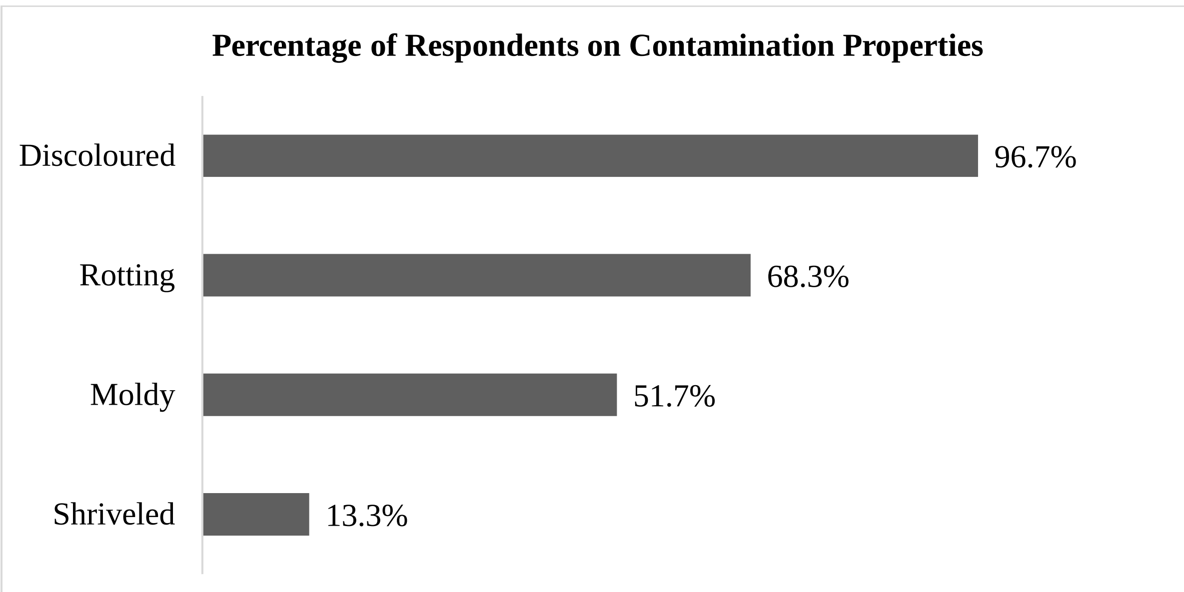
Variables	Responses	Frequency	Percentage (%)
Awareness of Aflatoxin	Yes	61	84.7
	No	11	15.3
Training Related to Storage and Safe Handling of Foods	Yes	19	26.8
	No	52	73.2
Do Poor Storage Conditions Promote the Presence of Aflatoxins in Foods	Yes	61	84.7
	No	11	15.3

Figure 4.8 shows responses from the study respondents who indicated that they were aware of aflatoxin on properties of foods contaminated by aflatoxins. Of the responses, 96.7% mentioned discoloured, 68.3% mentioned rotting, 51.7% mentioned moldy, and 13.3% mentioned shriveled all which are properties of cereals and grains contaminated with aflatoxin. The main source of awareness to the study respondents on aflatoxins was from: other farmers, farmer groups and Officers from the Department of Agriculture. Public Health Officers are too few in the region and only bring out aflatoxin messages when contamination is detected. At the time of the study, 3,945 cereals and grains farmers in the region had organized themselves into 12 community-based organizations (CBOs) for cereals and grains aggregation and marketing. Tharaka-South Sub-County had 8 CBOs with a membership of 2,395 farmers and Tharaka-North Sub-County had 4

CBOs with a membership of 1,550 farmers. These forums provide an opportunity to the Extension Officers for information dissemination to the farmers and an opportunity for the farmers to identify their problems and encourage each other to practice the modern technologies and make informed decisions on aflatoxin management. Most participants linked aflatoxin contamination to occurrences of poisoning outbreaks without information on the risks of consumption of low-level aflatoxin contamination in foods.

Figure 4.8

Properties of Foods Contaminated by Aflatoxins

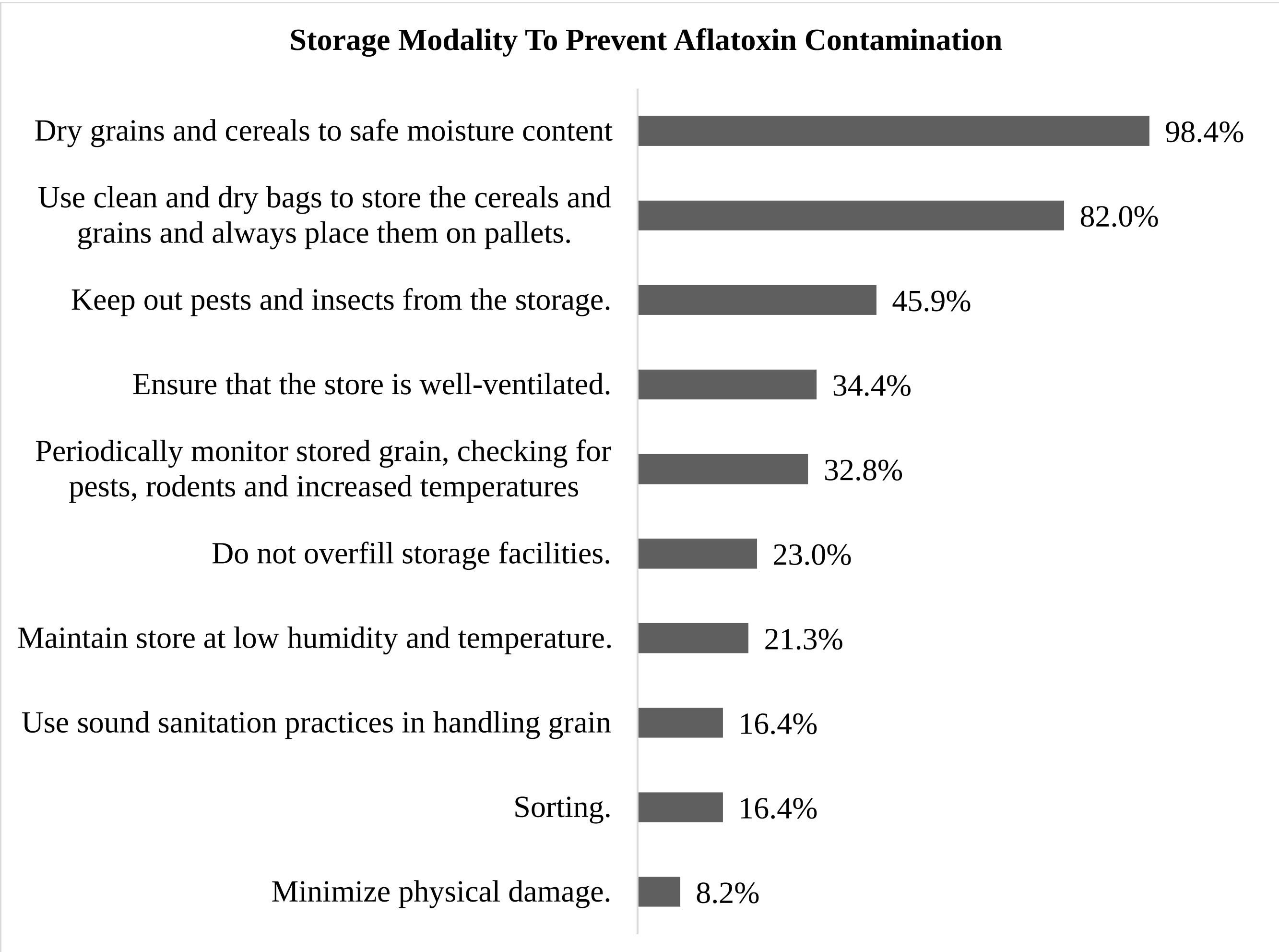


Of the study respondents who indicated that they are aware of aflatoxin, 84.7% indicated that poor storage conditions promoted the presence of aflatoxins in foods whereas 15.3% were not aware that this can lead to contamination. The study found that the apparent post-harvest management practices used by majority of the study respondents to prevent aflatoxin contamination was drying of grains and cereals to safe moisture content (98.4%) and the use of clean and dry bags to store the cereals and grains and always placing them on pallets (82%). Majority of the farmers use sundrying to dry their cereals and grains in the region because it has adequate sunshine despite reporting challenges of increasingly common rain showers during the harvesting time. The study found out that information on suitable storage conditions to minimize aflatoxin contamination was scanty as seen in figure 4.9. This underlies the need for awareness and sensitization meetings for farmers on strategies for prevention and control of aflatoxin contamination during storage.

These findings corroborate the results of a study conducted in 2011 in Western and Eastern Kenya which documented that majority of the farmers were still drying and threshing their cereals and grains on bare soil and had poor storage structures despite their recognition of aflatoxin contamination. The study also found out that although cheap technologies were available to mitigate aflatoxin contamination, their use was not pervasive because of lack of adequate facilities for effective drying and storage, farmers' inadequate knowledge and skills of the issue, and possible solutions (IFPRI, 2011).

Figure 4.9

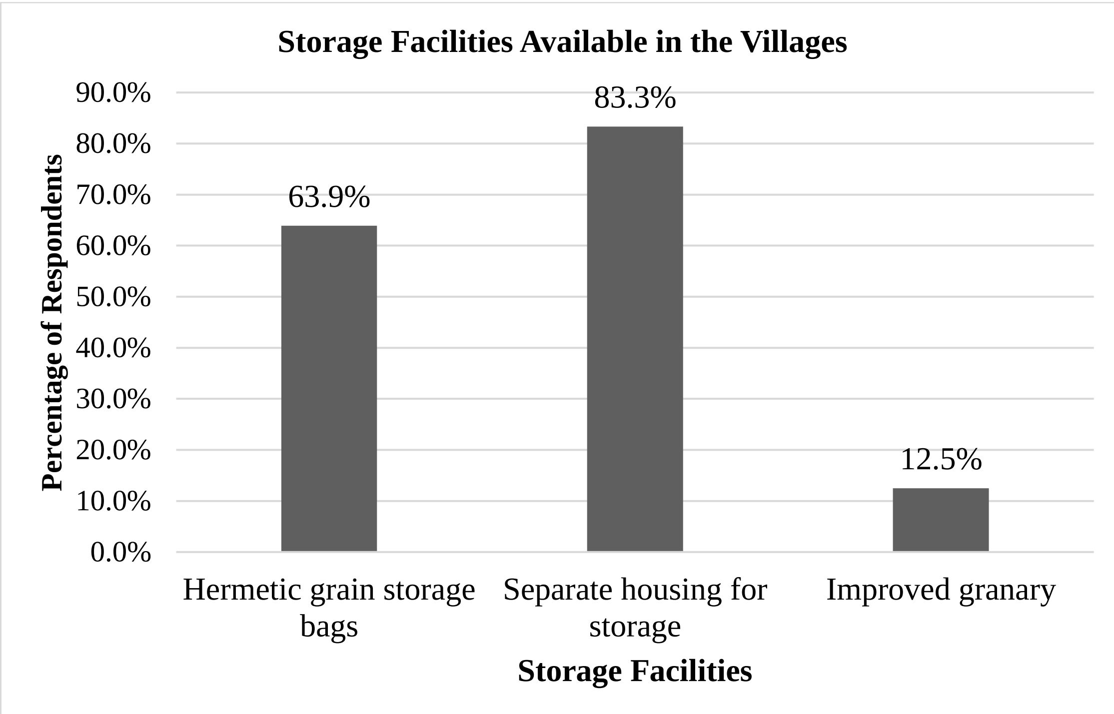
How Farmers Store Foods to Prevent Aflatoxin Contamination during Storage



Of the study respondents, 83.3% reported that they have separate housing for storage, 63.9% indicated that hermetic grain storage silos are available in their villages as improved storage facilities, and 12.5% improved granaries (Figure 4.10).

Figure 4.10

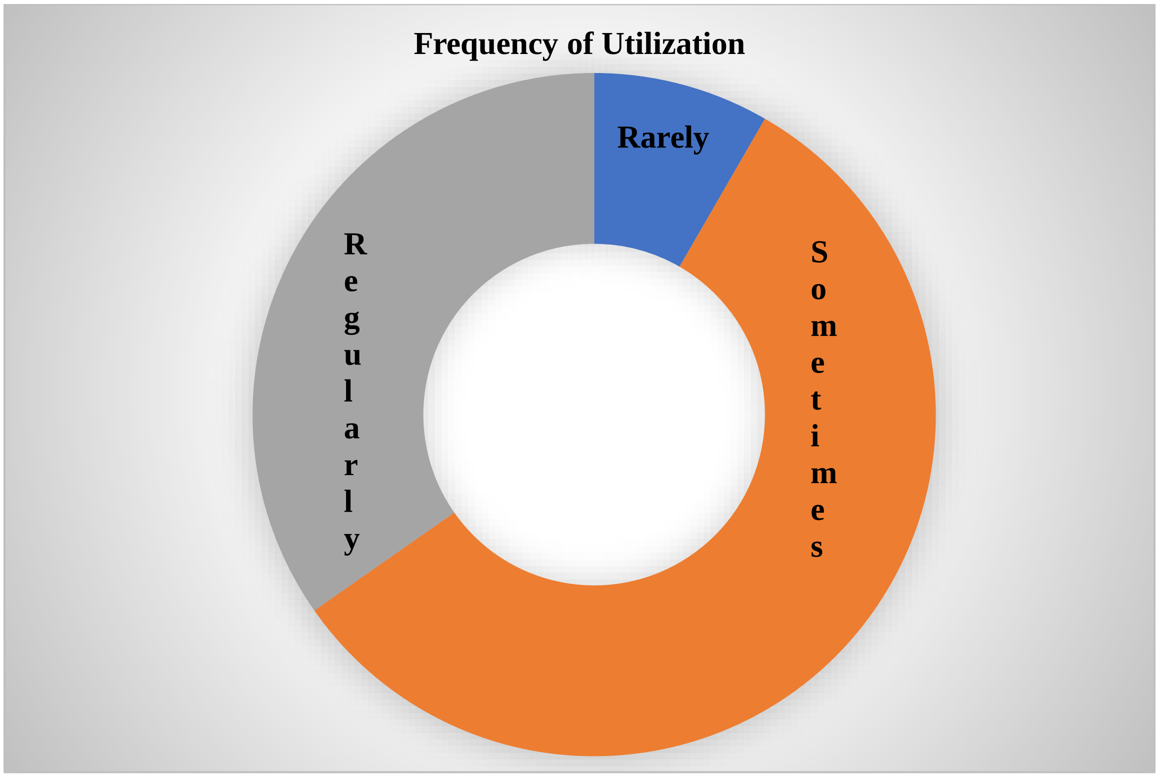
Types of Improved Storage Facilities Available



On how often these improved storage facilities are used; 57% of the farmers reported sometimes using them, 35% often use them and 8% rarely use them (Figure 4.11). Observations made during the study found out that some farmers do not use the recommended stores for their crops and sometimes use floors and living houses. Some have no suitable stores while others are unwilling to use them. Most farmers stored their harvested produce in polypropylene bags, and not in the recommended hermetic grain storage bags, due to the high cost of the hermetic bags. Awareness on what type of bag was appropriate for what time (duration) of storage was lacking among the farmers.

