MAIZE POST-HARVEST HANDLING, KNOWLEDGE AND PRACTICES OF FARMERS IN SOMALIA (A CASE OF MAIZE MEAL AFLATOXIN EXPOSURE)

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I, Hussein Mohamed Ali Adle, declare that this thesis is my original work and has not been submitted for award of a degree in any other University:

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DEDICATION

I dedicate this thesis first and foremost to Allah for the success of the research project. I also dedicate it to my beloved parents Fatima and Mohamed for their prayer, support, and encouragement. Special dedication to my ever Supportive older brother Dr. Mustafa Mohamed for his restless support and compassion towards me during my study period.

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Abbreviations and acronyms

ELISA – Enzyme Linked Immunosorbent Assays

MoA – Ministry of Agriculture

EAC – East African Community

KEBS – Kenya Bureau of Standards

FAO – Food and Agriculture Organization of the United Nations

SPSS – Statistical Package for Social Scientists

WHO – World Health Organization

SSA – Sub-Saharan Africa

PHL – Post-harvest Losses

TLC – Thin layer chromatography

HPLC – High-performance liquid chromatography

MS – Mass spectrometry

LFIAs – Lateral flow immunoassays

Operational definition

Small-scale farmer: is often characterized as a family farmer since many rely on relatives' labor to meet production needs, and they typically retain a portion of their harvest for household consumption.

Maize: is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions.

Post-harvest handling is inter-disciplinary "Science and Technique" applied to agricultural produce after harvest for its protection, conservation, processing, packaging, distribution, marketing, and utilization to meet the food and nutritional requirements of the people in relation to their needs.

Aflatoxins: are a family of toxins produced by certain fungi (Aspergillus flavus and Aspergillus parasiticus, which are abundant in warm and humid regions of the world) that are found on agricultural crops such as maize (corn), peanuts, cottonseed, and tree nuts, Aflatoxin-producing fungi can contaminate crops in the field, at harvest, and during storage.

Dietary intake: is define as the quantity and quality of a specific food that is consumed for a given period of time.

Exposure to aflatoxins: is the eating of contaminated plant products (such as maize) or by consuming meat or dairy products from animals that ate contaminated feed with aflatoxins.

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GENERAL ABSTRACT

Maize is the leading essential food crop in Somalia, covering 30% of the cultivated area (approximately 15,000 hectares). It is grown twice a year, primarily under irrigation and under rain-fed conditions. Around 3-4 kg per 90 kg bag of post-harvest losses were estimated in the study area. However, the post-harvest handling procedures of maize grains had made maize very susceptible to mycotoxin contamination. There is adequate knowledge regarding maize post-harvest management, particularly among small-scale maize farmers. This study was set to assess the small-scale farmers' post-harvest knowledge, the practices they use in their daily operations, and how these factors affect the levels of aflatoxin in the final product. A semi-structured questionnaire was used in the baseline survey was used to find out farmers' knowledge and practices day to day activities including mode of harvesting, drying, shelling, and storage methods. The Statistical Package for Social Scientist (version 20.0) for Windows® was utilized to investigate the information. Frequencies, rates, means and standard deviations were obtained using descriptive statistics. A total of 384 respondents were interviewed. The current findings indicate that the males formed the largest percentage of respondents (54%) as compared to females (46%). There was no significant difference in numbers between females and males ($p > 0.05$). Female respondents had a higher knowledge score compared to males however, no significant difference ($p > 0.05$) was observed between gender in knowledge of the causes of toxigenic molds during harvesting and storage of maize. the findings showed that 34.1% of respondents had excellent knowledge of postharvest handling and aflatoxin contamination while (65.6%) had adequate knowledge of postharvest handling and aflatoxin contamination. Only one respondent had poor knowledge of postharvest handling and aflatoxin contamination. The majority of respondents (97.1%) are knowledgeable that rodents have a role in aflatoxin contamination of stored maize in storage facilities. Very few respondents (7%) knew that cancer in human beings can be caused by the consumption of aflatoxin-contaminated maize**.** Furthermore, 81.8% of the respondents knew that moldy maize is more likely to be infected by insects and damaged by rodent activity. According to the findings (97.9%) of respondents had reasonably practiced maize grains while (1.6%) poorly practiced maize grains. Only two respondents had practiced maize grains excellently. All respondents (100%) depended on their families as a source of human labor, Family members handled the entire maize harvesting process manually. Only 27.3% of respondents used a shelling machine to protect maize kernels from damage. The majority of respondents (96%) could afford to rent a warehouse with poor ventilation to store their maize to reduce risking mold infestation at their homes. Total aflatoxin levels in the initial sample ranged from 0.00 to 31.8 µg/kg, with a mean of 3.5 µg/kg. Aflatoxin levels were found to be ranged from 1.10 to 77.63 µg/kg after one month of storage, with a mean of 10.22µg/kg. Aflatoxin levels were found to be between 2.59 to 81.13 µg/kg after two months of storage, with a mean of 14.41µg/kg. aflatoxin levels were found to be higher than the WHO-recommended maximum intake level of 10 ppb. Aflatoxin levels were significantly lower at harvest stages compared to the post-harvest storage periods. The mean of maize-based diet consumption (kg/kg BW/day) was 0.244. The mean of aflatoxin intake levels in a maize-based diet (µg/kg BW/day) was 0.0321. Small-scale farmers' post-harvest handling of maize may lead to higher levels of aflatoxin contamination in diets based on maize and high aflatoxin exposure. The level of aflatoxin contamination should be reduced to a minimum-level through preventative measures. Training programs and the recruitment of more extension officers can increase farmers' knowledge levels.

CHAPTER ONE: GENERAL INTRODUCTION

1.0 Background information

Maize (*Zea mays L.,*) was domesticated more than 9,000 years ago in southern Mexico/Meso America (Kennett *et al.*, 2020), following the earlier domestication some 10,000 years ago of wheat in the Fertile Crescent of the Near East and rice in the Yangtze Valley, China (Erenstein *et al*., 2022). maize has quickly disseminated across the globe since then and has become the leading global staple cereal in terms of annual production exceeding 1 billion metric tons (García-Lara & Serna-Saldivar, 2019).

Maize is the leading essential food crop in Somalia, covering 30% of the cultivated area (approximately 15,000 hectares). It is grown twice a year, primarily under irrigation and to a lesser degree under rain-fed conditions. Maize yield in farmers' fields is 800 to 1000 kg/ha due to the application of local yields, and little use of fertilizers.

The maintenance of maize grains' quality and safety while it is delivered to customers and utilized in trade involves proper post-harvest handling practices. Lack of knowledge among smallholder farmers and other factors along maize value chains pose challenge in post-harvest loss reduction and mitigation of maize grain contamination by aflatoxin in Sub-Saharan Africa (SSA) (Kachapulula *et al*., 2017).

The primary causes of fungi infestation and the resulting creation of aflatoxins in crops have been reported to be unfavorable conditions and poor postharvest handling practices (Suleiman & Kurt 2015). Post-harvest losses (PHLs) to fungi infestation remains a persistent challenge in Africa. According to the World Resources Institute, approximately twenty-three percent (23%) of the available food in SSA is lost or wasted. Among cereals, coffee, fruits, cassava, and groundnuts, maize is one of the crops that are most prone to toxigenic fungal mold growth, which results in mycotoxin contamination of the crop (Misihairabgwi & Cheikhyoussef 2017). Mycotoxins, which are secondary metabolites produced by fungi, can be found at each step of the production of cereals, including pre-harvest, harvest, postharvest, and processing. Each of these stages has crucial points that needs to be under control to avoid the growth of microorganisms that produce mycotoxins, which can prevent dry matter, quality, and nutritional losses as well as reduce risks to the cereal chain (Gómez-Salazar *et al.*, 2021). Particular genus Aspergillus species produce aflatoxins in various crops including maize in the form of toxins (Wu, 2015). Aflatoxins (AFs) are mycotoxins produced by certain species of *Aspergillus flavus and Aspergillus parasiticus* that grow on a wide variety of crops, mainly cereals.

They have been classified in Group 1 as the most potent human carcinogens known, according to the International Agency for Research on Cancer. AFs can be classified into six types: AFs B1 (AFB1), B2 (AFB2), G1 (AFG1), G2 (AFG2), M1 (AFM1), and M2 (AFM2) (Schaarschmidt & Fauhl-Hassek 2021). AFG1 and AFG2 are released by *A. parasiticus*, whereas AFB1 and AFB2 are produced by *A. flavus* (Pandey *et al*., 2019). AFM1 (a metabolite of B1) and AFM2 are frequently found in animal by-products, such as milk and dairy products, whereas AFB1, AFB2, AFG1, and AFG2 are usually found in food crops (Kumar *et al*., 2021). A huge number of food and agricultural products are contaminated with aflatoxins, a group of poisonous, mutagenic, and carcinogenic mycotoxins with a special affinity towards cereals and nuts. Fungal growth and resulting mycotoxin excretion could occur at any stage of the agricultural production chain depending on environmental factors (temperature, humidity, and rainfall) and farm management techniques (cropping, harvesting, and storage conditions) (Eskola *et al*., 2019). Due to their climatic conditions, AF contamination primarily affects agricultural products in African and Southeast Asian countries (Jallow *et al*., 2021) where hot and humid tropical and subtropical climates with mean annual rainfalls > 700 mm provide favourable conditions necessary to the growth of molds and post-harvest products stored under conditions with high relative humidity and poor aeration that promote fungal growth (Benkerroum, 2020). However, with increasing global warming, AF is now becoming a threat in previously unaffected countries, including Europe (Leggieri *et al*., 2021). Long-term exposure to AFs has the potential to adversely affect both human and animal physiology by causing DNA damage, liver cancer, and improper embryo development (Peles *et al*., 2021).

1.2 Statement of the problem

In Somalia, maize is grown throughout the Jowhar district, especially in climatic conditions which promote the growth and development of fungi. The production of aflatoxin as a result of grain deterioration and fungal contamination has been created likely due to irregular weather patterns. The majority of Somalia's maize harvesting regions have experienced altered weather patterns as a result, which has affected not just proper grain drying quality but also created favorable conditions for fungus infestation. Due to inadequate information and a lack of methods for detecting and preventing aflatoxin contamination in maize grains, there is a considerable risk of contamination of maize after harvest. A scientific research on aflatoxin contamination in maize has never been carried out in this region, yet Maize is the staple food in this region by majority.

1.3 Justification of the study

Maize production in Somalia is by small-scale farmers who depend on maize production for consumption and economic livelihood. Diseases, mechanical damage during harvesting, insect infestation at pre- and post-harvest periods, and slow or unsuitable drying of the maize can all be identified as the primary causes of post-harvest losses. The objective of establishing post-harvest handling knowledge and practices was to serve as a signal to government officials and extension staff where should be the focus of the training programs. To prevent contamination and protect farmers from crop losses, mycotoxin surveillance is necessary throughout the post-harvest stages. This will also help to avoid the health threats that come along with these situations. Aflatoxin intake in Jowhar district has never been thoroughly researched, although the fact that maize is the region's main food and is consumed by a large number of people. Government planners will be fully aware of the threat by determining the aflatoxin contamination level in the study area where the majority of the population consumes maize meals. Policymakers, researchers, academics, households, consumers, farmers, maize producers, and non-governmental organizations (NGOs) will all greatly benefit from the results of this study. Determining the exposure levels in the maize meal is essential to demonstrate the facts of the situation, assist in developing the necessary intervention strategies, and enable the implementation of preventive measures.