Figure 4.11

Frequency of Utilization of Storage Facilities



4.6 Factors Contributing to Aflatoxin Contamination of Cereals Used as Staple Foods

Figure 4.12 shows what the farmers mentioned as factors that encouraged the contamination of aflatoxins in foods. From the farmers' responses, the factor that mostly encouraged contamination of aflatoxin was not drying cereals and grains to safe moisture content (98.2%). Other significant factors were rains during the harvesting season (60.7%), pest infestation (57.1%), poor sanitation practices in handling grains and cereals (51.8%), late harvesting (14.3%), and physical damage of cereals and grains (12.5%).

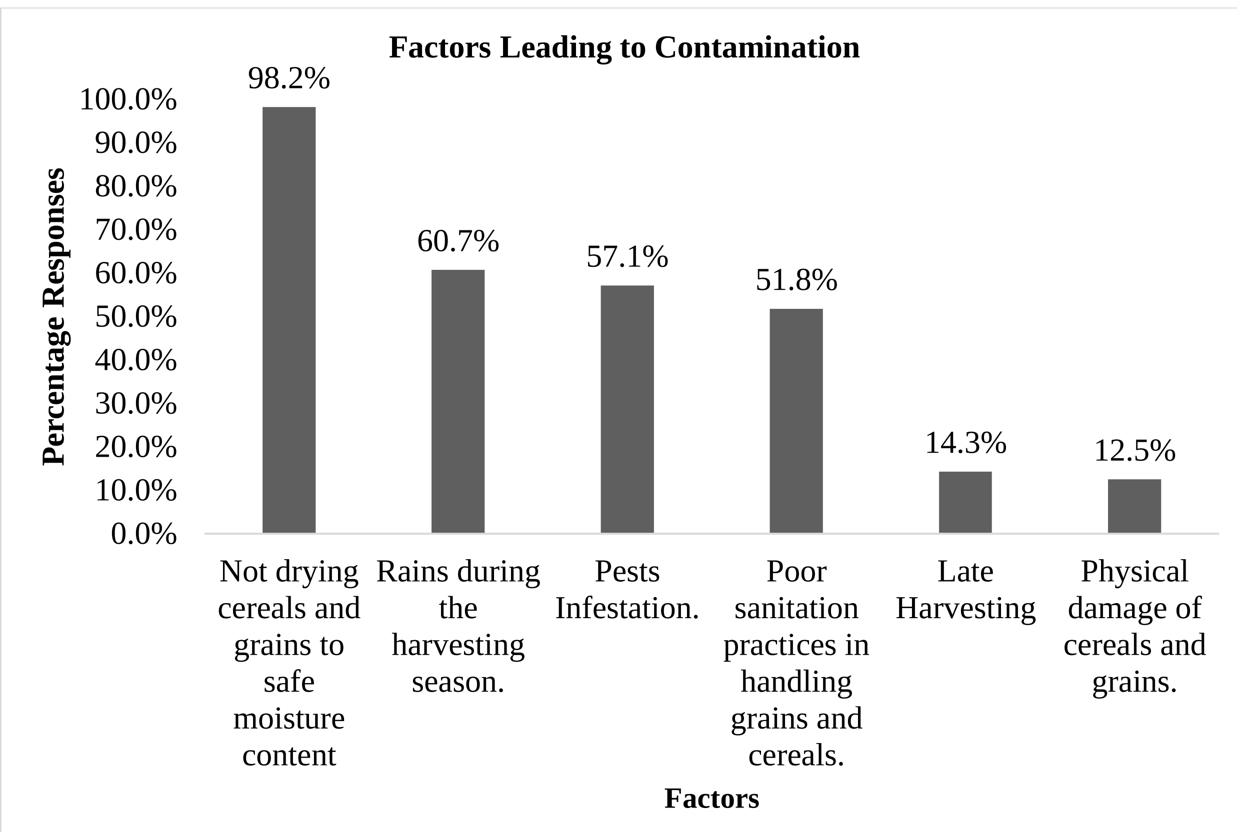
The unpredictable weather nowadays was a concern to the farmers who reported that their mature crops were usually rained on when ready for harvest and during drying and this increased the chances for aflatoxin contamination. Drying of the cereals and grains reduces the moisture content consequently inhibiting the growth of fungi which leads to aflatoxin production and the resultant contamination. The physical damage to the cereals and grains increases the chances of the mycotoxin's penetration thus the growth of fungi which leads to aflatoxin production. Poor sanitation practices when handling the cereals and grains leads to soiling of the crops resulting in fungal contamination and aflatoxin production.

A similar study conducted on probable aspects which escalate the growth of fungal toxic compounds in maize in Kenya found out that ideal circulation of air was the major the challenge experienced with the traditional storage structures forcing the farmers to dry their crops for extended periods of time before storing them. The same study established that the main influence of aflatoxin contamination in maize was the storage of maize at varying temperatures and moisture content. Lengthy storage periods encouraged the growth of mycotoxins producing fungi. This growth was also encouraged by the accumulation of insects' infestation which is common during extended storage periods. In addition, the study found out that the transportation of the maize from the farms to the market through the different stakeholders in the transport chain is sometimes done in adverse climatic conditions e.g., the rains which provided the opportunity for the growth of moulds consequently leading to mycotoxins contamination of the maize (Moturi, 2008).

From the farmers' responses, it was evident that the farmers do not have adequate information on what encourages contamination of aflatoxins in foods. During the samples collection, several observations were made which confirm the above responses from the study respondents. These observations were common across the two regions and included: the use of dirty sacks or containers for collection and transport of the crops after harvesting, drying the crops on bare ground/soil exposing the crops to dirt and other contaminants, some of the crops were harvested early due to lack of food or due to the farmers being afraid of destruction from wild animals, sorting was not done to remove the infected crops, crops were not cleaned and sorted to remove damaged crops and foreign matters before storage, and piling of harvested crops for long periods of time in traditional granaries prior to shelling/threshing or drying which increased the risk of fungal growth. This was also evidenced in the region in 2019 and 2020 during the locust's invasion when majority of the farmers panicked and harvested their crops from their farms some of which were not mature and other were not well dry.

Figure 4.12

Factors Encouraging the Contamination of Aflatoxins in Foods



The storage facilities at the market centers were not well ventilated and protected from entry of rodents and pests. Some of the storage structures lacked wooden pallets to raise the storage bags with the store owners not arranging the bags properly for aeration by having distances between bags and away from the walls. Such findings differs from the results of research conducted by Strosnider et al. (2006) who indicated that cereals and grains are ideally stored off the ground placed on wooden pallets in stores with adequate ventilation to prevent moisture increase and attack by pests and rodents during storage. During the discussions with the study respondents, most of them reported that they used the shelling machines propelled by tractors.

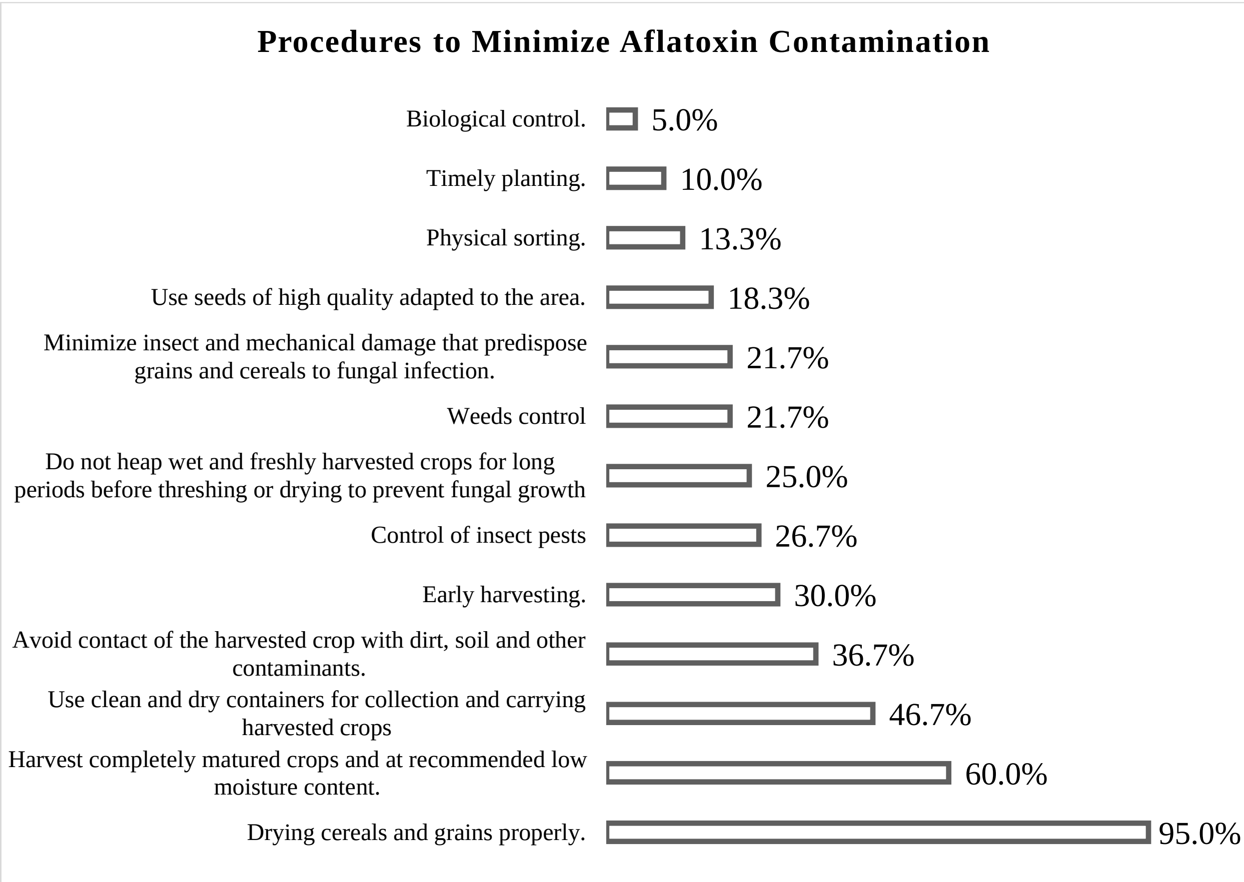
These shelling machines have the capacity to cause physical damage to the cereals and grains if not well calibrated to suit the different varieties of cereals and grains. The resultant broken cereals provide routes for the penetration of aflatoxin producing fungi. These observations were like the findings of Kang'ethe (2011) where he conducted the situation analysis of the maize value chain in Kenya and recommended the standardization of these shelling machines for the farmers to effectively mitigate this problem. Sorting and selection of grains and cereals after shelling is rarely done by most of the farmers in the region which increases aflatoxin infestation during storage. Nearly all the study respondents (95%) supported the drying of cereals and grains properly as a method to minimize aflatoxin contamination (Figure 4.13).

Other significant methods supported included: harvesting of completely matured crops at recommended low moisture content (60%), use of clean and dry containers for collection and carrying harvested crops (46.7%), and avoiding contact of harvested crop with dirt, soil, and other contaminants (36.7%). These findings are also like the findings of Kang'ethe (2011) where he reported that majority of the maize farmers in Kenya dry their produce on the ground on canvas to avoid contact with the soil. The study revealed that on many occasions the farmers dry the maize along the roads or in open fields and in such cases, soil is brown onto the dried maize though being on the canvas. This practice is also very common in Tharaka-Nithi County. The dust brown on the cereals by the wind or by the vehicles passing by could be containing fungal spores which are easily introduced to the cereals thus increasing the chances of aflatoxin contamination.

Discussions and observations made during the households' visits and assessment of the cereal bulking stores corroborated the above findings that the farmers do not have adequate information and do not practise Good Agricultural Practices (GAP) necessary for prevention of aflatoxin contamination. Information on modern technologies e.g., the new biocontrol product called Aflasafe being recommended by the Department of Agriculture to fight aflatoxin contamination was lacking in almost all the interviewed farmers. This confirms the reports that nearly all farmers in Kenya are not aware of biocontrols recommended to protect the crops from the harmful effects of aflatoxin (Ngotho, 2019). Even though a lot of research has been conducted on technologies that can minimize aflatoxin contamination especially in maize in Kenya, most of the research findings are not disseminated to the farmers. This underlies the need for the Government through the Department of Agriculture to conduct more sensitizations for the farmers on biocontrol technologies.

Figure 4.13

Procedures to Minimize Aflatoxin Contamination in Food



Farmers should be encouraged to adopt these modern technologies e.g., Aflasafe which when embraced by the farmers allows them a simple and safe way of guarding their produce both in the farms and in the stores after harvesting. Findings of a similar research conducted in in Meru, Embu and Tharaka-Nithi Counties which are hotspots of aflatoxin by Hoffmann et al. (2018) showed that production risk was the main barrier to the acceptance of food safety technologies. The farmers who were the main study respondents felt that the use of these food safety technologies increased the production costs of crops either consumed locally at the household level or sold (Hoffmann et al., 2018). Another good agronomic practice that was lacking in the region is timely planting which was only mentioned by 10% of the study respondents.