1.4 Aim of study

The research contributes to knowledge on post-harvest maize handling procedures and evaluating the level of aflatoxin exposure by maize meal consumed.

1.5 Purpose of study

To create engagement which will assist improve the knowledge of small scale maize farmers on post-harvest handling and practices to avoid Aflatoxin at the post-harvest level.

1.6 Objectives

1.6.1 Main objective

To assess the knowledge of small scale maize farmers on post-harvest handling and practices in Jowhar district and evaluate the level of aflatoxin exposure by maize meal consumed.

1.6.2 Specific objectives

i. To evaluate knowledge of small scale maize farmers on post-harvest handling and practices in the Jowhar District-Somalia

ii. To assess aflatoxins exposure through consumption of maize based diets stored in slums Jowhar District-Somalia

iii. To determine prevalence of aflatoxin in maize at the post-harvest level.

1.7 Hypothesis

i. There is no relationship among knowledge and the practices of food handlers and food contamination with aflatoxins

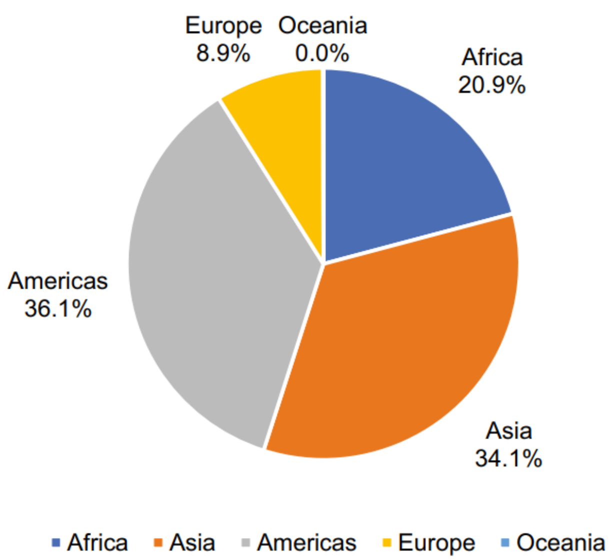
ii. Maize from the markets located within the study area does not have more than the recommended aflatoxin level.

iii. Maize meal consumers in middle Shebelle, Somalia do not have a high level of aflatoxin exposure.

CHAPTER TWO: LITERATURE REVIEW

2.1 Maize production and consumption

Domestication of maize (*Zea mays L.,)* began in southern Mexico/Meso America more than 9,000 years ago (Kennett, 2020). Since then, it has spread rapidly over the world, becoming the most widely grown grain in the world with an annual output of over a billion tons (García-Lara & Serna-Saldivar,). In 165 countries across the Americas, Asia, Europe, and Africa, maize is cultivated for human use (FAOStat, 2021). Over a third of the world's maize acreage is located in the Americas and Asia, with a further fifth in Africa and ten percent in Europe (TE2019, Fig. 2). The amount of maize produced varies greatly from region to region. In this example, America (TE2019) produces fifty percent of the world's maize supply, followed by Asia (32%) and Europe (11%) and Africa (7.4%) (Fig. 2). Each area of the continent has its own distinct culture and history. Northern America (mostly the United States) and Central and South America each account for a quarter of the Americas' total maize area.



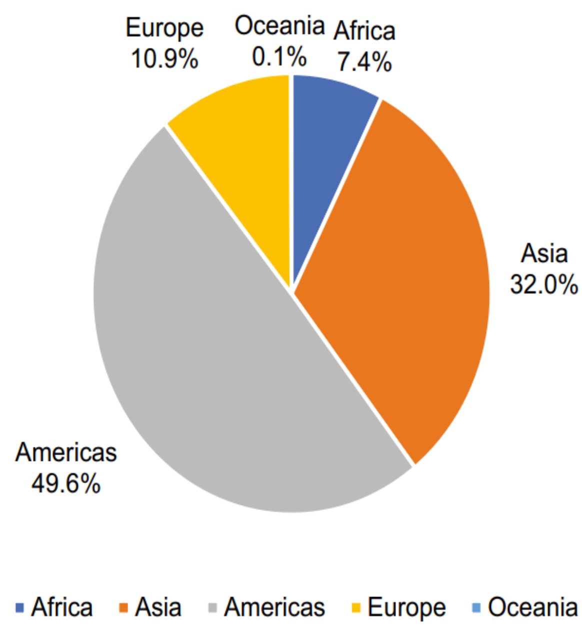


Figure 2.1: AREA SHARE OF MAIZE Figure 2.2: PRODUCTION SHARE OF MAIZE BY REGION, TE2019. SOURCE: FAOSTAT (2021)

Maize is an established and important human food crop in a number of countries, especially in sub-Saharan Africa (SSA), Latin America, and a few countries in Asia, where maize consumed as human food contributes over 20% of food calories, in terms of maize production area coverage, Nigeria with over 33 million tons, Nigeria's largest African producer, followed by South Africa, Egypt, and Ethiopia (Shukla *et al.*, 2019). Maize is used to generate income by most of East African households (Abate *et al.*, 2015). Maize production yields in African countries has been greatly affected negatively by unreliable rains, extreme weather events such as droughts and heat, which are anticipated to be recurring under climate change in East Africa (Kiwia *et al*., 2022).

2.1.1 Maize consumption patterns

In terms of direct channel, processed, or unprocessed cereal ingestion by humans, maize grain ranks third, behind only rice and wheat. Over 50 kg/capita/year is consumed in 22 countries, most of which are in eastern and southern Africa (9 countries) and Latin America (7 countries), according to FAOStat (2021). In addition to Mexico, the southern African countries of Lesotho, Malawi, Zambia, and South Africa have some of the highest per capita maize food consumption rates in the world (with averages above 100 kg/capita/year). When it comes to feeding livestock, maize is by far the most popular choice worldwide. Monogastric and ruminant animals use more than half of the world's maize (dry grain) supply. Wet milling, dry milling, and distilling are just a few of the many industrial uses for maize that provide byproducts that can be used as supplemental feed for cattle (Loy & Lundy 2019). One kilogram of boneless meat may be produced from three kilograms of human-edible feed (mostly maize grain and soy) (on average, 2.8 kilograms are needed in ruminant systems and 3.2 kilograms are needed in monogastric systems; Mottaleb, 2018).

2.2 Post-harvest handling practices

Improper post-harvest handling during maize grain harvesting, storage, and transportation can compromise the grain's quality and safety. Reducing post-harvest loss and maize grain contamination by aflatoxins in Sub-Saharan Africa is complicated by a lack of information among smallholder farmers and other factors along the value chains (Kachapulula *et al.*, 2017). Most communities in sub-Saharan Africa (SSA) rely heavily on farm produce for income, making post-harvest losses (PHL) an important area of emphasis (Lee, 2020). Maize storage pests have been highlighted as a significant problem (Makinya *et al.*, 2021). Extreme post-harvest losses and shifting weather patterns have been blamed in part for this. It is estimated that 20-30% of the yearly staple maize yield is lost due to these factors (Tefera, 2012; about US$4 billion). Inadequate maize post-harvest procedures, unreliable distribution networks, and unfavorable climatic conditions are all to blame for the massive post-harvest losses. Insect and fungus infestations are also a contributing issue. High maize grain damage and losses have been linked specifically to insect pests. Post-harvest insect pests account for over 40% of maize grain weight loss in Africa (Tefera, 2012), accounting for around 30% of total maize grain loss in Africa. Post-harvest losses are a major obstacle to food safety and security in Africa. Food prices rise because of post-harvest losses, which in turn causes shortages and hunger (Yusuf, 2011).

2.2.1 Post-harvest process for small scale farmers

Post-harvest handling practices represent stages of crop production that immediately after harvest. Post-harvest handling practices largely determines the final quality. Post-harvest sector includes all points in the value chain from harvesting of crop until its consumption (Gill & Sharma 2021). It includes harvesting, handling, storage, processing, and transportation:

i. **Harvesting**: One of the most important areas in maize production where farmers need to be timely in maize harvest. In Kenya and most African countries farmers lose approximately 15 to 40 percent of their harvest. During harvesting the farmers cut the maize and make stakes in the field which are left to dry. Cobs are removed sometimes later where they are thrown to the ground as they are separated from the husks and later picked for storage before shelling (Magazine for sustainable agriculture in Kenya 2007).

ii. **Transportation**: Women and children traditionally undertake the bulk of the moving. They use their heads, shoulders, backs, wheel barrows, carts, and pack-animals like donkeys and mules to transport the harvested maize. Clear vans should be used to carry the maize grain to prevent the grain from being wet or contaminated if it rains during transport. When corn is wetted during transportation or storage, fungi may easily infest it, reducing its value and making it less marketable. Markets, processing facilities, grain storage facilities, etc., are typical final destinations. The biological, technological, and socio-economic viability of the technology must all be taken into account when making a decision on which on-farm technology to use.

iii. **Drying:** The primary goals of drying grain are to stop the germination of grains as well as bacteria, fungus, insects and mites. The crop must be dried to a moisture content of 12-13% before it can be safely stored. Because drying requires direct sunlight, it can only take place throughout the day and in dry weather. Traditional methods of crop drying in the field not only leave the crop vulnerable to field pests, but also prevent it from reaching an acceptable moisture level for storage.

iv. **Shelling:** Preparing maize for storage or use entails shelling the kernels. Women and children traditionally perform the work of shelling maize. Hands-on methods include pressing two cobs together while holding one in either hand or smashing cobs in a bag with a stick to remove the grain. Over 70% of farmers in the Eastern, Central, and Coast provinces were reported by FAO research in 2009 to have physically beaten their corn to shell it. This caused the grain to fracture, leaving it vulnerable to fungal and secondary pest assault, which ultimately lowered the grain's quality and shortened the lifespan of the seeds. Broken grains enhance the likelihood of fungal mycelia to penetrate into the maize grains to produce the aflatoxin when shelled using machines that are not calibrated according to the maize variety of type (flint and dent maize).

v. **Storage:** The primary goal of any storage arrangement is to keep the stored product in excellent condition, preventing any loss in quality or quantity. Numerous technical shortcomings in the design of conventional storage systems exist. These flaws lessen the capacity of the facilities to manage and store the harvest in a secure manner for a fair amount of time. The product may either be preserved or deteriorated depending on the kind of storage medium utilized. Fungal infection is common in grains kept in polypropylene for more than a month, especially if they have a high moisture content to begin with. Since natural fibers may be dried out even further, they are suitable for long-term preservation. According to the Food and Agriculture Organization of the United Nations (FAO), maize should be stored in natural fiber bags as opposed to polypropylene bags that constitute around 80% packaging material in small-scale farmers in Kenya.

2.3 Occurrence and exposure to aflatoxin

The two types of mycotoxins that are most frequently found in maize and peanuts in the East Africa community region and throughout Africa are aflatoxins and fumonisins (Magembe *et al.*, 2016). Humans are primarily exposed to mycotoxins through eating contaminated plant-based foods, but they can also be exposed through animal-based products like milk, meat, and eggs to carry-over mycotoxins and their metabolites (Alshannaq & Yu 2017). Two closely related species of fungi, *Aspergillus flavus and Aspergillus parasiticus*, are the main sources of aflatoxins. The most common types of aflatoxins are aflatoxins AFB1, aflatoxins AFB2, aflatoxins AFG1, and aflatoxins AFG2. Aflatoxins B1 and B2 are produced by Aspergillus flavus, whereas aflatoxins B1, B2, G1, and G2 are produced by Aspergillus parasiticus. Common foods that contain aflatoxins include nuts, cereals, especially dried fruit (Taniwaki *et al.*, 2018). The AFB1 strain is the most lethal to animals compared to the others (Okoth, 2016). Acute exposure to aflatoxin may cause deadly liver cirrhosis in individuals as well as animals. Inhaling or absorbing modest quantities of aflatoxins through the skin may lead to liver cancer and long-term immunosuppression (Heshmati *et al*., 2019).

2.4 Aflatoxin prevalence in maize

In the East African Community region, maize is a staple grain which is widely grown and consumed. The maize crop and its products are susceptible to microbial development and mycotoxin contamination (Omara *et al.,* 2020). Most mycotoxin studies in the East African region have concentrated on aflatoxins in maize and peanuts, with some studies aiming at fumonisin contamination in maize (Lukwago *et al*., 2019). The estimated annual consumption of maize in the region is between 94 and 128 kilograms per person. According to studies, Tanzania and Kenya have the highest rates of both maize production and consumption, at 355 to 400 grams per person per day. Uganda had maize consumption rates of 177g/person/day, which are lower than Kenya and Tanzania but higher than the region's average of 93.2g/person/day for groundnuts (Udomkun *et al.*, 2017).

2.4.1 Implications of the aflatoxin on human health

Aflatoxin exposure is seriously harmful to both people and animals. Aflatoxin exposures, which have been associated to liver cancer, liver damage, stunted growth, and impaired development, are especially common in children (Awuchi *et al.*, 2020). In addition, reliable research hasn't definitely shown a link between aflatoxin exposure and childhood stunting, however, similar studies are currently being conducted. (Smith *et al.,* 2015) Adults are at risk but also have a higher tolerance to aflatoxins. Aflatoxin is one of the most cancer-causing chemicals ever discovered by man. Most aflatoxins are consumed directly. Although aflatoxin B1, the most dangerous aflatoxin, may penetrate the skin (WHO ,2018People are frequently exposed to at risk of getting aflatoxins through eating infected plants (such as corn, peanuts, wheat, and ginger) as well as through consuming dairy products or meat that has been prepared with an animal fed with contaminated feed. Farmers and most farm workers can get exposure via breathing in the dirt created by processing and handling of contaminated feeds as well as crops. National estimates of dietary aflatoxin exposures show disparity between the developing and developed countries (WHO,2018). The average dietary exposure to aflatoxin in highly developed nations is often less than 1 ng/kg body weight (bw) per day, whereas it is typically greater than 100 ng/kg body weight per day in the majority of sub-Saharan African countries (WHO,2018), though the estimations are usually generated from few data. “The estimates of dietary exposures to AFM1 have rarely surpassed 1 ng/kg body weight per day in any country, though up to 8.8 and 6.5 ng/kg bw per day for breastfed infants and young children have been reported”

2.5 Current aflatoxin detection methods

To safeguard their citizens from the dangers of aflatoxins, almost 120 nations have implemented safety standards. Fast, precise, and reliable methods of finding and measuring aflatoxins within foodstuffs are necessary for monitoring and enforcement of these regulatory limitations. This has led to the creation of a variety of detection techniques (Jallow *et al.,* 2021). Sensitive, accurate, repeatable, and user-friendly detection techniques are needed. The processes used to identify aflatoxin are multi-step affairs. They include collecting samples, preparing them for analysis, performing that analysis, and interpreting the results (Wolf & Schweigert 2018). However, it has been shown that sampling is a major cause of inaccuracy when looking for aflatoxin in food samples. The two most frequent sampling errors are rejecting an excellent lot (a lot whose overall content falls within the specified limit) and accepting a poor lot. Adequate and appropriate sampling lessens the variance of findings and reduces the amount of incorrectly labeled samples. Thus, regardless of the detection technique used, sampling is an important part of the whole process (Jallow *et al.,* 2021). Other factors that can affect mycotoxin and fungal Occurance include insect damage, bioavailability of micronutrients (Smith *et al.*, 2016).

2.5.1 Chromatographic methods

One of the earliest and most used techniques for detecting aflatoxin is chromatographic analysis. The most common aflatoxin detection techniques based on this method include:

2.5.1.1 Thin layer chromatography (TLC)

TLC is still one of the most frequently used laboratory techniques for the study of aflatoxins. It is sometimes referred to as flat-bed chromatography or planar chromatography. TLC was considered to be a quick, effective, and affordable approach for mycotoxin analysis before HPLC became available. It is used to separate, identify, and evaluate the purity of aflatoxins. This technique is quicker and can detect aflatoxins at a concentration of just 1 ng/g (Mahfuz *et al.,* 2018)

2.5.1.2 High-Performance liquid chromatography (HPLC)

One of the most well-liked and accurate techniques for analyzing aflatoxins in food is HPLC. It has been used in combination with detectors for UV absorption, fluorescence, mass spectrometry, and amperometry. In HPLC, a solvent solution can be used as a liquid mobile phase coupled with an immobilized liquid stationary phase to move the sample through the column (Coskun,2016)

2.5.1.3 Mass spectrometry (MS)

This technique does not require sample derivatization, which is typically done to improve the fluorescence activity (Aiko *et al.*, 2015). Additionally, the application of MS provides highly accurate and focused detection. This newly developed methods is now regarded as the most advanced technique to find aflatoxins. One of modern techniques use only one liquid extraction and direct instrumental measurement without a cleanup step (Mahfuz *et al.*, 2018).

2.5.2 Immunochemical methods

For determining aflatoxins, highly specific antibody-based methods have been available. However, there is still a significant need for simple, quick, and sensitive methods for detecting aflatoxins in a variety of materials. Aflatoxin molecules are small molecules with a low molecular weight (Mahfuz *et al.*, 2018).

2.5.2.1 Enzyme-Linked immunosorbent assays (ELISA)

For the identification of mycotoxins in food samples, ELISA is one of the most used immunochemical methods currently available (Agriopoulou *et al*., 2020). ELISA relies on the standard operating premise of printing a panel of antibodies onto a microplate or column. Since high-performance liquid chromatography (HPLC) is the most sensitive and accurate technique for quantifying aflatoxin quantity, it will be utilized to test the samples following a qualitative screening using enzyme-linked immunosorbent assays (ELISAs).

2.5.2.2 Lateral flow immunoassays (LFIAs)

LFIAs devices are another name for immunodipstick techniques. For the purpose of determining food contaminants, it was originally reported in 2002. The micro-well-type immunoassays use the same methodology and materials. The authors discussed a straightforward nitrocellulose strip with a plastic backing that may identify AFB1(Mahfuz *et al.*, 2018).

2.6 Aflatoxins control methods in pre- harvest and post-harvest

Controlling aflatoxins is necessary during pre-harvest handling, post-harvest handling, and storage. The WHO states that improving the ability of the food crop to resist fungus infection and/or inhibit aflatoxins production by the attacking fungi is the "most stable, long-term solution to controlling the pre-harvest aflatoxins contamination" (WHO,2018). Although the method is laborious and time-consuming, it may be accomplished through genetic engineering or by breeding particular crops. Pre-harvest interventions must be carried out using ways that are long-lasting, effective, and broadly applicable. "Biological control using non-toxic *Aspergillus flavus* isolates has received significant attention for aflatoxins reduction prior to harvest." (WHO,2018) These non-toxigenic strains may compete with and replace the toxigenic strains due to their ability to live in the same environments as the naturally occurring toxigenic strains. The approach is applicable on food crops such as cotton, figs, pistachios, maize, peanuts, and maize in Africa, as well as peanuts in Australia, China, and Argentina. The method is also implemented on maize in Thailand to assess the effectiveness of the treatment prior to as well as after harvest; the results have been positive (WHO,2018). "Post-harvest interventions include preventive measures to address proper storage conditions (temperature, mechanical or insect damage, aeration, and moisture), which influence the contamination and production of toxins by mold," according to the study. Other methods may be used to remove the aflatoxin from the already contaminated foods, such as the use of enterosorbents or chemical decontamination (WHO,2018).

Key words: post-harvest handling, small-scale farmers, contamination, aflatoxin, maize

CHAPTER THREE: POST-HARVEST HANDLING KNOWLEDGE AND PRACTICES OF SMALL-SCALE MAIZE FARMERS IN JOWHAR DISTRICT, SOMALIA

Abstract

Post-harvest handling procedures are a phase of maize production that comes just after maize is harvested. The final quality is mainly affected by post-harvest handling practices. Including All points along the value chain, from maize harvest until consumption. Furthermore, most people in the study area depend primarily on small-scale maize farming for their economic and social well-being. The primary goal of this research was to decide the post-harvest handling knowledge and practices of small-scale farmers in Jowhar District Somalia especially on contamination of maize-based diets with toxigenic molds. A structured questionnaire was provided to 384 small-scale maize farmers who were randomly selected from seven sub-districts of Jowhar for the study. Using descriptive statistics, the primary data was analyzed. Males made up the bulk of the respondents in the research (54%). According to the findings (34.1%) of respondents had excellent knowledge of post-harvest handling and aflatoxin contamination while (65.6%) had adequate knowledge of post-harvest handling and aflatoxin contamination. Only one respondent had poor knowledge of post-harvest handling and aflatoxin contamination. The results show that there is adequate knowledge of post-harvest handling and aflatoxin contamination and no significant difference in the small-scale farmer's knowledge on contamination of maize-based diets with toxigenic molds and post-harvest handling techniques across the study area ($P > 0.05$). According to the findings (97.9%) of respondents had reasonably practiced maize grains while (1.6%) poorly practiced maize grains. Only two respondents had practiced maize grains excellently. This study showed that reasonable post-harvest handling practices existed in Jowhar, particularly among small-scale maize farmers, and recommends training of farmers on maize handling practices.