When farmers' plant at the right time, their crops escapes drought stress, and diseases while in the farm. Nearly all farmers did not have access to the seasonal calendar to enable them to choose the correct planting time. Crops that are planted at the right time grow healthy and can fight diseases and pests. However, when the crops are planted early, they mature during the rains, and this increases the chances of aflatoxin contamination. The risk of infestation by Aspergillus flavus increases when crops grow under stress and when the wrong inputs e.g., fertilizers are applied without regards to the soil types and not in a timely manner. Physical sorting of the dried cereals and grains to remove the diseased grains was not commonly done in the region during drying and this facilitates contamination during storage as verified by only 13.3% % of the interviewed farmers being aware of sorting as one of the procedures that can minimize aflatoxin contamination during storage.

Most of the farmers in the region did not use seeds of high quality adapted to the area. This was only reported by 18.3% of the study respondents' who were aware that the lack of use of certified seeds adapted to the region results in crops stress increasing the chances of aflatoxin contamination. Most of the farmers in the region do not procure good quality and certified seeds from agro-dealers or approved outlets in the County during the planting of cereals and grains. The farmers also do not contact the Agricultural Field Extension workers for information on which seed varieties do better in the two regions. The farmers thus use their previously harvested and stored cereals and grains as the planting material increasing the chances of aflatoxin contamination which is common in home-stored cereals and grains. Insects and mechanical damage of the cereals and grains predisposes the crops to fungal infection.

Pests and insect's invasion increases the rate of fungal penetration. Damage by insects provides routes for fungal invasion which was mentioned by only 21.7% of the interviewed farmers.

Only 21.7% of the study respondents had information that lack of weed control increases the risks of aflatoxin contamination. Weeds compete for nutrients and water with the crops causing nutrients and water stress which increases the rate of fungal colonization and aflatoxin accumulation. Therefore, weeding must be done in a timely manner to reduce this competition either manually or by using herbicides. Another practice that was common in the area after harvesting the cereals and grains, was the heaping of wet and freshly harvested crops for long periods before threshing or drying to prevent fungal growth. This was only mentioned by 25% of the study respondents because majority of the farmers heaped the harvested crops in the farm or at home for the crops to dry before storage. This was done irrespective of the fact that some of the crops had been lying on the ground for extended periods in the farms with some already attacked by pests increasing the chances of contamination. The findings are comparable to a research conducted by Moturi (2008) which observed that one common post-harvest practice in Kenya is that majority of the farmers cut and pile their matured maize crops placing them on fences or trees and leave them to dry naturally. This encourages the extended periods of drying the crops and exposes them to the unfavorable weather conditions e.g., the rains which encourages the occurrence of mycotoxins (Moturi, 2008).

Timely harvesting decreases aflatoxin contamination. Only 30% of the study respondents were aware that delayed harvesting increases the chances of mycotoxins and pests' infestation, and destruction by birds.

Few farmers in the region do not harvest their crops immediately after they mature and at recommended low moisture content which increases the risk of contamination as was mentioned by only 60% of the study respondents. When the crops are mature, they have a specific moisture content and certain distinct characteristics that minimize post-harvest losses. Some of the farmers because of lack of storage facilities let their crops remain in the farms for extended periods of time to completely dry. This practice increases the risks of losses through pests, birds and rodents' attacks, and the crops may fall to the ground exposing them to dirt, soil and other contaminants which increase the risk of aflatoxin infestation. The findings are comparable to a research conducted by Moturi (2008) on the factors responsible for contamination of maize in Kenya which revealed that the pre- and post-harvest practices are the main factors encouraging this contamination. The study observed that most of the farmers leave their matured maize crops to dry naturally in the farms for extended periods of time. During these extended drying periods, the maize is unprotected to the undesirable weather conditions, prone to the attack of insects and pests and the growth of moulds all which influence the contamination.

Observation made during the study showed that some farmers were not drying their cereals and grains on tarpaulins or mats but were doing it on the bare ground. This was evidenced by only 36.7% of the farmers who indicated that avoiding contact of the harvested crop with dirt, soil and other contaminants decreases the risks of contamination. These findings reveal that majority of the farmers were not privy to the information that Aspergillus flavus lives in the soil and drying the cereals and grains on the soil increases the risk of the contamination because the crops are in contact with the soil. Hygienic agronomic practices are vital to minimize the contamination. This was only mentioned by 46.7% of the farmers who indicated that the use of clean and dry containers for collection and carrying harvested crops from the farms to the drying and storage facilities is a good agricultural practice.

Other observations done by the researcher during the study includes: The type of soils in most of the areas in the two Sub-Counties was sandy soils which are more likely to support fungal growth and crop invasion due to water stress. Tillage was also not done properly by majority of the farmers. Lack of tillage makes the soils to have high populations of aflatoxigenic fungi than properly deep tilled land. Another agronomic practice common in the region was lack of crop residue management. Most farmers left crops residue on the farms increasing the populations of aflatoxigenic fungi in the soil. There was also lack of water conservation measures leading to water stress. Water stress reduces the plants’ ability to resist fungal infections and affects biosynthetic process increasing aflatoxin production and accumulation. High temperatures experienced in the areas and low rainfall increases pre-harvest contamination. Majority of the farmers did not practice crop rotation. Growing of the same crop each season increases the rate of fungal invasion and aflatoxin accumulation. Majority of the farmers lacked adequate information on proper storage procedures and periods. Some farmers had grains stored for lengthy periods of time, others were mixing the newly harvested cereals and grains with the old crops. The reasons given for this practice was that in seasons when there is bumper harvests of the cereals in the region the farmers did not get good market prices for their produce. The next season crop was harvested before the older one was sold or consumed by the farmers meaning that the cereals were stored for extended periods of time.

4.7 Summary of the Findings

The main cereals used as staple foods among households in Tharaka-Nithi included: maize, pearl millet, sorghum, cow peas, and green grams. However, with the excessive temperature and humidity experienced in the County, these cereals' structure ideal substrates for aflatoxin-producing fungi. Overall, aflatoxin contamination in 25.8% of sampled cereal and grains was above the legal threshold of 10ppb Kenyan standards with 17.2% of cereals and grains exceeding the established human tolerance levels of greater than 20ppb that cause symptomatic aflatoxicosis. The findings indicated that pearl millet and sorghum were least affected by aflatoxin with maize being the most affected. The aflatoxin contamination levels of almost half (44.4%) of the market samples was greater than the Kenyan tolerable limits.

Based on the Chi-Square test for association, it was evident that the level of aflatoxin in all the cereals and grains sourced from the households and markets was associated with the type of cereals and grains (p-value 0.001, which was less than 0.05 at 95% Confidence level). Therefore, cereals and grains levels of contamination differed as they were exposed. Based on the results from the t-Test of equality of means, the difference was not significant (p-value for Maize= 0.89, Sorghum= 0.47 and Pearl Millet=0.64). Thus, the mean level of aflatoxin in the cereals and grains in the two Sub-Counties did not differ. Levene's Test for Equality of Variances showed that there is no statistically significant difference between the variability of conditions in sorghum and pearl millet collected in the households and those from the marketplaces (p-value for sorghum=0.157 and pearl millet=0.893). However, for maize, the analysis showed that there is a statistical significance (0.02) in the variability on the mean of aflatoxin levels of samples collected from the two places.

The t-Test for Equality of Means, showed that the difference between the means of the level of aflatoxin in the cereals in the two places of collection was not statistically significant (p-value for maize=0.294, sorghum=0.422 and pearl millet=0.918, all of which are greater than 0.05). Thus, there was no difference in mean level of aflatoxin in the cereals and grains collected from the marketplaces and households. Taking into consideration, the mean of level aflatoxin levels of cereals and grains sourced from the households and those from marketplaces, the mean level of aflatoxin for maize sourced from the marketplaces was higher as compared to those sourced from households. While the mean level of aflatoxin in sorghum and pearl millet sourced from the marketplaces was lower as compared to the ones sourced from households.

The main players and stakeholders in the cereals and grains value chains in the County included: farmers, farmer groups, community-based organizations, cereals and grain traders, aggregators, transporters, posho millers, consumers (community and institutions) and the government departments (Health, Agriculture and Trade) responsible for enforcing the aflatoxin regulatory standards. The awareness levels on aflatoxin contamination among the study respondents was at 84.7%. Majority of the farmers were aware of aflatoxin as a dangerous poison found in cereals and grains especially that are not properly dried to safe moisture content. However, detailed information on the nature, formation, effects, prevention, and control of aflatoxins was scanty and inconsistent. In general, there was low or lack of awareness on aflatoxin contamination. Most of the farmers lacked adequate information on mitigation procedures which underlies the need for stepping up the awareness and sensitizations to manage aflatoxin contamination. The study also found out that the adoption of the recommended technologies to mitigate aflatoxin contamination was low despite their availability in the County.

This was because of the farmers' perception that the adoption will increase the production costs and because of the farmers' inadequate knowledge on aflatoxin contamination. The proposed sensitizations of farmers will encourage them to try out the new management practices accessible in the County towards mitigation of aflatoxin contamination. The study findings indicated a limited number of County Officers trained on aflatoxin management. These Officers were also too few in the region and only brought out aflatoxin messages when contamination was detected. For effective control of aflatoxin contamination, it is vital that all local staffs are well trained on aflatoxin management.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

Mycotoxins are organic compounds of microfungi that adulterate majority of the recurrently eaten crops globally. Amongst the mycotoxins, aflatoxins are the most harmful and poisonous. These poisonous substances originate from the Aspergillus genera. Aflatoxins are especially problematical in dry and hot climates. Aflatoxin contamination is aggravated by pests, drought, delayed harvest, poor post-harvest handling and inadequate drying. Instant loss of life can happen to both people and animals after consumption of foods adulterated with excessive amounts of aflatoxins. Immune suppression because of steady worsening of health and damage to the liver ensue from prolonged exposure to low amounts of aflatoxins. Stunting in children has been associated with exposure to aflatoxins. Aflatoxins B1, B2, G1, and G2 are found in plant derived food. Animal source foods contain M1 and M2 type of aflatoxins. The most lethal type of aflatoxin is B1 and is linked to cancer of the liver in humans. There are recognized approaches developed to mitigate aflatoxin contamination even though these mycotoxins are invisible. Kenya has established aflatoxin contamination limits at 10 parts per billion (ppb) in foods eaten by people and food eaten by animals. Maize sourced from households during one of the major aflatoxicosis outbreaks in Kenya was found to be contaminated by aflatoxins with reported magnitudes of 1000ppb. Studies conducted in the country especially in the Eastern Province of Kenya show that cereals and grains including maize, millet, sorghum, groundnuts, and cashew nuts are the crops commonly affected by aflatoxin contamination. The main purposes of this study was to evaluate the levels of aflatoxin in cereals commonly used as staple foods sourced from households and marketplaces, to evaluate households' awareness on suitable conditions for storage of foods regarding aflatoxin contamination, and to identify factors contributing to aflatoxin contamination.

5.2 Conclusions

Aflatoxin contamination needs to be prioritized to ensure that appropriate mitigation measures are put in place to minimize its detrimental health effects. Context-specific information on the aflatoxin occurrence in the County makes it possible to document vulnerable staple crops, their level of toxicity in the County and make recommendations to reduce aflatoxin contamination. The study findings showed that the socio-demographic characteristics e.g., education levels have an impact on the farmers' awareness on aflatoxin contamination and its mitigation. The study findings showed that majority of the farmers (56.9%) had low education. Further analysis of the study findings showed that higher educational level increased the chances of the farmers to have heard about aflatoxins. Therefore, this shows that educational levels had substantial influence on aflatoxin contamination awareness. This implies that when majority of the population are educated in a community, awareness levels are increased and trickle-down effect of information in the community is enhanced.

The study demonstrated that the main cereals used as staple foods among households in Tharaka-Nithi County i.e., sorghum, pearl millet, and maize are contaminated with aflatoxins. These staple foods are widely utilized in households in the County putting the health of majority of the population in danger. Magnitudes ranging from <1 to 30.79ppb was reported in maize tested which was the most affected crop. The other cereals were also contaminated with sorghum appearing to be less commonly contaminated than maize and pearl millet. All the maize samples collected from each of the sampling markets had aflatoxin levels above 10ppb. Statistical procedures confirmed that level of aflatoxin in the cereals and grains was associated with the type of cereals and grains. Furthermore, there was no contrast in mean aflatoxin amounts in cereals and grains in the two study areas and in the cereals and grains collected from the market and households. However, the mean level of aflatoxin in all cereals and grains sourced from the households in Tharaka-North was slightly higher as compared to the ones sourced from Tharaka-South. Therefore, this study recommends the promotion of dietary diversity in the households through nutrition education to reduce this exposure. Almost half (44.4%) of the market samples contained aflatoxin amounts greater than the Kenyan tolerable limits with 5.6% of the samples collected from the households having aflatoxin levels greater than >30ppb.

Analysis of the data for the source of cereals and grains eaten at home revealed that majority of the households (98.6%) were consuming homegrown cereals and grains. The households were also purchasing other cereals and grains not produced in the study area from the markets for households' consumption as reported by 93.1% of the interviewed households. Therefore, this underlies the need for control of cereals and grains trading and marketing routes in the County with mechanisms for traceability of the grains during trading, processing, and marketing to minimize aflatoxin contamination among all the stakeholders in the cereals and grains value chains. This finding points to awareness problems in the markets and therefore the researcher recommends the development of market led strategies for aflatoxin management in the County and the training of Public Health Officers and Agricultural Extension Officers on grain inspection skills such as sampling, grading, moisture determination and aflatoxin testing.

The study found out that the farmers' awareness levels on aflatoxin contamination was at 84.7%. Majority of the study respondents could identify the cereals and grains prone to aflatoxin contamination. However, the farmers' knowledge and skills on aflatoxin management was rather low. This lack of information resulted to low adoption of the Good Agricultural Practices (GAP) necessary for prevention of aflatoxin contamination by the farmers in the region. The farmers reported that the adoption of the modern technologies would increase their cost of production. Therefore, the researcher recommends the need for stepping up farmers' sensitizations for improved households' awareness on suitable conditions for storage of foods, awareness on dangers of aflatoxins in foods, and cost-effective and successful post-harvest and storage techniques.