3.1 Introduction

The most significant cereal crop in Sub-Saharan Africa (SSA) is maize *(Zea mays L.)*, which is grown on more than 35 million hectares, primarily in smallholder farming systems, and provides more than 70 million metric tons of grain annually (Boddupalli *et al.*, 2020). Several million smallholders across SSA, especially in eastern and southern Africa, where approximately 85% of the maize produced is consumed as food, depending on the crop for their food security, income, and daily life.

In Somalia, maize occupies for 30% of the country's total cultivated land, or over 15,000 hectares. Due to the effective application of local harvests in Somalia, crop growth in rain-fed conditions, using fertilizers, and excessive disease and pest management, maize yields in farmers' fields range from 800 to 1000 kg/ha. Changing weather patterns and the hot, humid climate in the tropics make maize more susceptible to fungus growth, pests, and diseases, especially during the harvesting and post-harvesting seasons (Makinya *et al.*, 2021). Additionally, poor post-harvest handling practices also contribute to maize grain harvest losses, mold growth and dry matter loss in the grains (Kamala, 2016). Maize is susceptible to fungal infestations, particularly those caused by the *Aspergillus species (*Mutungi *et al.*, 2019). This infestation is widespread from germination to harvest, transportation and storage, exposing grains to aflatoxin contamination, particularly aflatoxin as a result of fungal development (Koskei *et al*., 2020). The establishment and development of aflatoxin in maize has been strongly influenced by harvesting processes, post-harvest handling practices and storage strategies. (Kamala *et al.,* 2016). Jowhar was chosen as the research location because of the area's high maize production and substantial postharvest losses. The goal of this study was to determine small-scale farmers' post-harvest handling knowledge and practices in Jowhar district.

3.2 Materials and methods

3.2.1 Study area

Jowhar remains is part of seven districts in the Middle-Shebelle region found within central areas of Somalia (Figure 3.1). This area borders Galgadud to the Norther, Hiran to the West, Banadir and Lower Shebelle region towards the South, while the Indian Ocean lies towards the eastern side. The region’s population is estimated to be 1.5-2 million. The area is made up of seven districts. The agricultural production in the area includes livestock, agriculture (irrigated and rain-fed crops) and fisheries, with an annual rainfall ranging between about 150 and 500 millimetres. The area covers approximately 60,000 square kilometres; the area has a 400 kilometres coastline along the Indian Ocean. The Shebelle River within the area runs for 150 kilometres.

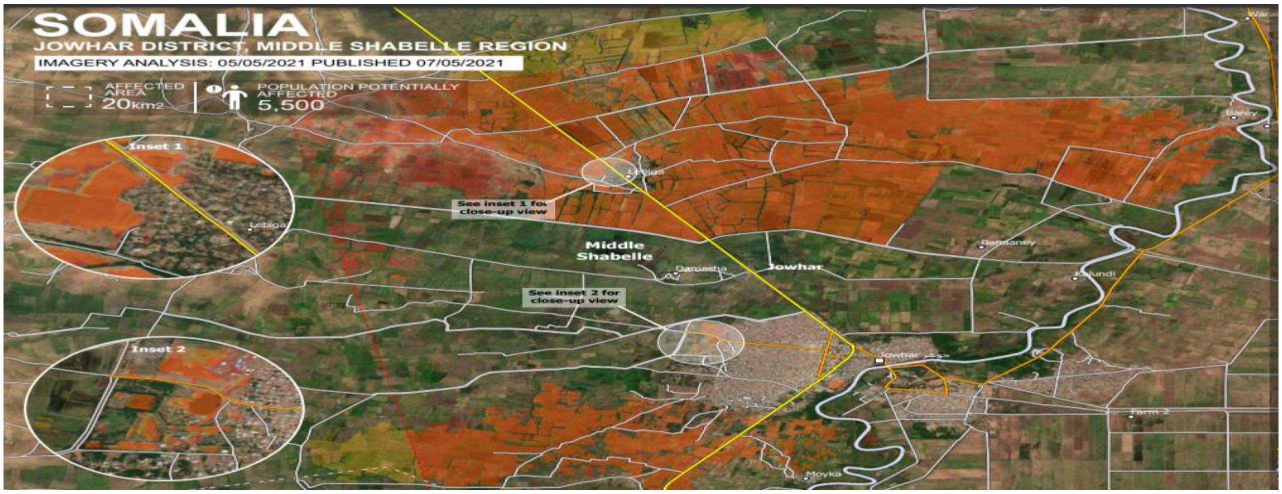


Figure 3.1: Study area, source: (UNOSAT 2021)

3.2.2 Study Design

A cross-sectional study with an analytical component was conducted. A structured questionnaire was used to assess postharvest handling practices and farmers' knowledge on aflatoxin contamination (AppendixI&II).

3.2.3 Sample Size Determination

Cochran's formula (1977) was used in the determination of the sample size:

$$n = \frac{z^2 * p * q}{d^2}$$

z= 1.96 (confidence level at 95%)

p = population proportion with desired characteristics (small scale maize farmers)

q = p-1

d = acceptable degree of accuracy at 5% (0.05) level.

$$N = \frac{1.96^2 * 0.5 * 0.5}{0.05^2}$$

N = 384

3.2.4 Sampling Procedure

Jowhar district was chosen because it is primarily a maize-growing region in Somalia with a large number of small-scale maize farmers. The number of survey participants who were small-scale maize producers at the time of the interview was obtained using random sampling. Gaafaay, Timiro, Shamiindo, Jameeco, Maandheere, Buulofeermo, and Geeda-barkaan were the seven sub- districts surveyed. Households were chosen randomly from the sub-districts and a respondent from each was questioned. Data were collected on knowledge and practices relevant to post harvest handling. Structured questionnaires were administered during collection of information on post-harvest handling practices and farmers' knowledge of Aflatoxin contamination from respondents during face-to-face interviews. Before being administered, the questionnaires were validated through pretesting. The surveys were designed to gather information on the respondents' demographics, post-harvest handling practices, and knowledge of Aflatoxin contamination among small-scale farmers (Appendix Ⅰ&Ⅱ).

The respondents' knowledge was assessed using "True" and "False" statements as the practice evaluation was done using "Yes" and "No" questions and recorded observations. The general assessment of understanding was done using Blooms cut-off points with grade scores as follows ≤49 % as poor knowledge, 50-75 % as reasonable knowledge and above 75% excellent understanding (Nahida., 2007; Abdullahi *et al.*, 2016). Gender, age, marital status, degree of education, and socio-economic status like the family's source of income and farm size were all components in the Farmer's social demographics.

3.2.5 Statistical Data Analysis

Windows®'s Statistical Package for Social Scientist (version 20.0) was used in data analysis. The descriptive statistics was used to determine the standard deviations, percentages, frequencies, and means. This study used the one-way analysis of variance (ANOVA) to contrast median scores of respondents' demographic characteristics. The respondents' knowledge of toxigenic molds was compared using the independent t-test and familiarization with the significant difference in the median scores of demographic characteristics. Pearson Correlations were used to explore the relation between food handlers' knowledge, practices, and demographic characteristics (Appendix I&II).

3.3 Results

3.3.1 Demographic Characteristics of the Respondents

Male formed the largest percentage of respondents (54%) as compared to females (46%). No significant difference in numbers between females and males ($p > 0.05$ while the youngest was 30 years old and the oldest was 90 years old (Table 3.1). There was also no established significant difference between male and females with regard to age ($p > 0.05$). Out of the all the 384 maize farmers none has ever had any formal education (100% illiterate). No significance different was observed in ages for males and female in the study (p: 0.0511).

Table 3. 1: Demographic characteristics of small-scale maize farmers in Jowhar district

Category	Groups	Frequency	Percentage (%)
Sex	Male	207	54.0
	Female	177	46.0
Age group	30-40	26	6.8
	41-50	96	25
	51-60	112	29.1
	61-70	94	24.5
	71-90	56	14.6

3.3.2 Post-harvest handling practices of small-scale farms

3.3.2.1 Methods of harvesting and storing maize

During harvesting, all respondents (100%) depended on their families as a source of human labor. The entire maize harvesting process was handled manually. Majority of the respondents (94.3%) stored shelled maize, (42%) of the respondents shelled maize on the farm before the maize was moved into the storage facility and there was no precaution taken to prevent mold infestation.

Majority of the respondents 52% shelled the maize within the storage facility while (5.7%) of respondents kept maize on the cob without the sheath for long-term storage (table 3.2). P value was significantly different (p: 0.000).

Table 3. 2: Methods of storing maize

Categories	Percentages%
Farmers who Stored shelled maize	94.3%
Shelled maize on the farm	42%
Shelled maize within storage facility	52%
On the cob without sheath	5.7%

3.3.2.2 Period of storage of maize After harvesting

The majority of respondents (98.2%) stated that they kept their maize in the storage facility for 3 to 6 months, for home consumption or for selling, while 1.8 % of the farmers kept their maize at the storage facility for less than three months. The longer the storage duration, the more optimal storage conditions are required to preserve the crop from pests, diseases and toxigenic molds. The need to have food available for consumption by their families for as long as possible before the next harvest necessitate the storage period.

3.3.2.3 Post-harvest holding duration in the field

Nearly all respondents (99.5%) applied pre-storage by keeping the maize on the farm in a cleared area for a few days before bringing the product to the main storage to dry while (0.5%) of the farmers stored the maize directly after harvesting which was attributed to inadequate knowledge that high moisture content increases the growth of moulds in storage facilities.

3.3.2.4 Preparation of the storage facility before introducing the crop

Nearly all respondents (98.2%) removed old grains from the previous season before introducing the new crops into the storage facility. they swept the ground in the storage facilities with only water. only 1.8% of respondents did not remove grains kept in the storage facility before the new grains.

3.3.2.5 Mode of transport of harvested maize from the farm to the storage facility

Almost all the respondents (99.4%) transported the maize to the storage house using donkeys, only (0.6%) of the respondents transported the maize using bicycles and motor cycles. The maize was not protected during transportation and was therefore exposed to the external environment.

3.3.2.6 Duration, method of drying the maize and assessment of moisture content of grains by respondents

All farmers (100%) used sun drying method as the main method of drying maize with the duration of maize drying dependent on the strength and availability of the sun. All the respondents (100%) took two or more days to dry their maize that had been exposed to the sun for eight hours of sunny day. The main aim of the maize drying process was to decrease the moisture content of the grains to a level that the farmer thought ideal for long-term storage. All the respondents (100%) dried their maize in the same way, by open sun drying on the ground for two or more days to ensure the maize was sufficiently dried and ready for storage. The majority of respondents (83.9%) stated that moisture content is determined by physical methods such as picking a quantity of grains in their hands, shaking the grains in their hands and listening to the sound of the grains to determine the dryness of the grains, and observing the color of the maize grains. Other approaches, such as chewing grains, were used by several respondents. The grain is dry enough to store if it cracks and the kernels feel hard or make sharp sounds. If the grain is mushy, it could be moist and has to be dried further. The rest of respondents (16.1%) stored their maize without checking its moisture content.