This can only be achieved through enhancing the capacity of the County Field Extension Workers and Public Health Officers to effectively support farmers. These key messages can be disseminated through the already organized farmers' community-based organizations dealing with cereals and grains marketing in the region. For improved health, financial security, and national food security, all the potential grains and cereals investors i.e., Government authorities, farmers, processors, millers, traders, research institutes need to work together in the overall management of aflatoxin.

5.3 Recommendations

5.3.1 Recommendations on Research Findings

The study recommends the following to the County:

- Designate mitigation of aflatoxin contamination in cereals and grains used as staple foods among households.
- Training of agriculture officers, public health officers, farmers, farmer groups, aggregators, and all the other stakeholders in the cereals value chain on aflatoxin management.
- Develop awareness messages for posters, radio and stakeholder meetings in appropriate language and scope. Considering that the education and literacy levels amongst most farmers, traders, transporters, millers, and consumers is generally very low, it is recommended that awareness messages to be developed need to be simple, clear, precise, in vernacular language and within the relevant scope.
- Enhancement of the County technical capacity for aflatoxin diagnosis by providing the target Sub-Counties with moisture meters, equipment for cereals and grain grading, rapid aflatoxins testing equipment and testing kits, and establish basic testing laboratories in the County Headquarters.
- Develop market-led strategies for aflatoxin management by identifying and undertaking feasibility studies of opportunities for the involvement of local businesses, entrepreneurs, artisans, farmer groups, women groups, youth groups, private-public partnerships in management of aflatoxin contamination.
- Provide targeted subsidizations and trainings to farmers on technologies aimed at aflatoxin contamination mitigation in the regions prone to this contamination. This can include

provision of diagnostic kits to the smallholder farmers to check the moisture content of the cereals and grains and for the presence of aflatoxin at the farm level.

- Improve the existing building structures within the markets and give proper guidelines regarding storage for better food storage facilities within the open-air markets.
- Consider the construction of storage facilities which can be used by the whole community in the major cereals and grains production areas.
- Explore mechanisms of assessing foods which enter in the markets regarding contamination to help curb spread of aflatoxin from one region to another.
- Conduct more sensitizations to the farmers to promote the use of appropriate storage bags e.g., the hermetic bags instead of the polypropylene bags.
- Working closely with the Kenya Agricultural and Livestock Research Organization (KALRO), the Kenya Seed Company and the Kenya Farmers Association, develop strategies of reaching out to as many farmers as possible to encourage the adoption of the biocontrol product (Aflasafe) to combat aflatoxin.

  This could be done through encouraging the farmers to buy Aflasafe as they buy their seeds and other planting materials from the agro-vets at subsidized costs.

5.3.2 Recommendations for Further Research

The study recommends another research to be done on:

- Analysis of other aflatoxin susceptible foods produced in the region and sold in the markets e.g., groundnuts, cashew nuts, eggs, and milk etc.
- Studies to verify whether there is an affiliation between aflatoxin toxicity and child development.

- Studies to verify whether there is a relationship between the current rising cases of cancer and aflatoxin contamination.
- Disposal and management of aflatoxin-contaminated agricultural produce to ease the burden of managing large stocks of aflatoxin-contaminated cereals and grains.
- Production of seeds that are resistant to aflatoxins. These should be region specific with the ability to mitigate aflatoxin contamination.

These are based on the issues that emerged in the process of the research but could not be investigated since they were not of primary concern when the study was set up.

REFERENCES

Ashraf, N., Gine, X., & Karlan, D. (2009). Finding missing markets (and a distributing epilogue): Evidence from an export crop adoption and marketing intervention in Kenya. *American Journal of Agricultural Economics*, 91(4), 973-990. https://www.jstor.org/stable/20616255?seq=1

Azziz-Baumgartner, E., Lindblade, K., Gieseker, K., Rogers, H. S., Kieszak., S, Njapau, H., Schleicher, R., McCoy, L. F., Misore, A., & DeCock, K. (2005). Case-control study of an acute aflatoxicosis outbreak in Kenya-2004. *Environmental Health Perspectives*, 113(12), 1779-1783. https://pubmed.ncbi.nlm.nih.gov/16330363/

Bankole, S. A., & Mabekoje, O. (2004). *Occurrence of aflatoxins and fumonisins in preharvest maize from South-Western Nigeria*. Department of Biological Sciences, Olabisi Onabanjo University. 21(3), 251-255. https://pubmed.ncbi.nlm.nih.gov/15195472/

Bennett, J. W. (2010). An overview of the genus Aspergillus In: Machida, M., & Gomi, K. (Eds.), *Aspergillus Molecular Biology and Genomics*. (pp. 1-17) *Caister Academic Press.* http://www.sciepub.com/reference/100565

Bii, B. (2020, March 19). Aflatoxin levels in maize worry Kebs and millers. *The Daily Nation*. https://www.nation.co.ke/news/Aflatoxin-levels-in-maize.../index.html

Brown, R. L., Chen, Z. Y., Menkir, A., Cleveland, T.E., Cardwell, K., & Kling, J. (2001). Resistance to aflatoxin accumulation in kernels of maize inbreds selected for ear rot resistance in West and Central Africa. *Journal of Food Protection*, 64(3), 396-400. https://pubmed.ncbi.nlm.nih.gov/11252487/

Carvajal, M., & Castillo, P. (2007). Effects of aflatoxins contaminating food on human health. Tropical biology and conservation management. 7, 1-6. *Encyclopedia of life support systems (EOSLS).* https://www.eolss.net/sample-chapters/c20/e6-142-tpe-11.pdf

Centers for Disease Control and Prevention (CDC). (2004). Outbreak of aflatoxin poisoning-Eastern and Central provinces, Kenya, January-July 2004. *MMWR Morbidity and Mortality Weekly Report*, 53(34), 790-793. https://pubmed.ncbi.nlm.nih.gov/15343146/

Chulze, S. N. (2010). *Strategies to reduce mycotoxin levels in maize during storage*. National Library of Medicine. 27(5), 651-657. https://pubmed.ncbi.nlm.nih.gov/20349375/

Creppy, E. E. (2002). *Update of survey, regulation, and toxic effects of mycotoxins in Europe*. National Library of Medicine. 127 (1-3), 19-28. https://pubmed.ncbi.nlm.nih.gov/12052637/

Daniel, J. H., Lewis, L. W., Redwood, Y. A., Kieszak, S., Breiman, R. F., Flanders, W. D., Bell, C., Mwihia, J., Ogana, G., Likimani, S., & Straetemans, M. (2011). Comprehensive assessment of maize aflatoxin levels in Eastern Kenya, 2005-2007. *Environmental Health Perspectives*, 119 (12), 1794-1799. https://pubmed.ncbi.nlm.nih.gov/21843999/

Deshpande, S. S. (2002). *Handbook of food toxicology*. Marcel Dekker. https://www.worldcat.org/title/handbook-of-food-toxicology/oclc/61667793

Dosman, D. M., Adamowicz, W. L., & Hrudey, S. E. (2001). Socioeconomic determinants of health and food safety related risk perceptions. *National Library of Medicine*. 21(2), 307-314. https://pubmed.ncbi.nlm.nih.gov/11414539/

East African Standard. (2018, April). Disposal and alternative use of aflatoxin contaminated food. *East African Community Policy Brief 8*. https://www.eac.int/documents/category/aflatoxin-prevention-and-control.

Food and Agriculture Organization. (2002). *Good agricultural practices*. *(Second version)*. Food and Agriculture Organization. http://www.fao.org/tempref/docrep/fao/010/ag856e/ag856e00

Fung, F., & Clark, R. F. (2004). Health effects of mycotoxins: A toxicological overview. *Journal of Toxicology: Clinical Toxicology*. 42(2), 217-234. https://pubmed.ncbi.nlm.nih.gov/15214629/

Glanz, K., Rimer, B. K., & Lewis, F. M. (Eds.). (2002). *Health Behavior and Health Education* (3rd ed). Jossey-Bass. https://iums.ac.ir/files/hshe-soh/files/beeduhe_0787996149(1).pdf

Goncalez, E., Pinto, M. M., Manginelli, S., Felicio, J. D. (2004). Dairy cows poisoned with cottonseed meal naturally contaminated with aflatoxins. *Ciencia Rural*, 34 (1), 171-174. https://www.feedipedia.org/node/15908

Gong, Y. Y., Routledge, M., Kimanya, M. E., Musoke, G., Nelson, F., Sonoiya, S., & Manyong, V. (2015). *Building an aflatoxin safe East African community*. (*Technical policy paper 8)* Consultative Group on International Agricultural Research (CGIAR), 8, 1-30. https://aflasafe.com/wp-content/uploads/pdf/TPP-8-Aflatoxin-Standards-for-Food.pdf

Gong, Y. Y., Turner, P. C., Hall, A. J., & Wild, C. P. (2008). Aflatoxin exposure and impaired child growth in West Africa. *CAB International*. https://www.researchgate.net/publication/285963651

Gong, Y. Y., Hounsa, A., Egal, S., Turner, P. C., Sutcliffe, A. E., & Hall, A. J. (2004). Post weaning exposure to aflatoxin results in impaired child growth: A longitudinal study in Benin, West Africa. *Environmental Health Perspectives*, 112(13), 1334-1338. https://pubmed.ncbi.nlm.nih.gov/15345349/

Gong, Y. Y., Egal, S., Hounsa, A., Turner, P. C., Hall, A., Cardwell, K. F., & Wild, C. P. (2003). Determinants of aflatoxin exposure in young children from Benin and Togo, West Africa: The critical role of weaning. *International Journal of Epidemiology*, 32(4), 556-562. https://pubmed.ncbi.nlm.nih.gov/12913029/

Gong, Y. Y., Cardwell, K., Hounsa, A., Egal, S., Turner, P. C., & Hall, A. J. (2002). Dietary aflatoxin exposure and impaired growth in young children from Benin and Togo: cross sectional study. *The British Medical Journal*, 325(7354), 20-21. https://pubmed.ncbi.nlm.nih.gov/12098724/

Hell, K., & Mutegi, C. (2011). Aflatoxin control and prevention strategies in key crops of Sub-Saharan Africa. *African Journal of Microbiology Research*, 5 (5), 459-466. https://www.researchgate.net/publication/322579678

Hell, K., Cardwell, K. F., Setamou, M., & Poehling, H. (2000). The influence of storage operations on maize aflatoxin contamination. *Journal of Stored Products Research*, 36(4), 365-382. https://pubmed.ncbi.nlm.nih.gov/10880814/

Hochbaum, G. M. (1958). *Public participation in medical screening programs: A Socio psychological study*, *(PHS Publication no 572)* Department of Health Education and Welfare. https://openlibrary.org/books/OL6264119M

Hoffmann, V., Kariuki, S., Pieters, J., & Treurniet, M. (2018). *Can markets support smallholder adoption of a food safety technology*? *(Project note)* International Food Policy Research Institute. 1-17. http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/133044

Hoffmann, V., Jones, K. & Leroy, J. (2015). Mitigating aflatoxin exposure to improve child growth in Eastern Kenya: study protocol for a randomized controlled trial. *Trials* 16(1), 1-7. https://doi.org/10.1186/s13063-015-1064-8

International Agency for Research on Cancer (IARC). (2012). *Chemical agents and related occupations*. https://www.ncbi.nlm.nih.gov/books/NBK304416/

International Food Policy Research Institute (IFPRI). (2011). *Spread of aflatoxins in Kenya*. https://www.ifpri.org/sites/default/files/News%20Release/pressrel20110113.pdf

Kabale, N. (2019, February 5). Kebs blacklists 2 more companies in aflatoxin purge. *The Daily Nation*. https://www.nation.co.ke/business/Kebs.two.aflatoxin../index.html

Kang'ethe, E. K., Gatwiri, M., Sirma, A. J., Ouko, E. O., Musoti-M. 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 Quality and Safety Journal*, 1(2), 131-137. https://academic.oup.com/fqs/article/1/2/131/3854890

Kang'ethe, E. (2011). *Situation analysis: Improving food safety in the maize value chain in Kenya*. Food and Agriculture Organization. http://erepository.uonbi.ac.ke/bitstream/handle/11295/86436/Kang'ethe_Situation%20analysis%20%20improving%20food%20safety%20in%20the%20maize%20%20value%20chain%20in%20Kenya.pdf?sequence=1

Kenya National Bureau of Statistics. (KNBS). (2019). *Kenya Population and Housing Census Volume 1: Population by County and Sub-County*. https://www.knbs.or.ke/?wpdmpro=2019-kenya-population-and-housing-census-volume-i-population-by-county-and-sub-county

Khlangwiset, P., Shephard, G.S., & Wu, F. (2011). Aflatoxins and growth impairment. A Review. *Critical Reviews in Toxicology*, 41(9), 740-755. https://pubmed.ncbi.nlm.nih.gov/21711088/

Kimanya, M. E., Shirima, C. R., Magoha, H., Shewiyo, D. H., De Meulenaer, B., Kolsteren, P., & Gong, Y.Y. (2014). Co-exposures of aflatoxins with deoxynivalenol and fumonisins from maize based complementary foods in Rombo, Northern Tanzania. *Food Control*, 41(1), 76-81.https://doi.org/10.1016/j.foodcont.2013.12.034

Kumar, P., Mahato, D. K., Kamle, M., Mohanta, T. K., & Kang, S. G. (2017). Aflatoxins: A global concern for food safety, human health, and their management. *Front Microbial*, 7(468), 1-10. https://pubmed.ncbi.nlm.nih.gov/28144235/

Leroy, J. L., Wang, J. S., & Jones, K. (2015). *Exposure to aflatoxins greater among poor in Eastern Kenya. (Project note 3)* International Food Policy Research Institute. https://www.ifpri.org/publication/exposure-aflatoxins-greater-among-poor-eastern-kenya

Leroy, J. L., Jones, K., & Hoffmann, V. (2013). *Mitigating Aflatoxin exposure to improve child growth in Eastern Kenya*. International Food Policy Research Institute. https://www.researchgate.net/publication/285658162