Table 3.3: Duration and method of drying the maize

Method	**Percentage**
Two more days	100%
Sun drying method	100 %
Assessment of moisture content of grains by respondents	
Mc checked by physical method	83.9 %
Mc did not check	16.1%

3.3.2.7 Method of shelling maize and proportion of the grain lost to pests and other contamination

Almost half of the respondents (49.2%) indicated that they shelled the maize by hand while 23.5% of the respondents shelled by hitting the maize within a bag. The maize kernels were physically damaged by shelling and hitting the maize, which produced a lot of dust while 27.3% of respondents used a shelling machine to protect maize kernels from damage. Most of the respondents (98.4%) estimated their post-harvest losses to be 1-2 kg for every 90 kg bag while 1.6 percent estimated their post-harvest losses to be around 3-4 kg per 90 kg bag (Table 3.3). The major possible contributors of post-harvest lose include substantial postharvest maize practices, informal systems of unfavorable environmental and physical factors. No significant difference was observed (p:0.355).

Table 3.4: Method of shelling maize and proportion of the grain lost to pests and other contamination

Method	Percentage
By hand	49.2%
By hitting maize within a bag	23.5%
Shelling machine	27.3%
proportion of the grain lost to pests and other contamination	
1-2 kg per 90 kg bag losses	98.4%
3-4 kg per 90 kg bag losses	1.6%

3.3.2.8 Packaging of the product during storage

Almost half of the respondents (45.1%) used treated polypropylene bags provided by (FAO) for storage of the maize, 37.5% of the respondents used steel metal barrels to store their maize and it is the best method for long term storage while 17.4% of the respondents used large earthen pots.

3.3.2.9 Mode of maize storage and other crops stored with maize in the same storage house

The majority of respondents (96%) could afford to rent a warehouse with poor ventilation to store their maize to reduce risking mold infestation at their homes while 4% of respondents couldn't afford to pay the warehouse rent, so they stored their maize wherever they could, regardless of whether the area was suitable for the product or not. Majority of the respondents (99.5%) stored the maize in a facility alone while (0.5%) stored maize crops with other crops including beans, nuts, and sesame for economic reason.

3.3.2.10 Inspection of the Color of Maize After Storage by respondents

About 4 out of 10 respondents (41.7%) reported slight change in color of maize crops after a couple of months of storage. Nearly 3 out of 10 (27.3%) respondents observed big change in color of maize after storage period. About eleven percent (10.9%) of the respondents reported retained color, due to proper storage practices (Table 3.4). They mostly used steel metal barrels over six months to eight months and no change in color occurred while 20.1% of respondents did not check the color of the maize grains after storage period because of lack of knowledge on the link between color change and mold infestation.

Table 3.5: Inspection of the color of maize after storage by respondents

Categories	Percentages %
Slight change in color	41.7%
Big change in color	27.3%
Retained color	10.9%
Color was not checked	20.1%

3.3.2.11 Removal of contaminated maize

Moldy maize is removed and used as animal feed by 74.7% of respondents while (25.3%) of respondents considered the grains to be unfit for human and livestock use, thus they disposed of the moldy maize crops on their farms by burying the grains below ground for use as manure.

3.3.3 Post-harvest knowledge of the small-scale farmers

3.3.3.1 Knowledge on causes of aflatoxin during the harvesting and storage stages

All respondents (100%) had knowledge of the fact that wet storage and inadequate drying (high moisture content) of maize raise the probability of development of aflatoxin contamination. The majority of respondents (97.1%) are knowledgeable that rodents have a role in contamination of stored maize by aflatoxin in storage facilities. The formation of toxigenic moulds significantly increase when maize is stored in storage facilities without windows and completely shut off from the outside air. The majority of the respondents know that wet environments during harvest and storage, as well as insufficient drying of maize grains increase the danger of toxigenic mold formation. Nearly half the respondents (47.4%) had knowledge that during harvesting and drying. Putting maize on the soil ground in the field exposed maize to the risk of mold development. All of the respondents (100%) had knowledge that damaged/broken maize grains when shelling makes grains more prone to fungal growth exhibited through the mould growth. Furthermore, 81.8% of the respondents had knowledge that moldy maize is more likely to be infected by insects and damaged by rodent activity. Overall, 85% of the respondents had excellent knowledge on the causes of the toxicogenic molds in maize. Female respondents had a higher knowledge score compared to male but no significance difference ($p > 0.05$) seen between genders in knowledge of the causes of toxicogenic molds during harvesting and storage of maize.

3.3.3.2 Knowledge of the respondents on the side effects of toxicogenic mold consumption

Very few respondents (7%) had knowledge that cancer in human beings can be caused by consumption of aflatoxin contaminated maize. About 9 out 10 respondents (93.8%) had knowledge that ordinarily human beings cannot die within one week after consumption of Aflatoxin contaminated maize. Roughly 5.7% of the respondents had knowledge that ingesting maize contaminated by aflatoxin can affect children's growth. Overall, 35% of respondents had poor knowledge on how aflatoxin-contaminated maize affects human health in general; however, no significant differences. Female respondents had a higher knowledge score compared to male however, not significant ($p > 0.05$) differences were found between genders or age group.

Table 3. 6: Inspection of the color of maize after storage by respondents

Categories	Percentages %
Cancer in human beings can be caused by consumption of aflatoxin contaminated maize	7%
Human beings cannot die within one week after consumption of aflatoxin contaminated maize	93.7%
Ingesting maize contaminated by aflatoxin can affect children's growth.	5.7%

3.3.3.3 Knowledge of the respondents on the control of toxicogenic mold

The majority of respondents (96.6%) had knowledge that rodents and aflatoxin contamination in warehouses can be avoided by cleaning and disinfecting the storage facility before bringing in new grains and treating maize with insecticides. More than six in every ten respondents (68.5%) had knowledge that cooking processes like boiling of maize flour cannot eradicate aflatoxin and make it safe for human consumption. The knowledge about control measures of toxigenic molds by the other demographic regions varied significantly ($p<0.05$).

3.4 Discussion

3.4.1 Demographic characteristics of the respondents

Demographic characteristics indicated that men were majority respondents compared to women and this could be linked to the fact that maize production by small scale farmers in the study area is dominated by men. These results seem to be disagree with previous research by (Midega *et al*., 2016) conducted in western Kenya, where women made up the majority of small-scale farmers, in this case, could be attributed to the regional tradition and cultural belief that men are the owners of all resources. Female respondents had a higher knowledge score compared to male however, no significance difference ($p > 0.05$) was observed between gender on knowledge on the causes of toxicogenic molds during harvesting and storage of maize. Education and formal training provide an opportunity to understand new technological advancements in several fields, including agriculture, as well as to develop an awareness of emerging challenges such as aflatoxin in agriculture and current Good Agricultural Practices. With a clear awareness of the increasing issues in agriculture and knowledge gained from enormous amounts of digital data, the younger generation will be better able to assist their communities in overcoming the challenges they face while farming.

3.4.2 Post-harvest handling practices during maize harvesting

Maize is grown for domestic consumption in the majority of households and surplus is marketed. During harvesting, all respondents depended on their families as a source of human labor. Family labor is uncompensated. Furthermore, manual harvesting takes a long time, and the crop is left on the farm for long periods enhancing the risk of contamination. After shelling, the majority of respondents store their crop as maize grains. Due to simplicity of storing shelled maize and the lack of space available to small-scale farmers, this mode is preferred by the majority of farmers. The present study found out respondents' preferred maize stored on the cob without the sheath. After being separated from the maize cob, the sheath is used as animal feed. Shelling/dehusking exposes the grains to the sun and reduces the time the maize takes to dry. Furthermore, the sheath provides sufficient heat, which, along with the maize's high moisture content, provides optimal conditions for toxicogenic mold growth. According to the AfloSTOP survey, which included farmers in the Rift Valley and Eastern parts of Kenya, maize on cobs was dried for more than two days per season. These findings are related to the findings from the current study (Koskei *et al.,* 2020) maize was stored in storage facilities for three to six months by most respondents, either for selling or for household consumption, the study findings disagree with the study by (Thamaga-Chitja et al, 2004) in South Africa, Where the period of time maize stored from 6-8 months on average, showing that maize is utilized up before the next harvest.

Most of the respondents left the harvested maize on the farm for more than two days to dry. The harvest is exposed to severe environmental and weather conditions due to the longer maize holding period with humid conditions and light rains during the harvest season that increase the risk of fungal contamination as well as insect infestation. This was also the case in Ghana, where most farmers heaped and left the maize on the field after harvesting (Akowuah *et al*., 2015).

In the present study, nearly all respondents reported that they cleaned the storage facility and old grains from the previous season were removed before introducing the new maize into the storage facility. Storage facilities harbor insects and other microbial contaminants for an elongated duration due to the availability of food and the conducive climatic conditions. The results from the current study agree with an initial research done (Mendoza *et al*., 2017) in Guatemala that cleaning of the storage facility was actually done. As was the case in this study, a study by (Kamala *et al.*, 2016) in Tanzania found that most farmers cleaned their storage facilities and cleared it of old maize grain stock before loading them with a new stock.

Donkey transportation was the most common mode of transportation in this region due to the proximity of the farm to the homesteads for small scale maize farmers, these results agrees with the study by (Machekano *et al.*, 2018) in Zimbabwe where there was more preference for the carts compared to the human loaders. The longer harvest season, including the delayed transportation process increases the time the harvested crop is held on the farm.

Farmers reported that sun drying of maize was the most preferred method. Sun drying uses a low- cost source of energy that is available naturally and is accessible to small-scale farmers. However, drying maize on the ground exposes it to insects and fungal growth and is related to aflatoxin and fumonisin contamination (Kamala *et al*., 2016). Placing the grains or cobs directly on the ground might cause the maize to absorb fungal spores as well as moisture from the ground, making the maize more susceptible to aflatoxin contamination. Varying weather patterns in the tropics has a significant impact on maize drying duration and effectiveness (Koskei *et al*., 2020). The length of time the maize took to dry maize was mostly determined by the availability of sunlight. Maize took more than two days for all of the respondents to dry their maize. The moisture content of the grains is reduced by an effective drying procedure, which minimizes the water activity in the grains.

Physical methods such as chewing a portion of the grains or shaking the grains and listening to the sound of the maize were used to determine the dryness of the grains. Physical approaches cannot be relied on to provide accurate results because they are subjective and dependent on the individual's strength or listening abilities. In a study conducted by Kamala and colleagues in 2016 in Tanzania, farmers used the same approach of chewing/biting maize and listening to the maize sounds in a tin can. Inaccurate moisture content detection can result in maize being stored with a high moisture content which promotes grain germination or even toxigenic fungus development. In Ghana, the farmers were reported to check for maize dryness using their teeth by biting (Akowuah *et al*., 2015). Due to lack of knowledge of moisture meters and extension services support from the Government or non-government organizations in Middle-Shebelle region, however, this current study is in agreement with a previous study on appropriate grain and seed storage for small scale farmers.

The present study also compares well with the findings by Koskei *et a*l (2020) in Kenya, Kamala *et al.*, (2016) in Tanzania, Machekano *et al.*, (2018) in Zimbabwe and Mendoza *et al.*, (2017) in Guatemala where all studies reported the use of biting of the grain by the farmers and listening to the sound of the grains as the most widely used methods for moisture content checking.

Maize shelling by hand was most preferred method by farmers. The results obtained from the current study agree with the previous study conducted in Ethiopia by (Fufa *et al*., 2021) where most of the small scale farmers shell their maize using hand to dissociate the grains from the cobs. More physical damage to the maize kernels is caused by this method of maize shelling, it also generates a lot of dust. The quantity and quality of maize grains are both affected by mechanical damage during shelling. damage to the seed coat makes the grain more susceptible to mold attack and increases the storage hazard for a given temperature and kernel moisture combination. Most farmers lost their maize crops to pests and other contaminations and estimated around 1-2 kg of every 90 kg bags. The results of present study agree with the study in Tanzania by (Abass *et al.*, 2018*).*

Almost half of respondents used treated polypropylene bags provided by United Nations' FAO. Metal steel barrels were used by some respondents to store maize crops and it is the most suitable method for long-term storage. Some insecticide tablets were placed in the maize grains within the metal steel barrel to mitigate against the pests. the majority of farmers in SSA make use of different storage practices, including the use of wooden baskets, jute bags, polyethylene bags, thatched structures, and raised platforms. The current study agrees with a study by (Abass *et al.,* 2018*)* in Tanzania reported that most small-scale farmers used polypropylene bags for storage of maize crops.

Almost all of maize farmers store their maize in rented storage facilities, while other respondents keep their crops in their homes. Some of the main factors driving this trend of storage are a lack of resources in putting up a specialized maize storage facility and a fear for the safety of their maize. The rented premises and living areas were poorly lit, with only one door and the few available windows either closed for safety reasons or inaccessible due to the congestion in the store. the facility's poor aeration, results in buildup of heat and moisture in the storage room, providing perfect situations for toxigenic molds to thrive. Temperatures above 25°C and relative humidity above 65% are favorable for these toxigenic fungi, and they also increase the risk of insect infestation (Alshannaq & Yu2017).

In the present study, almost all respondents indicated that maize was kept alone in storage facilities, while a very few respondents stored maize together with other food products including sesame, beans, and groundnuts. The susceptibility of different crops to toxigenic molds vary by crop, but storing diverse harvests in the same safe facility increases the risk of pests, insects, and other microbial contamination spreading from the more susceptible crops to the rest of the harvest. This method reported in Kenya by (Koskei *et al*., 2020) where most farmers keep their maize crops alone.

Respondents considered the grains were unfit for human and livestock consumption, thus they disposed of the moldy maize crops on their farms by burying the grains below ground for use as manure for crops. Aflatoxin B1 has been found in commercial feeds, and aflatoxin M1 has been found in milk. Aflatoxin levels above the recommended maximum value have a severe impact on livestock production, making them more susceptible to infectious disease and stunting their growth (Kang'Ethe, *et al.,* 2017). The burying of contaminated maize grains is an acceptable method of disposal. The National Environmental Management Act abolished open-air burning of materials and the release of untreated harmful material into the climate, including burying in the earth. The current study contradicts that the study by (Koskei *et al*., 2020) in Kenya where farmers believe that moldy maize is safe for both human consumption and animal feed.

3.4.3 Post-harvest knowledge of respondents

Majority of participants had an excellent knowledge of the causes of toxicogenic mold. There were little variations in awareness of sources of toxicogenic molds across demographic areas of participants. The participants in this research were considered to have same access to knowledge on toxicogenic molds. The study's outcomes contradict a study by (Magembe *et al.*, 2016) who wrote that female participants were highly informed about mold contamination in foods than male participants, and respondents with greater knowledge levels were highly informed on mold contamination in foods than those with a lower knowledge level.

This study results support the findings of other researchers that observed that the rural population in developing countries are more knowledgeable of toxicogenic mold in maize foods (Udomkun *et al.,* 2018; Matumba *et al.,* 2015). However, all respondents had knowledge the role of moisture in mold growth and development. All respondents stated that drying the maize can help reduce the moisture content to acceptable levels. Insects attack and increase fungal proliferation and aflatoxin generation in foods due to poor temperature control, soil contact, and inadequate ventilation (Misihairabgwi *et al.* 2017; Matumba *et al.* 2015).

According to the findings of the present, the majority of respondents had limited understanding of the health effects of toxicogenic molds due to lack of information on mold-related health issues in Somalia, no formal maize handling training for food safety, and no serious cases of aflatoxin outbreak.

This observation agrees with the study by (Mendoza *et al* 2017). The discoveries of this review compliment other studies that report that the Southern Africa rural community population have very limited understanding on the health effects of ingesting moldy polluted maize foods (Matumba *et al.*, 2015) Anyone who consumes aflatoxin contaminated foods expose themselves to the risk of substantial acute and chronic health effects such as immunosuppression, teratogenic, hepatotoxic and carcinogenic.

The present study found that respondents had insufficient information and poor knowledge on control measures for toxicogenic molds, which is relevant to aflatoxin. Capacity building on aflatoxin has never been done and may contribute to inadequate knowledge of aflatoxin control. There is scarce information on control methods of aflatoxin contamination in food items (Phokane *et al.,* 2019)

3.5 Conclusions

Farmers in the Jowhar district have adequate knowledge of the optimal post-harvest handling procedures for protecting maize from aflatoxin contamination. Furthermore, all small scale farmers practiced manual harvesting. Donkey was a common transportation method and maize was not protected during transportation and was therefore exposed to external environment. Economic factors play a critical role in storing maize product in a special room for the safety. The majority of small-scale farmers have inadequate knowledge on aflatoxin contamination, crop protection, and contaminated maize grains disposal.

CHAPTER FOUR: EXPOSURE TO AFLATOXINS THROUGH CONSUMPTION OF STORED MAIZE BASED DIETS IN SLUMS IN JOWHAR DISTRICT, SOMALIA

Abstract

Food contaminated by aflatoxin is a main risk to human wellness. The goal of this research was to establish aflatoxins' contamination range in the district, with a focus on aflatoxin contamination levels in post-harvest maize and aflatoxin exposure from contaminated maize consumption. Maize grains were picked from 67 subsistence farmers selected randomly in Jowhar district. The samples obtained in triplicates from the seven sub-districts were considered representative of the maize distribution in the district because the sub-districts are in the same Agro-Ecological Zone. Random sampling techniques were used to extract approximately 100g of samples from farmers' storages. Aflatoxin levels were determined in the samples at the Kenya Bureau of Standards (KEBS) laboratory using ELISA techniques. Total aflatoxin levels in the initial sample ranged from 0.00 to 31.8 µg/kg, with a mean of 3.5 µg/kg. Aflatoxin levels were found to be ranged from 1.10 to 77.63 µg/kg after one month of storage, with a mean of 10.22µg/kg. Aflatoxin levels were observed to be between 2.59 to 81.13 µg/kg after two months of storage, with a mean of 14.41µg/kg. there was a significant difference (p: 0.001). aflatoxin levels were observed to be greater in the samples than the EAC-recommended maximum level of 10ppb. Aflatoxin levels were significantly lower at harvest stages compared to the post-harvest storage periods. The mean of maize based diet consumption (kg/kg bw/day) was 0.244. The mean of aflatoxin intake levels in maize-based diet (µg/kgbw/day) was 0.0321. Additional research on a larger population is needed to ensure protective measures are in place to reduce the chance of exposure to aflatoxin poisoning by consumers.

Key Words: Exposure, Aflatoxin, Consumption, Maize, Intake

4.1 Introduction

The main staple food and cereal for populations in warm climatic conditions in Africa, Asia, and the United States are predisposed to the impacts of climatic shifts through producing, consuming, and generating income. It was originally introduced by the Portuguese as they supplied their trading forts, but because of high energy yield, low work demands and short growing season, the African farmers quickly adopted the crop (Cherniwchan & Moreno-Cruz, 2019). Tropical climatic conditions have proven to be favorable for the crop's long-term viability. Maize is the main staple food in eastern Africa, accounting for nearly 50% of total calorie intake in the region and an annual production of 28 million metric tons on 25% of the agricultural area (Rezende *et al.*, 2020). The Food and Agricultural Organization (FAO) estimates that maize is grown on more than 197 million hectares of land worldwide, with a yield of 1.13 billion tons (FAO, 2020). Therefore, it is crucial to ensure the quality and safety of maize for both human and animal consumption, especially in considering raising concerns over global shortages of food. The contamination of maize kernels with mycotoxin-producing fungus is a significant quality and safety concern. These are well-known climate-sensitive species. Because of its substantial significance in the food and feed supply chain and its susceptibility to aflatoxin contamination, maize contamination is a concern on a global level (Pickova *et al.*, 2021). Aflatoxins falls in mycotoxins groups produced by *Aspergillus flavus* and *Aspergillus parasiticus*, and are known to have impacts on human being's health. Aflatoxins are additionally both cancer-causing and hepatotoxic relying upon the length and level of exposure. Areas that are prone to hepatitis B infection cases are at a higher risk of chronic dietary exposure to aflatoxin (Nji *et al.*, 2022). Chronic exposure is common where there is a high prevalence of aflatoxins in food staples and where there are poor control and monitoring systems and poor enforcement of regulations. Multiple studies show that in Africa, both the feed and food chains and their supply chains are highly contaminated with aflatoxins, which exposes consumers, particularly through basic foods (Ahlberg *et al.*, 2019). The Somali government recently 2021 established an institution (Somali Bureau of Standards) that observes food safety and quality both commodities from outside of the country and local production to mitigate food hazards to consumers. The Somali Bureau of Standards is trying to practice the mycotoxin limits as recommended by EAC with the maximum limit for Aflatoxin at 10 ppb (10• g/kg) and for fumonisin at 1 ppm (1mg/kg).

The aim of this research was to establish the aflatoxin levels in maize-based meals produced by small-scale farmers in Jowhar district as well as the intake levels of aflatoxin as a result of consumed maize meals by consumers.

4.2 Materials and Methods

4.2.1 Study Design

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

4.2.2 Study Area

The study area is as described in section 3.2.1

4.2.3 Sample size determination

The sample size determination is as described in section 3.2.3.

4.3 Sampling of the maize for the analysis

Sixty-seven small-scale farmer households from throughout the seven sub-districts were chosen as potential sampling sites. The samples obtained in triplicates from the seven sub-districts were considered representative of the maize distribution in the district because the sub-districts are in the same Agro-Ecological Zone. Random sampling techniques were used to extract approximately 100g of samples from farmers' storage. Samples were drawn at three depths: top, middle, and bottom. A 100g homogenous sample was drawn in duplicate for lab analysis after the sub-samples were well mixed. Storage samples were taken using the same approach as the initial sampling after one and two months of maize storage. The samples were transported to the lab in zip bags.