Lewis, L., Onsongo, M., Njapau, H., Schurz-Rogers, H., Luber, G., & Kieszak, S. (2005). Aflatoxin contamination of commercial maize products during an outbreak of acute aflatoxicosis in eastern and central Kenya. *Environmental Health Perspectives*, 113(12), 1763-1767. https://pubmed.ncbi.nlm.nih.gov/16330360/

Liu, Y. & Wu, F. (2010). Global burden of aflatoxin-induced hepatocellular carcinoma: A risk assessment. *Environmental Health Perspectives*, 118(6), 818-824. https://pubmed.ncbi.nlm.nih.gov/20172840/

Magoha, H., Kimanya, M., De Meulenaer, B., Roberfroid, D., Lachat, C., & Kolsteren, P. (2014). Association between aflatoxin M1 exposure through breast milk and growth impairment in infants from Northern Tanzania. *World Mycotoxin Journal*, 7(3), 277-284. https://www.wageningenacademic.com/doi/abs/10.3920/WMJ2014.1705

Mahdavi, R., Nikniaz, L., Arefhosseini, S. R., & Vahed, J. M. (2010). Determination of aflatoxin M1 in breast milk samples in Tabriz-Iran. *Maternal Child Health Journal*, 14(1), 141-145. https://pubmed.ncbi.nlm.nih.gov/19093194/

Marechera, G., & Ndwiga, J. (2014). Farmer perceptions of aflatoxins management strategies in Lower Eastern Kenya. *African Agricultural Technology Foundation Journal*, 6 (12), 382-394. http://www.academicjournals.org/app/webroot/article/article1416313420

Milicevic, D. R., Skrinjar, M., & Baltic, T. (2010). Real and perceived risks for mycotoxins contamination in foods and feeds: Challenges for food safety control. *Toxins (Basel)*, 2(4), 572-592. https://www.researchgate.net/publication/51785380

Ministry of Agriculture, Livestock and Fisheries. (2017). *Climate risk profile for Tharaka Nithi County*. *Kenya county climate risk profile series*. (MoALF), Kenya. https://ccafs.cgiar.org/publications/climate-risk-profile-tharaka-nithi-county-kenya-county-climate-risk-profile-series#.X2mENqBR2Uk

Moturi, W. K. (2008). Factors likely to enhance mycotoxin introduction into the human diet through maize in Kenya. *African Journal of Food, Agriculture, Nutrition and Development*, 8 (3), 1-13. https://www.researchgate.net/publication/272458603

Murimi, J. (2019, October 15). Sh 200m for aflatoxin battle in Counties. *The Daily Nation*. https://www.nation.co.ke/business/Farmers-to...aflatoxin.../index.html

Musasia, P. (2020, February 6). Maize flour with high aflatoxin levels destroyed in Nakuru. *The Daily Nation*. https://www.nation.co.ke/counties/nakuru/index.html

Mwanda, O. W., Otieno, C. F., & Omonge, E. (2005). Acute aflatoxicosis: Case Report. *East African Medical Journal*, 82(6), 320-324. https://www.ajol.info/index.php/eamj/article/view/9305

Mwihia, J. T., Straetemans, M., Ibrahim, A., Njau, J., Muhenje, O., & Guracha, A. (2008). Aflatoxin levels in locally grown maize from Makueni District, Kenya. *East African Medical Journal*, 85(7), 311-317. https://pubmed.ncbi.nlm.nih.gov/19133419/

Mwinzi, B. (2019, November 10). Five maize flour brands banned over cancer exposure. *The Daily Nation*. https://www.nation.co.ke/news/-Kebs-bans-5-maize-flour-brands-cancer-/1056-5343594-i472ud/index.html

National Drought Management Authority. (NDMA). (2018). *Short Rains Assessment (SRA) for Tharaka-Nithi County*. https://www.ndma.go.ke/index.php/resource-center/category/7-tharaka-nithi

Nation Reporter. (2020, January 30). Kebs withdraws 17 maize flour brands over high Aflatoxin. *The Daily Nation.* https://www.nation.co.ke/news/Kebswithdraws/index.html

Negash, D. (2018). A review of aflatoxin: Occurrence, prevention, and gaps in both food and feed safety. *Journal of Nutritional Health & Food Engineering.* 8(2), 190-197. https://www.researchgate.net/publication/327397386

Ng'ang'a, J., Mutungi, C., Imathiu, S., & Affognon, H. (2016). Effect of triple-layer hermetic bagging on mould infection and aflatoxin contamination of maize during multi-month on-farm storage in Kenya. *Journal of Stored Products Research*, 69(5), 119-128. https://www.researchgate.net/publication/305991352

Ngindu, A., Johnson, B. K., Kenya, P. R., Ngira, J. A., Ocheng, D. M., Nandwa, H., Omondi, T. N., Jansen, A. J., Ngare, W., & Kaviti, J. N. (1982). Outbreak of acute hepatitis caused by aflatoxin poisoning in Kenya. *Lancet*, 319(8285), 1346-1348. https://pubmed.ncbi.nlm.nih.gov/6123648/

Ngotho, A. (2019, April 8). Kenya an aflatoxin hotspot. *The Star*. https://www.the-star.co.ke/news/2019-04-08-new-aflatoxin-product-available-farmers-unaware/

Njapau, H., Nelson, F., Wesonga, T., & Manyong, V. (2015). Aflatoxin: Alternative uses and disposal systems. *International Institute for Tropical Agriculture (IITA)*. 9, 21-27. https://aflasafe.com/wp-content/uploads/pdf/TPP-9-Aflatoxin-Alternative-Uses-and-Disposal.pdf

Nutbeam, D., & Harris, E. (2004). Theory in a nutshell: A practical guide to health promotion theories. *NSW*. https://www.amazon.co.uk/Theory-Nutshell-Guide-Health-Promotion/dp/0074713329

Ogumo, E. (2019, November 16). Key steps in curbing aflatoxin in maize. *The Daily Nation*. https://www.nation.co.ke/business/seedsofgold/...aflatoxin.../index.html

Okoth, S. A., & Ohingo, M. (2004). Dietary aflatoxin exposure and impaired growth in young children from Kisumu District, Kenya: Cross-sectional study. *African Journal of Health Sciences*, 11(1-2) 43-54. https://pubmed.ncbi.nlm.nih.gov/17298116/

Ono, E.Y., Sasaki, E.Y., Hashimoto, E. H., Hara, L. N., Correa, B., Itano, E.N., Sugiura, T., Ueno, Y., & Hirooka, E.Y. (2002). Post-harvest storage of corn: effect of beginning moisture content on mycoflora and fumonisin contamination. *Food Additives and Contaminants*, 19(11), 1081-1090. https://pubmed.ncbi.nlm.nih.gov/12456280/

Panariti, E. (2001). Seasonal variations of aflatoxin M1 in the farm milk in Albania. *Arh Hig Rada Toksikol*, 52 (1), 37-41. https://www.unboundmedicine.com/medline/citation/11370297/

Pitt, J. I., Wild, C. P., Gelderblom, W., Miller, J., Riley, R. T., Wu, F., & Bann, R. A. (2012). *Improving public health through mycotoxin control (Publication No. 158*) International Agency for Research on Cancer. https://scabusa.org/pdfs/IARC_STP-158_Dec-2012.pdf

Reddy, K. R. N., Reddy, C. S., & Muralidharan, K. (2009). Potential of botanicals and biocontrol agents on growth and aflatoxin production by Aspergillus flavus infecting rice grains. *Food Control*, 20 (2),173-178. https://www.sciencedirect.com/science/article/abs/pii/S0956713508000996

Ricci, K., Girosi, F., Tarr, P., Lim, Y., Mason, C., Hughes, J., Seidlein, V., Agosti, J., & Guerrant, R. (2006). Reducing stunting among children: The potential contribution and diagnostics. *Nature*, 444(1), 29-38. https://pubmed.ncbi.nlm.nih.gov/17159892/

Sadeghi, N., Oveisi, M., Jannat, B., Hajimahmoodi, M., Bonyani, H., & Jannat, F. (2009). Incidence of aflatoxin M1 in human breast milk in Tehran, Iran. *Food Control*, 20(1), 75-78. https://www.researchgate.net/publication/229412401

Schmale, D. G. (1998). *Mycotoxins in crops. A threat to human and domestic animal health*. Virginia Polytechnic Institute and State University, Ames, US. https://www.apsnet.org/edcenter/disimpactmngmnt/topc/Mycotoxins/Pages/default.aspx

Scudamore, K. A. (2008). Fate of fusarium mycotoxins in the cereal industry: Recent UK studies. *World Aflatoxin Journal*, 1 (13), 315-323. https://www.wageningenacademic.com/doi/abs/10.3920/WMJ2008.x034

Shephard, G. S. (2003). Aflatoxin and food safety. *Journal of Toxicology*, 22(2&3), 267-286. https://www.tandfonline.com/doi/abs/10.1081/TXR-120024094

Shephard, G. S. (2004). Mycotoxins worldwide: current issues in Africa. In: Barug, D., Van Egmond, H. P., Lopez-Garcia, R., Van Osenbruggen, W. A., & Visconti, A. *Meeting the mycotoxin menace.* (pp.81-88). *Wageningen Academic Publishers*, https://www.tandfonline.com/doi/full/10.1080/02652030701567442

Shirima, C. P., Kimanya, M. E., Kinabo, J. L., Routledge, M. N., Srey, C., Wild, C. P., & Gong, Y. Y. (2013). Dietary exposure to aflatoxin and fumonisin among Tanzanian children as determined using biomarkers of exposure. *Molecular Nutrition and Food Research*, 57(10), 1874-1881. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4044922/

Shuaib, F. M., Jolly, P. E., Ehiri. J. E., Yatich, N., Jiang, Y., Funkhouser, E., Peterson, S. D., Wilson, C., Wang, O., & Williams, J. H. (2010). Association between birth outcomes and Aflatoxin B1 biomarker blood levels in pregnant women in Kumasi Ghana. *Tropical Medicine and International Health,* 15(2), 160-167. https://pubmed.ncbi.nlm.nih.gov/20003033/

Sirma, A. J., Lindahl, J. F., Makita, K., Senerwa, D., Mtimet, N., Kang'ethe, E. K., & Grace, D. (2018). The impacts of aflatoxin standards on health and nutrition in sub-Saharan Africa. The case of Kenya. *Global Food Security*, 18(1), 57-61. https://www.sciencedirect.com/science/article/pii/S2211912418300531

Sirma, A. J., Senerwa, D. M., Grace, D., Makita, K., Mtimet, N., Kang'ethe, E. K., & Lindahl, J. F. (2016). Aflatoxin B1 occurrence in millet, sorghum, and maize from four agro-ecological zones in Kenya. *African Journal of Food, Agriculture, Nutrition and Development*, 16(3), 1-13. https://www.ajol.info/index.php/ajfand/article/view/141925

Strosnider, H., Azziz-Baumgartner, E., Banziger, M., & Bhat, R.V. (2006). Workgroup report: Public health strategies for reducing aflatoxin exposure in developing countries. *Environmental Health Perspectives*, 114(12), 1898-1903. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1764136/

Turner, P. C. (2013). The molecular epidemiology of chronic aflatoxin driven impaired child growth. *Scientifica* , 2013(3), 1-22. https://www.hindawi.com/journals/scientifica/2013/152879/

Turner, P. C., Collinson, A. C., Cheung, Y. B., Gong, Y., Hall, A. J., & Prentice, A. M. (2007). Aflatoxin exposure in utero causes growth faltering in Gambian infants. *International Journal of Epidemiology*, 36(5), 1119-1125. https://pubmed.ncbi.nlm.nih.gov/17576701/

Turner, P. C., Sylla A., Gong, Y. Y., Diallo, M. S., Sutcliffe, A. E., Hall, A. J., & Wild, C. P. (2005). Reduction in exposure to carcinogenic aflatoxins by postharvest intervention measures in west Africa: a community-based intervention study. *Lancet*, 365(9475),1950-1956. https://pubmed.ncbi.nlm.nih.gov/15936422/

United States Agency International Development (USAID). (2012). *Aflatoxin: A synthesis of the research in health, agriculture, and trade*. https://pdf.usaid.gov/pdf_docs/PBAAH773.pdf

United States Agency International Development (USAID). (2018). *Household Monitoring Exercise in Tharaka-Nithi County*. The Kenya Nutrition and Health Program plus (NHPplus).

Wagacha, J. M., & Muthoni, J. W. (2008). Mycotoxin problem in Africa: Current status, implications to food safety and health and possible management strategies. *International Journal of Food Microbiology*, 124(1), 1-12. https://pubmed.ncbi.nlm.nih.gov/18258326/

Walker, S., Jaime, R., Kagot, V., & Probst, C. (2018). Comparative effects of hermetic and traditional storage devices on maize grain: Mycotoxin development, insect infestation and grain quality. *Journal of Stored Product Research*, 77(3), 34-44. https://www.sciencedirect.com/science/article/abs/pii/S0022474X17301443

Wild, C. P., & Gong, Y. Y. (2010). Mycotoxins and human disease: a largely ignored global health issue. *Oxford Academic*, 31(1), 71-82. https://europepmc.org/article/pmc/pmc2802673

Wild, C. P. (2007). Aflatoxin exposure in developing countries: The critical interface of agriculture and health. *Food and Nutrition Bulletin*, 28(2), 372-380. https://pubmed.ncbi.nlm.nih.gov/17658084/

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. *The American Journal of Clinical Nutrition*, 80(5), 1106-1122. https://pubmed.ncbi.nlm.nih.gov/15531656/

World Health Organization (WHO). (2003). *Global strategy for infant and young child feeding*. https://www.who.int/nutrition/publications/gs_infant_feeding_text_eng.pdf

World Health Organization (WHO). (2015). *WHO estimates of the global burden of foodborne diseases*. http://www.who.int/foodsafety/areas_work/foodborne-diseases/ferg/en/

Wu, F., Stacy, S. L., & Kensler, T. W. (2013). Global risk assessment of aflatoxins in maize and peanuts: Are regulatory standards adequate protective? *Toxicological Sciences*, 135(1), 251-259. https://pubmed.ncbi.nlm.nih.gov/23761295/

Wu F., Bhatnagar D., Bui-Klimke T., Carbone I., Hellmich R., & Munkvold, G. (2011). Climate change impacts on mycotoxin risks in US maize. *World Mycotoxin Journal*. 4(1), 79-93. https://lib.dr.iastate.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=1127&context=ent_pubs

Wu, F. (2001). *Aflatoxin in foods*. (*Risk assessment studies report No. 5)*. Food and Environmental Hygiene Department (FEHD), Hong Kong. https://www.cfs.gov.hk/english/programme/programme_rafs/files/report.pdf

Wu, Q., Jezkova, A., Yuan, Z., Pavlikova, L., Dohnal, V., & Kuca, K. (2009). Biological degradation of aflatoxins. *Drug Metabolism Reviews*, 41(1), 1-7. https://www.researchgate.net/publication/26281199

Zarba, A., Wild, C. P., Hall, A. J., Montesano, R., Hudson, G. J., & Groopman, J. D. (1992). Aflatoxin M1 in human breast milk from the Gambia, West Africa. *Carcinogenesis*, 13(5), 891-894. https://pubmed.ncbi.nlm.nih.gov/1587004/

APPENDICES

Appendix I : General Informed Consent Form

Purpose

Iam Victor Mwiti Marangu, a postgraduate student in the school of medicine and health sciences of Kenya Methodist University. I am conducting a research to evaluate the aflatoxin levels in cereals used as staple foods among households in Tharaka-Nithi County. These include sorghum, pearl millet, and maize. In this study I request for your cooperation by allowing me to pick samples of grains and cereals from your household/store for analysis.

This study will provide crucial information whether these major cereals are contaminated with aflatoxin. The study is also expected to provide important information regarding the households' awareness on suitable conditions for storage of foods, awareness on dangers of aflatoxins in foods, and cost-effective and successful post-harvest and storage techniques. This information will be key in raising awareness of and attention to the various effects of aflatoxin contamination, as well as advancing awareness, and use of sustainable low-cost storage and post-harvest practices to reduce this contamination.

Procedures

If you agree to take part in the research, the following will be anticipated of you:

- Sign the consent form.
- Allow the researcher to collect samples of grains and cereals from your household/store.

- Participate in the personal interview with the researcher.
- You are free to withdraw from this research study at any time before the samples are analyzed.

Duration

- The researcher will take approximately 1 hour of your time to conduct the personal interview and collect the samples for analysis from your household/store.
- Feedback on the outcome of the analysis will be shared with the County after receiving the results from the testing laboratories approximately a month after sample collection.

Confidentiality

- All the information on the analysis results will be treated with strict confidence and under no circumstances will they be attributed to any household or store.

Risks

- To maintain good relationships with rural communities, it will be vital that the households are not left with the impression that their food is being stolen when samples are taken. Before sampling is done, you as the household's head will sign this consent form to willingly agree to take part in this research.
- The researcher will provide you with adequate explanations that are in your best interest to cooperate in the study.
- You will not be charged any cost incurred on the analysis of the samples.
- You will not be penalized or held liable if any sample collected from your household/store is found to be contaminated.

- The analysis results will under no circumstances be attributed to any household or store.

Benefits

- This study will provide crucial information whether these major cereals are contaminated with aflatoxin.
- The study is also expected to provide important information regarding the households' awareness on suitable conditions for storage of foods, awareness on dangers of aflatoxins in foods and cost-effective and successful post-harvest and storage techniques.
- This information will be key in raising awareness of and attention to the various effects of aflatoxin contamination, as well as advancing awareness and use of sustainable, low-cost storage and post-harvest practices to reduce this contamination.

Withdrawal

- You are free to withdraw from this research study at any time before the samples are analyzed.

Concerns

- You are free to contact me, Victor Mwiti Marangu **@ 0721 – 684 099 / 0735 – 194 004** for answers to any questions you may have about the research or related matters.
- You can also visit the County Agriculture, Water, Irrigation, Livestock and Fisheries or the Public Health and Sanitation Departments for clarifications or support to any concerns that you may have about the research or related matters.

Consent

I Mr. / Mrs. / Miss …………………………………………………………... am the legal owner of this household/bulking store located

at/ known as………………...

I hereby willingly agree to take part in this research. The researcher has explained to me the value of my participation in the research.

I understand that my participation in this study will not affect my family/business in any way.

I also recognize that all the data collected from my household / bulking store will be handled with the strictest confidence.

Name of the Household/Store Owner…………………..…………………………………………

Sign………………………………………………………………. Date………………………

Name of Witness ………………………………………………………………………………

Sign………………………………………………………. Date…………………………...

Recruitment and Selection of Subjects

- With the guidance of the Crop Officers and Village Extension Officers, villages that cultivate the crops of interest and households that could have some stock of the crops will be selected.
- One village will be selected from each Sub-Location. In each village four households will be selected. The samples from these households will be combined to one sample according to the ‘coning and quartering’ principle.
- All four of the samples will be put together on a pile and afterwards divided in four equal parts. Two parts that will be diametrical towards each other will be combined until an average of 1 kg is collected. Thus, the sample of 1 kg will represent the composition of the whole village.
- The researcher will assume homogeneity and hence the idea that Tharaka-South and Tharaka-North Sub-Counties will be treated as one homogeneous population.
- A total of 24 sorghum samples, 24 pearl millet samples and 24 maize samples will be collected from 24 villages located in all the Sub-Locations. Marimanti Ward comprises: Kaguma, Gituma, Rukenya, Kamatungu, Kirangare, Kithingiri, Marimanti, Ibote, Kanyuru, Kathuura, Karocho, and Turima Sub–Locations. Gatunga Ward comprises: Comprises Kamwathu, Gatunga, Kanjoro, Kamaguna, Twanthanju, and Kathangachini sub–Locations. Mukothima Ward comprises: Irunduni, Mauthini, Ntoroni, Mukothima, Thiiti, and Kirundi Sub–Locations.

- Three major open-air markets within Tharaka-North and Tharaka-South Sub-Counties will be selected based on size. These markets will be chosen because they serve a large population of the County and are main source of commodities for even the small markets.
- Cereals and grain samples will be drawn from these markets. Sample quantities of 1kg of each cereal type will be obtained from each market. The researcher will therefore have 72 samples from the households and 9 samples of the cereals from the markets.

Appendix II : Research Questionnaire

General Objective

To analyze cereals used as staple foods among households – sorghum, pearl millet, and maize for aflatoxin contamination in Tharaka-Nithi County, Kenya.

Specific Objectives

i. To analyze the levels of aflatoxin in the cereals used as staple foods among households – sorghum, pearl millet, and maize from two major grain producing areas of Tharaka-Nithi County.

ii. To assess the difference in levels of aflatoxin in cereals sourced from households and marketplaces in Tharaka-Nithi County.

iii. To evaluate households' awareness on suitable conditions for storage of foods regarding aflatoxin contamination.

iv. To identify factors contributing to aflatoxin contamination of cereals used as staple foods among households – sorghum, pearl millet, and maize from two major grain producing areas of Tharaka-Nithi County.

Introduction

Iam Victor Mwiti Marangu, a postgraduate student in the school of medicine and health sciences of Kenya Methodist University. I am conducting a research to evaluate the aflatoxin levels in cereals used as staple foods among households in Tharaka-Nithi County. These include sorghum, pearl millet, and maize. In this study I request for your cooperation by allowing me to pick samples of grains and cereals from your household for analysis. This study will provide crucial information whether these major cereals are contaminated with aflatoxin. The study is also expected to provide important information regarding the households' awareness on suitable conditions for storage of foods, awareness on dangers of aflatoxins in foods and cost-effective and successful post-harvest and storage techniques. This information will be key in raising awareness of and attention to the various effects of aflatoxin contamination, as well as advancing awareness and use of sustainable low-cost storage, and post-harvest practices to reduce this contamination.

Questionnaire to Assess Households' Awareness on Aflatoxin Contamination in Foods

Survey Information	**Response**
Village Name	
Household GIS Coordinates	
County Name	
Sub-County Name	
Ward Name	
Sub-Location Name	
Household Number	
Interviewer's Name	
Date of Interview (DD/MM/YY)	
Consent has been read and obtained	1 = Yes 2 = No **If NO END**
Interview Language	1 = English 2 = Kiswahili 3 = Other (Specify): ______________________

Start Time (Hrs.: Mins)	
Name of Household Head	
Sex of the Respondent	1 = Male 2 = Female
What is your highest level of education achieved?	1 = Primary Education 2 = Secondary Education 3 = College Level 4 = Vocational 99 = Other (Specify)______________________
What type of cereals/grains do you farm? (Tick all mentioned)	1 = Maize 2 = Finger Millet 3 = Pearl Millet 4 = Sorghum 5 = Beans 6 = Pigeon Peas 7 = Green Grams 8 = Cow Peas 9 = Groundnuts 10 = Cashew nuts 99 = Other (Specify)_______________________

What are the most important staples in this village? (List all mentioned)	
What is the source of cereals and grains currently being eaten by members in the household? (Tick all mentioned)	1 = Homegrown 2 = Purchased 3 = Relief (Government or NGOs) 99 = Other (Specify)____________
What are the amounts of homegrown cereals and grains that were produced in your farm during the current harvest? (Report the number of kilograms of all cereals and grains produced during the current harvest)	
Do you have other alternative sources of cereals and grains?	1 = Yes 2 = No
If yes, what are they? (List all mentioned)	
Have you heard about aflatoxins?	1 = Yes 2 = No
If yes, what are they? (List all mentioned)	

If yes, what are the properties of foods contaminated by aflatoxins? (Tick all mentioned)	1 = Moldy 2 = Discoloured 3 = Shriveled 4 = Rotting 99 = Other (Specify)_________
Which of the most important staples in this village are susceptible to aflatoxin contamination? (List all mentioned)	
Have you attended any training related to safe handling and storage of foods?	1 = Yes 2 = No
If yes, specify the type of training (workshop or seminar) (List all mentioned)	
Which organization or entity offered the training? (List all mentioned)	
Do poor storage conditions promote the presence of aflatoxins in foods?	1 = Yes 2 = No
How do you store your foods to prevent aflatoxin contamination during storage? (Tick all mentioned)	1 = Dry grains and cereals to safe moisture content. 2 = Minimize physical damage. 3 = Sorting.

	4 = Use sound sanitation practices in handling grain. 5 = Maintain store at low humidity and temperature. 6 = Keep out pests and insects from the storage. 7 = Do not overfill storage facilities. 8 = Periodically monitor stored grain, checking for pests, rodents, and increased temperatures. 9 = Ensure that the store is well-ventilated. 10 = Use clean and dry bags to store the cereals and grains and always place them on pallets. 99 = Other (Specify)____________
What types of improved storage facilities are available in this village? (Tick all mentioned)	1 = Hermetic grain storage bags 2 = Silos 3 = Separate housing for storage 4 = Improved granary 99 = Other (Specify)____________
How often are they used?	1 = Rarely 2 = Sometimes 3 = Often 99 = Other (Specify)____________

What encourages the contamination of aflatoxins in foods? (Tick all mentioned)	1 = Not drying cereals and grains to safe moisture content. 2 = Rains during the harvesting season. 3 = Physical damage of cereals and grains. 4 = Late Harvesting. 5 = Pests Infestation. 6 = Poor sanitation practices in handling grains and cereals. 99 = Other (Specify)____________
Mention examples of procedures that can be done to minimize aflatoxin contamination in food. (Tick all mentioned)	1 = Use seeds of high quality adapted to the area. 2 = Timely planting. 3 = Weeds control. 4 = Drying cereals and grains properly. 5 = Early harvesting. 6 = Harvest completely matured crops and at recommended low moisture content. 7 = Use clean and dry containers for collection and carrying harvested crops from the farms to the

	drying and storage facilities. 8 = Avoid contact of the harvested crop with dirt, soil, and other contaminants. 9 = Do not heap wet and freshly harvested crops for long periods before threshing or drying to prevent fungal growth. 10 = Minimize insect and mechanical damage that predispose grains and cereals to fungal infection. 11 = Physical sorting. 12 = Biological control. 13 = Control of insect pests. 99 = Other (Specify)____________
What is the importance of timely harvesting? (List all mentioned)	
Do farmers know/understand the importance of timely harvesting?	1 = Yes 2 = No
If yes, do they practice timely harvesting?	1 = Yes 2 = No
If they don’t practice timely harvesting, please mention the reasons.	

(List all mentioned)	
If they know the risks of aflatoxins, are they more likely to harvest in a timely fashion?	1 = Yes 2 = No
Are there local manufacturers of recommended drying bags, insecticides, and storage inputs? If yes, who and where are they located?	1 = Yes 2 = No 3 = Don't Know
How do farmers typically dry their crops in this village? (List all mentioned)	
Are hermetic grain storage bags recommended for grain storage?	1 = Yes 2 = No 3 = Don't Know
If yes, are they available and affordable?	1 = Available and affordable 2 = Available and not affordable 3 = Not Available 4 = Other (Specify)________

Does the Department of Agriculture in this County see it as its mandate to help rural communities use and access improved storage facilities?	1 = Yes 2 = No 3 = Don't Know
What are the responsibilities of the Department of Agriculture in the control of aflatoxin contamination? (List all mentioned)	
Can intake of foods with aflatoxins have adverse health implications?	1 = Yes 2 = No 3 = Don't Know
In your view, what are the barriers encountered in preventing and mitigating aflatoxins contamination? (List all mentioned)	
In your view, what opportunities exists that can be utilized in preventing and mitigating aflatoxins contamination? (List all mentioned)	
End Time (Hrs.: Mins)	

Appendix III: KeMU (SERC) Ethical Clearance for the Study

KENYA METHODIST UNIVERSITY

P. O. BOX 267 MERU - 60200, KENYA
TEL: 254-064-30301/31229/30367/31171

FAX: 254-64-30162
EMAIL: INFO@KEMU.AC.KE

23rd May 2019

KeMU/SERC/PHT/46/2019

Victor Mwiti Marangu
PHT-3-0577-1/2017
Kenya Methodist University

Dear Victor,

SUBJECT: ETHICAL CLEARANCE OF A MASTERS' DEGREE RESEARCH THESIS

Your request for ethical clearance for your Masters' Degree Research Thesis titled "Analysis of Cereal Based Infant and Young Child Complementary Foods-Sorghum, Pearl, Millet and Maize for Aflatoxin Contamination, A Case of Tharaka-Nithi County, Kenya." has been provisionally granted to you in accordance with the content of your research thesis subject to tabling it in the full Board of Scientific and Ethics Review Committee (SERC) for ratification.