The sample size for aflatoxin test was determined using Cochran's formula (1977) was used in the determination of the sample size: N= z2pqD / d2, Whereby N was the sample size (when population is >10,000), Z was the confidence level at 95% (1.96), and P was the average prevalence of 50%

Applying the formula, the result for $N = \frac{1.96^2 * 0.5 * (1-0.5)}{0.12^2}$, N = 66.7 and therefore the number of respondents were ≈ 67 farmer households.

4.3.1 Aflatoxin determination

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

4.3.2 Intake levels of aflatoxin through maize-based diets

The exposure evaluation of aflatoxin because of utilization of maize based-diet was surveyed probabilistically, utilizing @Risk TopRank Palisade (UK) risk investigation programming for succeed (Palisade, UK) Version 8.2, where information for aflatoxin levels in maize-based samples, consumption levels and estimated mycotoxin intakes were fed into the excel to get the best fit dispersion. The maize utilization information was acquired in view of everyday utilization of maize-based diet per kg body weight of individual respondents furthermore, partitioning again by 7 days JECFA (2011) to get the sum consumed per kg body weight each day. The aflatoxin dissemination in maize was gotten by determining the amount of the mycotoxins per kg of maize assessed in the lab while the aflatoxin intake was calculated as per equation 1-3.

$$Maize\ consumption\left(\frac{\frac{kg}{kgbw}}{day}\right) = \frac{Maize\ product\ consumed\ per\ day\ (kg)}{body\ weight} \quad \text{–Equation 1}$$

$$Aflatoxin\ levels\ (\mu g/kg)) = \frac{Aflatoxin\ in\ Maize\ products\ (\mu g)}{Weight\ \ of\ Maize\ sample\ (kg)} \quad \text{- Equation 2}$$

$$\text{Aflatoxin intake } (\mu g/\text{kgbw/day}) = \frac{Aflatoxin\ levels\ in\ \ diet\ (\mu g/kg) *}{Maize\ consumption\ kg/kgbw/day} \quad \text{- Equation 3}$$

The mean admission levels were acquired for assessment of Margins of exposure (MoE) through the Monte Carlo reenactment model which was done to choose capriciousness for exposure at a million cycles. The Tolerable Daily Intake (TDI) of aflatoxin was assessed in light of Margins of Exposure (MOE) of 10,000 for the low worry of general well-being (WHO, 2005; Benford *et al*., 2010). The Margins of Exposure of 10,000 was equivalent to 4-30 µg/ kg bwt/day for the populations consuming the maize based diets in accordance with EFSA (2007), Mahato *et al.* (2019) and Analysis and Africa (2015). Table 4.1 shows risk assessment simulation for aflatoxin exposure in maize.

Table 4.1: distribution function used in quantitative risk assessment simulation for aflatoxin exposure in maize

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

4.3.3 Statistical data analysis

Information got was exposed to Statistical Package for Social Scientists (variant 20.0) for windows®. The One-way investigation of change (ANOVA) was utilized to acquire implies, standard deviations and analyze massive contrasts of aflatoxin levels among the examples. at 95% certainty stretch was applied to dissect the factual importance among the examples. The acquired outcomes from aflatoxin examination were changed over from ppb to µg/kg for easy interpretation. The consumption and intake levels were examined utilizing Microsoft Excel @Risk TopRank Palisade(UK) V8.0.0 AddIn software.

4.4 Results

4.4.1 Respondents socio-demographic and consumption characteristics

Six in every ten respondents (64.1%) were females while the rest (35.9%) were males. The mean age of participants was 49.4±15.4 years with a minimum of 22 years and maximum of 76 years. There was additionally no significant difference between male and females with regard to age (p: 0.06). The body weights of members differed significantly ($P<0.05$) and ranged from 46 - 96 kilograms, with a typical weight of 72.7± 10.1 kg. It was additionally seen that there was no relationship between body weights and age ($r=0.056$, $P=0.000$).

4.4.2 Forms of maize consumption

Maize was consumed in form of either milled maize flour or whole grains. Seven in every ten respondents (76.6%) indicated that they consumed maize in form of milled maize flour as 'Soor' stiff porridge (Ugali) and porridge (thin), while (23.4%) of respondents consumed the whole maize grains with beans cooked together. There was significance difference ($P<0.05$) between the two.

4.4.3 Dietary intake of aflatoxin through utilization of maize- based diets

Utilization levels of maize-based counts calories ranged from 200 to 500 grams for each body weight in Kg per day, with an average of 383.9±76.03 grams of maize-based calories consumed which were significantly ($P<0.05$) different among the participants. In any case, no significant was seen between age and utilization levels ($r = 0.261$, $P = 0.000$).

The utilization of maize-based calories resulted in an average intake of 0.03 µg/ Kg bwt/day with a Weibull distribution. Although the minimum likely intakes were likely to be none if consumed diets contained no aflatoxin, the consumption levels would be equally as much as the contamination levels in the maize were and therefore a maximum of infinite exposure through consuming contaminated maize.

The estimated average daily intake per person per day based on the average body weight of 72.7 Kg of the respondents, equally showed a much higher intake. Table 4.3 shows quantitative risk assessment for aflatoxin exposure in maize-based diets.

Table 4. 2: Distribution fitting and simulation used for quantitative risk assessment for aflatoxin exposure in maize-based diets

Variable	Mean output	90 % CI	
		Min	Max
Maize based diet utilization (kg/kg bw/day)	0.244	0.008	0.082
Aflatoxin levels in maize-based diet (µg /kg)	9.42	-∞	+∞
Aflatoxin intake levels in maize-based diet (µg/kgbw/day)	0.0321	-∞	+∞

4.4.4 Level of aflatoxin in maize grains in Jowhar district

For the initial samples drawn at harvesting, the mean of aflatoxin was 3.5 µg/kg. About 9 in every 10 (89.5%) of the samples analyzed for had palpable levels of aflatoxin with none of the sample above the levels recommended by WHO and EAC. The samples drawn after the post-harvest handling processes and storage of one month had the mean aflatoxin 10.22µg/kg. 19.42% of the samples had detectable levels of aflatoxin above the recommended level of 10ppb.

The samples drawn after the post-harvest handling processes and storage of two months had the mean aflatoxin 14.41µg/kg. 20.85% of the 67 samples analyzed had detectable levels of aflatoxin above the WHO and EAC recommended levels, massive significance difference was observed (p: 0.001). (Table 4.2).

Table 4. 3: Aflatoxin level at harvest, after 1 month and after 2 months' storage period in maize samples collected from Jowhar district

Sampling plan	Aflatoxins (µg/Kg)	Range (µg/Kg)
Initial Samples (At harvest)	3.5 ± 7.06	0-31.8
After 1 month storage period	10.2 ± 17.56	1.10-77.63
After 2 months storage periods	14.40±19.06	2.59-81.13

4.4.5 Maize meal consumption

The levels of aflatoxin in the sampled maize was higher compared to what Jere *et* al. (2020) (Figure 4.1) found and therefore a likelihood of higher intake among the Somali population. This would equally translate to approximately 145.4 µg/person/day on average with much higher intake levels expected within populations with higher concentration or consumption of highly contaminated maize based diets. The current consumption of maize-based diets was significantly higher those than reported by the consumption of maize-based porridge in Malawi by Jere *et* al. (2020) while the levels were slightly lower than the 150 to 500 grams/day daily estimated consumption levels in other East African and the South Africa (Gong et al., 2015; Shephard et al. 2007).

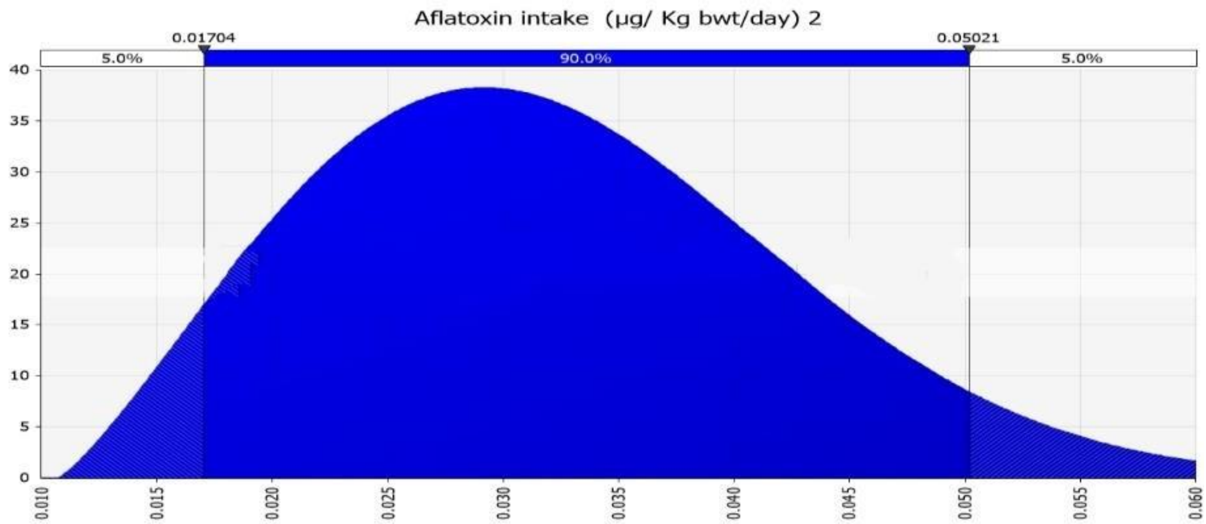


Figure 4.1: Distribution of aflatoxin intake through dietary exposure to contaminated maize based diets among Somali populations.

4.5 Discussion

The district of Jowhar's importance as a maize producing region can be attributed to the high maize consumption levels. It's worth mentioning, that consuming a variety of maize meals increases the risk of contracting mycotoxins. The levels of aflatoxin in the sampled maize were equally higher compared to what Jere *et* al., (2020) found and therefore a likelihood of higher intake among the Somali population with substantially greater intake levels expected within populations with higher consumption of severely contaminated maize-based diets, this would also equate to around 145.4 g/person/day on average. While levels were slightly lower than the 150 to 500 grams/day daily estimated consumption levels in other East African and the South Africa, the current consumption of maize-based diets was significantly higher than those reported by Jere *et* al., (2020), who found that consumption of maize-based porridge in Malawi on average 0.019 kg/kg g/day per child per day. Maize-based foods reported in other countries including such 356 grams/day in Tanzania (Burger *et al.,* 2014) 400 grams/day in Kenya (Nabwire *et al.*,2020).