As Principal Investigator, you are responsible for fulfilling the following requirements of approval:

1. All co-investigators must be kept informed of the status of the thesis.

2. Changes, amendments, and addenda to the protocol or the consent form must be submitted to the SERC for re-review and approval prior to the activation of the changes. The Thesis number assigned to the thesis should be cited in any correspondence.
3. Adverse events should be reported to the SERC. New information that becomes available which could change the risk: benefit ratio must be submitted promptly for SERC review. The SERC and outside agencies must review the information to determine if the protocol should be modified, discontinued, or continued as originally approved.
4. Only approved consent forms are to be used in the enrollment of participants. All consent forms signed by subjects and/or witnesses should be retained on file. The SERC may conduct audits of all study records, and consent documentation may be part of such audits.
5. SERC regulations require review of an approved study not less than once per 12rnonth period Therefore, a continuing review application must be submitted to the SERC in order to continue the study beyond the approved period. Failure to submit a continuing review application in a timely fashion will result in termination of the study, at which point new participants may not be enrolled and -currently enrolled participants must be taken off the study.

Please note that any substantial changes on the scope of your research will require an approval.

Thank You,

Dr. A. Warnachi
Chair, SERC

cc: Dean, RD&PGS

Appendix IV: NACOSTI Research Authorization

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone:+254-20-2213471,
2241349,3310571,2219420
Fax:+254-20-318245,318249
Email: dg@nacosti.go.ke
Website: www.nacosti.go.ke
When replying please quote

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No. **NACOSTI/P/19/20582/31074**

Date: **5th July, 2019.**

Victor Mwiti Marangu
Kenya Methodist University
P.O. Box 267- 60200
MERU.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Analysis of cereal-based infant and young child complementary foods – sorghum, pearl millet and maize for aflatoxin contamination: A case of Tharaka-Nithi County, Kenya."*** I am pleased to inform you that you have been authorized to undertake research in **Tharaka Nithi County** for the period ending **5th July, 2020.**

You are advised to report to **the County Commissioner, the County Director of Health Services, and the County Director of Education, Tharaka Nithi County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year of completion.** The soft copy of the same should be submitted through the Online Research Information System.

BONFACE WANYAMA.
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Tharaka Nithi County.

The County Director of Education
Tharaka Nithi County.

Appendix V: NACOSTI Research Permit

THIS IS TO CERTIFY THAT:
MR. VICTOR MWITI MARANGU
of KENYA METHODIST UNIVERSITY, NAIROBI CAMPUS, 0-60200 MERU, has been permitted to conduct research in *Tharaka-Nithi County*

on the topic: *ANALYSIS OF CEREAL-BASED INFANT AND YOUNG CHILD COMPLEMENTARY FOODS - SORGHUM, PEARL MILLET AND MAIZE FOR AFLATOXIN CONTAMINATION, A CASE OF THARAKA-NITHI COUNTY, KENYA.*

for the period ending:
5th July,2020

Permit No : NACOSTI/P/19/20582/31074
Date Of Issue : 5th July,2019
Fee Recieved :Ksh 1000

....
Applicant's Signature

....
Director General
National Commission for Science, Technology & Innovation

Appendix VI: ELISA Kit - Quality Control Certificate

SCAN for Total Aflatoxin

Package Insert

helica

Opened & standardized on 30/09/2019 Night By: Amy B.No: 03/19

QUALITY CONTROL CERTIFICATE

Kit Name	Catalog No.	Amount	Lot No.	Expiration
Total Aflatoxin Detection ELISA Kit, 96-wells	941AFL01M-96	96 wells	091319	10/2020

Component	Amount
Total Aflatoxin Microplate	96-wells
Total Aflatoxin Standards	6 vials
0.0 ng/mL	1.5 mL
0.2 ng/mL	1.5 mL
0.5 ng/mL	1.5 mL
1.0 ng/mL	1.5 mL
2.0 ng/mL	1.5 mL
4.0 ng/mL	1.5 mL
Total Aflatoxin HRP Conjugate	2 x 12 mL
TMB Substrate	12 mL
Stop Solution	12 mL
PBS-T Wash Buffer Powder	1 packet
Dilution Wells (Green)	96-wells

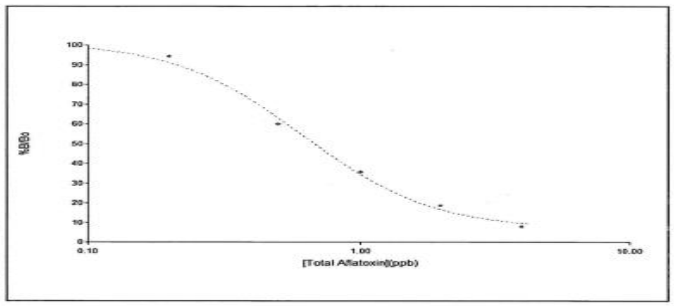


Figure 1 – Standard curve of this test kit

R^2-value:0.996

Absolute IC50:0.679

Standard (ng/mL)	%B/B0 Range	%B/B0	Mean OD	%CV
0	100	100	2.248	1.0
0.2	81 - 95	94	2.123	1.0
0.5	57 - 69	60	1.353	2.2
1.0	29 - 42	36	0.804	2.2
2.0	13 - 20	19	0.418	1.6
4.0	7 - 10	8	0.181	2.1

All standards were tested in triplicate.

I hereby certify that this kit's performance is within the expected parameters.

Signature/Title: Ryan Rosas / QC

Date: 09/13/2019

Appendix VII: Records of Households' Sample and Analysis Results Details

The Following Categories of Cereals and Grains Were Sampled from Households and Analyzed

Village Name	Latitude	Longitude	Sub-County	Ward	Sub Location	HH Head Name	Sample Name	Total Aflatoxin (ppb)
Magarini	S:0.1314	E:37.570	Tharaka-South	Marimanti	Kaguma	Elizabeth Gitonga	Maize	22.14
Rukenya	S:0.1150	E:37.541	Tharaka-South	Marimanti	Rukenya	Silas Muthomi	Maize	10.31
Karangi	S:0.939	E:37.5447	Tharaka-South	Marimanti	Kanyuru	Regina Kamene	Maize	26.45
Kasarani	S:0.847	E:37.5642	Tharaka-South	Marimanti	Karocho	Sharon Kanoti	Maize	<1
Kibung'a	S:0.433	E:37.558	Tharaka-South	Marimanti	Turima	Lucia Kamene	Maize	1.06
Kathuura	S:0.31	E:37.5444	Tharaka-South	Marimanti	Kathuura	Isabella Ruguna	Maize	29.59
Igumo	S:0.91	E:38.07	Tharaka-South	Marimanti	Kithingiri	Mary Wanjiku	Maize	29.04
Kamatungu	S:0.1041	E:37.5927	Tharaka-South	Marimanti	Kamatungu	Lilian Kainyu	Maize	<1
Mathiga	S:0.858	E:37.5817	Tharaka-South	Marimanti	Marimanti	Joseph Nguli	Maize	28.41
Nkararu	S:0.646	E:37.5545	Tharaka-South	Marimanti	Kirangare	Catherine Mwiti	Maize	<1
Gituma	S:0.1226	E:37.5739	Tharaka-South	Marimanti	Gituma	Julia Gatiria	Maize	20.73
Kithingiri	S: 0.1253	E:37.9043	Tharaka-South	Marimanti	Ibote	Salome Karimi	Maize	<1
Kaarani	S:0.1325	E:37.5654	Tharaka-South	Marimanti	Kaguma	Francis Mwithi	Sorghum	<1
Rukenya	S:0.1229	E:37.5436	Tharaka-South	Marimanti	Rukenya	Tarsila Karimi	Sorghum	<1
Kamigucwa	S:0.856	E:37.5421	Tharaka-South	Marimanti	Kanyuru	Samuel Kiunga Kunyia	Sorghum	<1
Gakunguguni	S:0.835	E:37.5532	Tharaka-South	Marimanti	Karocho	Dorcas Muthoni	Sorghum	<1
Mayarani	S:0.431	E:37.556	Tharaka-South	Marimanti	Turima	Joseph Mugao	Sorghum	1.24
Kandundu	S:0.31	E:37.5444	Tharaka-South	Marimanti	Kathuura	Moses John Mbugi	Sorghum	1.53
Igumo	S:0.91	E:38.07	Tharaka-South	Marimanti	Kithingiri	Rita Ciang'ombe	Sorghum	2.14
Kamatungu	S:0.1041	E:37.5927	Tharaka-South	Marimanti	Kamatungu	Muthengi Njeru	Sorghum	<1
Gituma	S:0.1226	E:37.5738	Tharaka-South	Marimanti	Gituma	James Gituma	Sorghum	6.95

Village Name	Latitude	Longitude	Sub-County	Ward	Sub Location	HH Head Name	Sample Name	Total Aflatoxin (ppb)
Kithingiri	S:0.645	E:37.5546	Tharaka-South	Marimanti	Ibote	Julius Kiranga	Sorghum	<1
Magundu	S:0.924	E:37.5826	Tharaka-South	Marimanti	Kirangare	Stephen Mwiti	Sorghum	<1
Mathiga	S:0.854	E:37.5811	Tharaka-South	Marimanti	Marimanti	Josphat Kinyua	Sorghum	<1
Kandundu	S:0.31	E:37.5444	Tharaka-South	Marimanti	Kathuura	Zaccheaus Kathiga	Pearl Millet	1.35
Kathuura	S:0.431	E:37.556	Tharaka-South	Marimanti	Turima	Patrick Mwithi	Pearl Millet	30.23
Rukenya	S:0.1229	E:37.5436	Tharaka-South	Marimanti	Rukenya	Simeon Kanyaru	Pearl Millet	<1
Rugucwa	S:0.0836	E:37.5531	Tharaka-South	Marimanti	Karocho	Lucy Nkuru	Pearl Millet	1.17
Kaguma	S:0.1325	E:37.5654	Tharaka-South	Marimanti	Kaguma	Mwithi Kagwiri	Pearl Millet	<1
Karangi	S:0.933	E:37.5445	Tharaka-South	Marimanti	Kanyuru	James Makunyi Kirebo	Pearl Millet	<1
Kamatungu	S:0.1041	E:37.5929	Tharaka-South	Marimanti	Kamatungu	Joseph Kiria	Pearl Millet	4.41
Igumo	S:0.92	E:38.08	Tharaka-South	Marimanti	Kithingiri	Joel Kithome	Pearl Millet	1.59
Ibote	S:0.646	E:37.5545	Tharaka-South	Marimanti	Ibote	Peter Mwenda	Pearl Millet	<1
Gituma	S:0.1226	E:37.5738	Tharaka-South	Marimanti	Gituma	Daniel Muriungi	Pearl Millet	<1
Mathiga	S:0.91	E:37.5816	Tharaka-South	Marimanti	Marimanti	Benard Mukumi	Pearl Millet	<1
Magondo	S:0.924	E:37.5827	Tharaka-South	Marimanti	Kirangare	Peter Muchoka	Pearl Millet	4.59
Gatunga	S:0.062	E:38.044	Tharaka-North	Gatunga	Gatunga	Julius Murithi	Maize	<1
Gacoroni	S:0.1145	E:38.312	Tharaka-North	Gatunga	Kamwathu	Jonathan Nyaga	Maize	<1

Village Name	**Latitude**	**Longitude**	**Sub-County**	**Ward**	**Sub Location**	**HH Head Name**	**Sample Name**	**Total Aflatoxin (ppb)**
Kamaguna	S:0.1030	E:38.822	Tharaka-North	Gatunga	Kamaguna	Josphat Maregi	Maize	<1
Kathangachini	S:0.538	E:38.96	Tharaka-North	Gatunga	Kathangachini	Edward Mugao	Maize	26.11
Gaceuni	S:0.22	E:38.1211	Tharaka-North	Gatunga	Twanthanju	Monica Kajira Mukembu	Maize	30.11
Iria-Ria-Mbogo	S:0.13	E:38.247	Tharaka-North	Gatunga	Kanjoro	Judith Karimi	Maize	26.85
Gatunga	S:0.62	E:38.043	Tharaka-North	Gatunga	Gatunga	Zipporah Gitonga	Sorghum	4.04
Gacoroni	S:0.1142	E:38.315	Tharaka-North	Gatunga	Kamwathu	Caroline Mukiri	Sorghum	<1
Kamaguna	S:0.1030	E:38.822	Tharaka-North	Gatunga	Kamaguna	Joseph Muembu	Sorghum	<1
Kathangachini	S:0.538	E:38.96	Tharaka-North	Gatunga	Kathangachini	Edward Mugao	Sorghum	<1
Gaceuni	S:0.22	E:38.1212	Tharaka-North	Gatunga	Twanthanju	Jackson Maregi	Sorghum	12.85
Manguru	S:0.147	E:38.127	Tharaka-North	Gatunga	Kanjoro	John Kinyua	Sorghum	<1
Gacoroni	S:1145	E:38.314	Tharaka-North	Gatunga	Kamwathu	Dorcas Kaburi	Pearl Millet	8.73
Maatha	S:0.111	E:38.512	Tharaka-North	Gatunga	Kamaguna	Mutiria Peter	Pearl Millet	20.49
Manguru	S:0.148	E:38.125	Tharaka-North	Gatunga	Kanjoro	Emmanuel Mugambi	Pearl Millet	1.20
Kathangachini	S:0.539	E:38.95	Tharaka-North	Gatunga	Kathangachini	Peter Makunyi	Pearl Millet	3.62
Gitugu	S:0.62	E:38.043	Tharaka-North	Gatunga	Gatunga	David Iguna Makembo	Pearl Millet	3.2
Twanthanju	S:0.22	E:38.1212	Tharaka-North	Gatunga	Twanthanju	Stanley Baiteru	Pearl Millet	<1
Mauthini	N:0.034	E:38.445	Tharaka-North	Mukothima	Mauthini	David Mwiti	Maize	29.25
Gatithini	N:0.31	E:38.08	Tharaka-North	Mukothima	Ntoroni	Luke Njagi	Maize	30.28
Kirundi	N:0.254	E:37.576	Tharaka-North	Mukothima	Kirundi	Lydia Karimi	Maize	<1
Kabuabua	S:0.600	E:37.5851	Tharaka-North	Mukothima	Irunduni	Jeremiah Gitonga	Maize	1.72

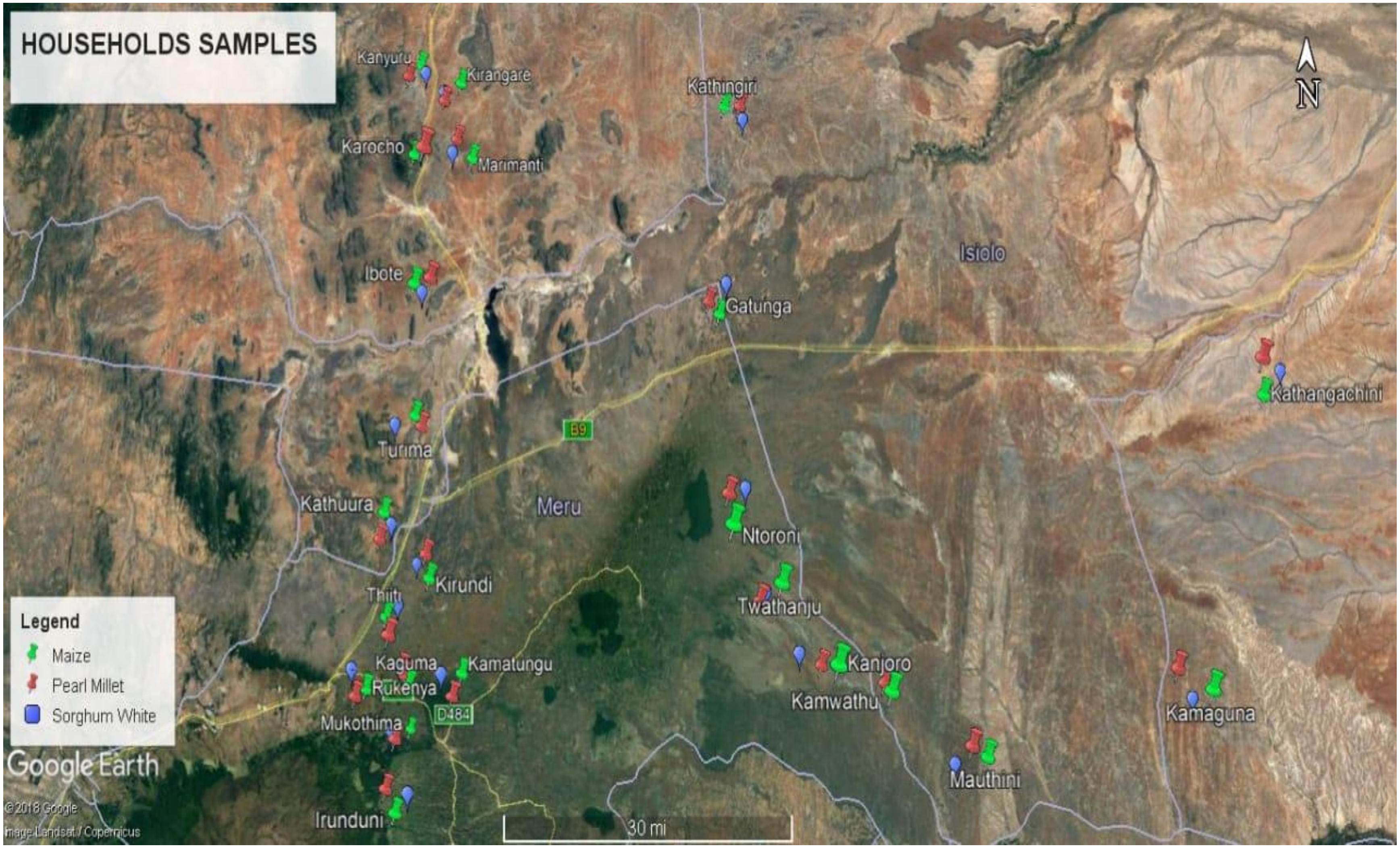
Village Name	Latitude	Longitude	Sub-County	Ward	Sub Location	HH Head Name	Sample Name	Total Aflatoxin (ppb)
Thiiti	N:0.127	E:37.5632	Tharaka-North	Mukothima	Thiiti	Josphat Muthengi	Maize	30.79
Kabutuko	N:0.047	E:37.5638	Tharaka-North	Mukothima	Mukothima	Japhet Kibaara	Maize	2.40
Iriani	N:0.012	E:37.593	Tharaka-North	Mukothima	Irunduni	Benard Njagi	Sorghum	1.49
Karanga	N:0.128	E:37.5620	Tharaka-North	Mukothima	Thiiti	Abel Mutugi	Sorghum	<1
Thanantu	N:0.048	E:37.5639	Tharaka-North	Mukothima	Mukothima	Jeremy Mwiti Kithuure	Sorghum	<1
Gakameni	N:0.035	E:38.444	Tharaka-North	Mukothima	Mauthini	Peter Kimathi	Sorghum	4.62
Gatithini	N:0.31	E:38.08	Tharaka-North	Mukothima	Ntoroni	Samuel Katheya Mugambi	Sorghum	<1
Kirundi	N:0.254	E:37.577	Tharaka-North	Mukothima	Kirundi	Benjamin Mwiti	Sorghum	<1
Makutano	N:0.035	E:38.445	Tharaka-North	Mukothima	Mauthini	Peter Nyaga	Pearl Millet	<1
Kirundi	N:0.254	E:37.577	Tharaka-North	Mukothima	Kirundi	Catherine Muthoni	Pearl Millet	3.82
Gatithini	N:0.32	E:38.07	Tharaka-North	Mukothima	Ntoroni	Josphat Muthiga	Pearl Millet	14.06
Kathangani	N:0.133	E:37.567	Tharaka-North	Mukothima	Thiiti	Erastus Nyamu Muchege	Pearl Millet	3.49
Kaboto	N:0.045	E:37.5640	Tharaka-North	Mukothima	Mukothima	Moses Mutugi Kinyua	Pearl Millet	2.14
Iriani	N:0.09	E:37.5939	Tharaka-North	Mukothima	Irunduni	Makembo Wa Kagwaya	Pearl Millet	<1

Appendix VIII: Records of Markets Sample and Analysis Results Details

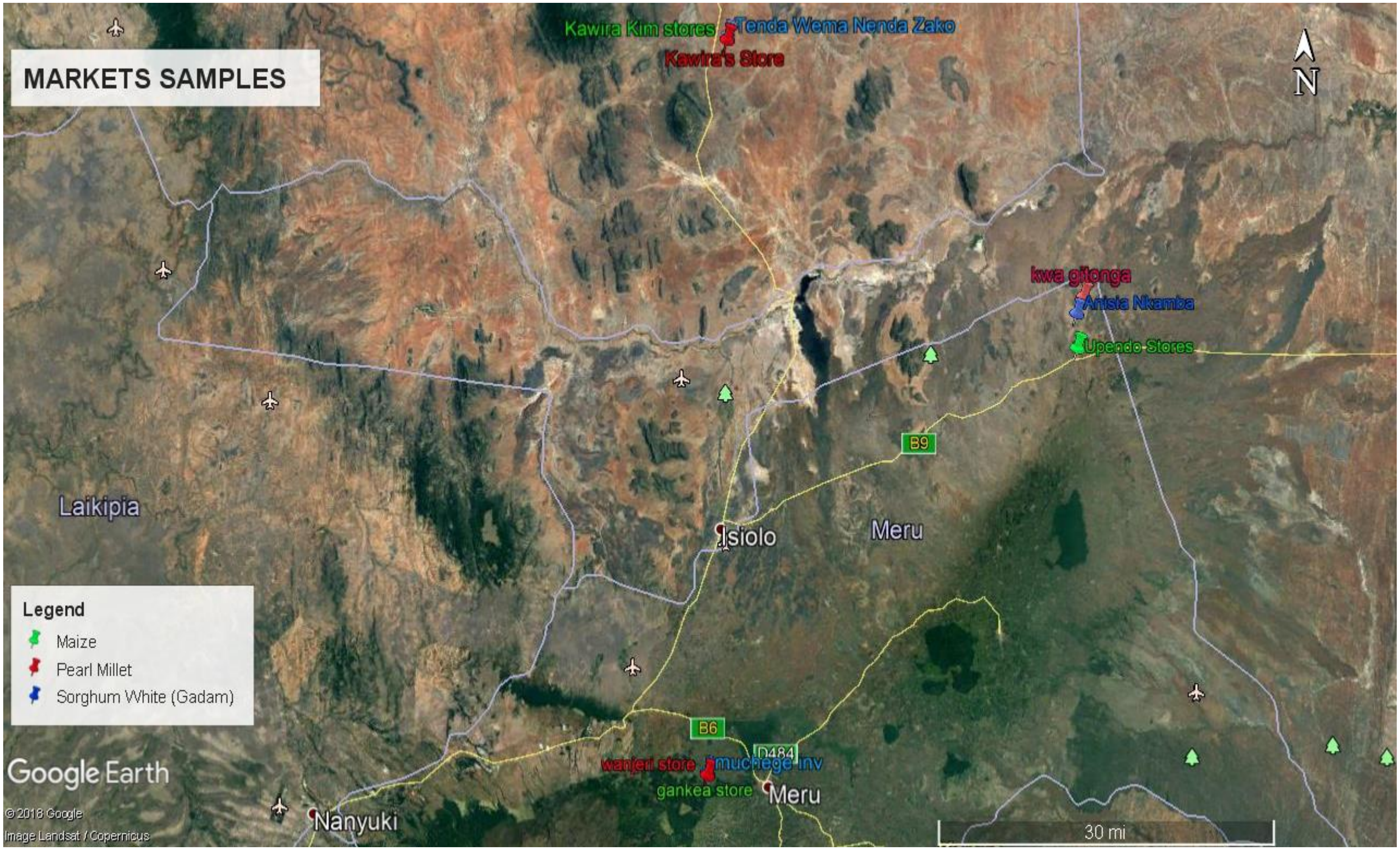
The Following Categories of Cereals and Grains Were Sampled from the Markets and Analyzed

Market Name	Latitude	Longitude	Sub-County	Ward	Sub-Location	Name Store	Sample Name	Total Aflatoxin (ppb)
Marimanti Market	S:0.929	E:37.5844	Tharaka-South	Marimanti	Marimanti	Tenda Wema Nenda Zako	White Sorghum (Gadam)	< 1
Marimanti Market	S:0.924	E:37.5838	Tharaka-South	Marimanti	Marimanti	Kawira's Store	Pearl Millet	1.37
Marimanti Market	S:0.925	E:37.5839	Tharaka-South	Marimanti	Marimanti	Kawira Kim Store	Maize	10.66
Gatunga Market	S:0.60	E:38.034	Tharaka-North	Gatunga	Gatunga	Anisia Nkamba	White Sorghum (Gadam)	< 1
Gatunga Market	S:0.062	E:38.043	Tharaka-North	Gatunga	Gatunga	Kwa Gitonga Stores	Pearl Millet	10.26
Gatunga Market	S:38.035	E:38.035	Tharaka-North	Gatunga	Gatunga	Upendo Stores	Maize	30.00
Mukothima Market	N:0.054	E:37.5637	Tharaka-North	Mukothima	Mukothima	Muchege Investment	White Sorghum (Gadam)	< 1
Mukothima Market	N:0.051	E:37.5639	Tharaka-North	Mukothima	Mukothima	Wa Njeri Stores	Pearl Millet	< 1
Mukothima Market	N:0.055	E:37.5636	Tharaka-North	Mukothima	Mukothima	Gankea Stores	Maize	29.08

Appendix IX: GIS Map Showing Households Samples Place of Collection



Appendix X: GIS Map Showing Markets Samples Place of Collection



Appendix XI: Reported Aflatoxin Contamination in Kenya (1960 – 2010)

Year	Those Affected	Numbers Affected	Locality (Location/District)	Sources of the Toxin	Observed Complications/ Effects
1960	Ducklings	16,000	White settler farmer Rift Valley	Aflatoxin contaminated groundnut feed	Death
1977	Dogs/Poultry	Large numbers	Nairobi, Mombasa/Eldoret	Contaminated products due to poor storage	Death
1981	Humans	12	Machakos	Contaminated maize	Death
1984/85	Poultry	Large numbers	Poultry farms	Contaminated imported maize	Death
1988	Human	3	Meru-North	Contaminated maize	Death and acute effects
2001	Humans	26	Meru-North Maua	Mouldy maize Contaminated maize	Death (16 deaths)
2002	Poultry/Dogs	Large numbers	Coast	Contaminated feed	Death
2003	Humans	6	Thika	Mouldy maize	Death

Year	Those Affected	Numbers Affected	Locality (Location/District)	Sources of the Toxin	Observed Complications/ Effects
2004	Humans	331	Eastern, Central Makueni Kitui	Aflatoxin contaminated grains	Acute poisoning 125 deaths
2005	Humans	75	Machakos ,Makueni, Kitui	Aflatoxin contaminated maize	Acute poisoning (75 cases with 32 deaths)
2006	Humans	20	Makueni, Kitui, Machakos	Contaminated maize	Acute poisoning 10 deaths
2007	Humans	4	Kibwezi, Makueni	Aflatoxin contaminated maize	2 deaths
2008	Humans	5	Kibwezi, Kajiado, Mutomo	Contaminated maize	3 hospitalized, 2 deaths
2010	Humans	29 Districts in Eastern Kenya	Suspected contaminated maize	Price spiral down and grain trade breakdown	

Source: Kang'ethe E.K. (2011)