However, other studies have found that consuming a lot of maize-based foods increases mycotoxins exposure (Alberts *et al.,* 2019). This study tracked down a critical degree of aflatoxin exposure from maize ingestion. Aflatoxin exposure may be connected to elevated degrees of aflatoxins-sullied maize consumption. The consumption of maize-based porridge in schools may have a severe impact on the health of children. The current findings are consistent with Tanzania's Kamala *et* al., (2017) who found that normal utilization of maize-based food sources exposes children to aflatoxin in the range of 0.14

to 120 ng/kg bwt/day. Aflatoxins have a substantial economic cost as well obliterating an expected 25% or a greater amount of the world's food crops every year. Aflatoxins, are primarily created by two firmly related fungi. *Aspergillus flavus* and *Aspergillus parasiticus*. When conditions are favorable, such as high temperatures and high moistness, these molds, which are typically observed on decaying and dead plant cover, can infect food crops, especially in tropical and subtropical climates (FAO/WHO, 2018).

This study laid out co-event and high aflatoxin levels in maize-based by household consumption. High aflatoxin levels could apparently be credited to poor post-harvest handling practices of maize grains. The range of detectable aflatoxin in Jowhar district both at the initial stage and after 2 months' storage was found to be much higher than the levels of recommended of 10ppb by WHO. Low rainfall during flowering and early pre-filling is linked to an increase in toxigenic fungal infection and aflatoxin growth (Udovicki *et al.,* 2019). The most of farmers in Jowhar district adopted inter-cropping with sesame, beans, and cow peas, which offered plant cover, reduced evaporate-transpiration, and provided much-needed nitrogen to the roots, these consequently reducing plant stress and restricting mycotoxin growth and development. The severe rains experienced during harvesting, post-harvest and storage might have contributed to the increase in Aflatoxin contamination after post-harvest processes. Some of the practices that can be attributed for the growth in aflatoxin include poor storage facility aeration, storage facilities that are overcrowded, and grain storage on the floor and next to the walls (Mbaisi *et al*., 2016). Several studies reported high aflatoxin levels in maize based food sources planned for human consumption in countries like Ghana (Agbetiameh *et* al 2019) and Nigeria (Ojuri *et* al., 2019).

4.6 Conclusions

The current study confirmed the presence of aflatoxin in maize that smallholder farmers kept and sampled. A high intake of aflatoxin was linked to high consumption while the levels of mycotoxins were beyond recommended safety limits. Due to the endemically contaminated local crop, consumers need to be informed about the importance of diversifying their meals while decreasing their daily consumption of maize.

CHAPTER FIVE: GENERAL CONCLUSION AND RECOMMENDATION

5.1 General conclusion

5.1.1 Post-harvest handling knowledge and practices of small-scale maize farmers in Jowhar district

Majority of small scale maize farmers in Jowhar have adequate knowledge on toxigenic mold contamination in maize foods such as moisture contest. Maize farmers are aware that inadequate drying (high moisture content) of maize raise the probability of development of aflatoxin contamination and drying maize to acceptable levels can help reduce the possibility of insects' attack, fungal proliferation and aflatoxin generation in maize. Although majority of respondents have limited knowledge on health effects of toxigenic molds due to lack of information on mold-related health issues in Somalia, there is no formal maize handling training for food safety, and no serious cases of aflatoxin outbreaks recorded. Sun drying of maize is the most preferred method as it uses a low- cost source of energy that is available naturally and is accessible to small-scale farmers. Nearly all respondents clean the storage facility and old grains from the previous season are removed before introducing the new maize into the storage facility. Steel metal barrels are used to store maize and it is the best method for long term storage.

5.1.2 Levels of intake of aflatoxin by maize consumers in Jowhar district, Somalia

This study discovered that maize-based foods contained aflatoxin, with levels were found to be ranged from 1.10 to 77.63 µg/kg after one month of storage, with a mean of 10.22µg/kg. Aflatoxin levels were observed to be between 2.59 to 81.13 µg/kg after two months of storage, with a mean of 14.41µg/kg of aflatoxin beyond EAC's recommended maximum limits. Poor post-harvest dealing with procedures of maize grains during transportation and storage may be to responsible for high levels of aflatoxin. Molds like *Aspergillus flavus* and *Aspergillus parasiticus* impact negatively on food crops at any stage of the supply chain, including during transportation. maize consumers are exposed to aflatoxin at levels that are above acceptable level. This would equally translate to approximately 145.4 µg/person/day on average with much higher intake levels expected within populations with higher concentration or consumption of highly contaminated maize based diets.

5.2 General recommendations

The study recommends raising awareness and promote good post-harvest handling methods by central ministry of agriculture through Hirshabelle state' ministry of agriculture, as well as provide effective maize storage facilities that extend shelf life and reduce the growth of toxigenic fungi to all stakeholders involved in maize production. To minimize fungal development,

maize farmers should be trained on advanced drying techniques to ensure grain for storage has the proper moisture content, which inhibits the development of toxigenic organisms and hence reduces mycotoxin production. To decrease the risk of grain contamination, farmers should be trained in post-harvest management measures including fungal control.

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APPENDIXS

APPENDIX I: POST HARVEST HANDLING PRACTICES QUESTIONNAIRE

A. DEMOGRAPHIC INFORMATION

Date of Interview		Name of Interviewer	
Name of Small-scale farmer			
Sex:	1 – Male 2 - Female		
Age			
Location /Area			
Size of Farm			
Crops grown on the farm			
Maize variety planted			

Education Level (Tick Correct)	1 - College/University 2 - Completed Secondary 3 - Completed primary 4 - Dropped from primary 5 - In primary 6 - In secondary 7 - Literate e.g., Adult Education 8 – Illiterate 9 - Pre-primary 10 - Others (specify)
Occupation (Tick Correct)	1 - Salaried employee 2 - Farmer 3 - Self-employment 4 - Casual laborers 5 - Student 6 - Housewife 7 - Unemployed 8- Others (specify) 9 - N/A

	9 - Pre-primary 10 - Others (specify)
Occupation (Tick Correct)	1 - Salaried employee 2 - Farmer 3 - Self-employment 4 - Casual laborers 5 - Student 8 - Housewife 9 - Unemployed 10 - Others (specify) 9 - N/A
Annual income what do you mean. Elaborate	

B. POST HARVEST HANDLING PRACTICES

	POST HARVEST PRACTICES		**Comments**	**Interviewer's remark**
1.	How do you harvest the maize from the farm?	1 - Casual Labourers 2 - Family 3 - Machinery		
2.	Are the farm equipment and Machinery cleaned and disinfected before being deployed to the farm?	1- Yes 2- No		

3.	For how long do you store the maize after harvesting	1- Less than three months 2- 3 to 6 months 3-7 to 9 months 4- 10 to 12 moths		
4	When is the Harvested maize stored	1- Directly after harvesting 2- Pre-stored for few days before being transferred to the main storage facility		
5	Do you remove old maize grains from the storage house before introduction of the new maize stalk?	1- Yes 2- No		
6	Which method do you use to treat the storage facility before the maize comes in?	1- Insecticide 2 - Smoke 3 - Manure 4 - Neem 5– other (specify)		
7	Do you store the maize together with other crops in the same storage house?	1- Yes 2- No		

8	Do you verify the moisture content of the Maize before, during and after storage and drying	1- Yes 2- No		
9	What is the mode of your transport of transport of your maize from the farm to the storage house?	1- By bicycle, 2- Motor vehicle, 3- Carriers on the head 4- donkey, Others (Specify)		
10	How do you dry the maize?	1 - Open sun drying, on ground 2 - Solar drier 3 - Others (specify)		
11	How long does it take to dry the maize?	1=less than 2 hours 2=2 days and over 3=2-8 hours 4=Do not dry		
12	Where do you store your maize?	1=special room, well ventilated 3=anywhere 2=special room, poorly ventilated 4=Do not store		

13	Do you own the structure that you store your maize grain in?	1- YES 2 -NO		
14	In which form are you storing maize?	1 - On cob without sheath 2 - On cob with sheath 3 - Shelled		
15	How do you shell the maize?	**1 -** By hand **2** - Shelling machine, **3** - Putting in a bag and hitting, - Others(specify)		
16	How do you package the maize before storage?	1- Polythene bags 2 - Crates/woven baskets 3 - Jute bags 4 – not packing – others (specify)		
17	What is the color of the maize after storage period?	1=retained color 2=big change in color 3=slight change in color		
18	Do you sort out the molded grain maize?	1- Yes 2- No		
19	What proportion of the maize grain do you lose to pests?	1 - 1-2 (90 kg bags) 2 - 3-4 (90 kg bags) 3 - > 4 bags (90 kg		

		bags)		

APENDIX II: POST HARVEST HANDLING KNOWLEDGE QUESTIONNAIRE

A. POST HARVEST HANDLING KNOWLEDGE QUESTIONNAIRE

	TICK APPROPRIATELY	**Feedback**	**Remarks**
1.	Aflatoxin contamination of maize is directly caused by storage of wet or not fully dried maize.	**True**	
		False	
2.	Rodents do not play a part in aflatoxin contamination of stored maize	**True**	
		False	
3.	Presence of damaged/broken maize increases the chances of aflatoxin contamination of stored maize.	**True**	
		False	
4.	Treatment of stored maize with insecticides prevents aflatoxin contamination.	**True**	
		False	
5.	Cancer in human beings can be caused by consumption of aflatoxin contaminated maize	**True**	
		False	
6.	Human beings cannot die within one-week after consumption of Aflatoxin contaminated maize	**True**	
		False	
7.	Consumption of aflatoxin contaminated maize cannot affect children's growth.	**True**	
		False	

8.	Mouldy maize is likely to be contaminated with aflatoxin.	**True**	
		False	
9.	Putting maize on the soil ground during harvesting, drying and storage cannot lead to aflatoxin contamination	**True**	
		False	
10.	Cooking maize or maize flour destroys aflatoxin and makes it safe for human consumption	**True**	

APPENDIX III: CONSUMPTION PATTERN FOR MAIZE MEAL QUESTIONNAIRE

A. DEMOGRAPHIC INFORMATION

Name of Interviewer		Date of Interview	
Name of Respondent			
Name of House hold head			
Relationship of Respondent to Household head			
Area/Location			
Sex: (Tick correct) applicable to all	Male=1 Female=2		

Age	1 = 18- 30 years 2 = 31-40 years 3 = 41 -50 years 4 = 51 -65 years 5 = Above 65 years
Education	1=University 2=Completed High school 3=Completed primary school 4=Dropped from primary school 5=In primary school 6=In secondary school 7=Literate e.g. Adult Education 8=Illiterate 9=Pre-primary 10= Others (specify)
Body weight(kg)	
Amount of maize consumed/day or /week	
Frequency of consumption	
Height(m)	
Marital status	1=Single 2=Separated 3=Married 4=Single 5=Divorced 6=N/A
Annual income in shilling Somali	

B. CONSUMER STUDY

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

8.	How many times in a week do you consume Maize?	1- Once 2- Twice 3- Thrice 4- Others (specify)		
9.	What unit quantity do you consume per day?	1- 100g 2- 250g 3- 500g 4- 1kg 5- >1kg 6- Others (specify)		
10	Do you clean the maize before preparing for consumption?	1 - Yes 2 – No		
11	Do you give molded maize to livestock?	1- Yes 2- No		