Aflatoxin Analysis in Staple Food Cereals and Assessment of Households' Awareness on its Management in Tharaka-Nithi County, Kenya

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Abstract
Aflatoxins are naturally occurring harmful toxins produced by the fungi *Aspergillus flavus* and *Aspergillus parasiticus*. Aflatoxin contamination is a cross-boundary and multifaceted problem that requires participation and involvement of both private and public stakeholders. Agriculture is the main economic activity of Tharaka-Nithi County, yet it is among the hot spots of aflatoxin in Kenya. The county is extremely vulnerable to climate-related risks; however, there is lack of local data on aflatoxin contamination to inform interventions chiefly due to lack of local research, testing facilities, and qualified personnel. The main purpose of this study was to analyze cereals used as staple foods for aflatoxin contamination and to evaluate households' awareness on the overall management of aflatoxin, and identify factors contributing to aflatoxin contamination. Eighty one samples were collected and laboratory analysis conducted using ELISA Kit. Aflatoxin levels in 25.8% of samples was above the Kenyan standards of 10ppb with 17.2% exceeding 20ppb. Aflatoxin levels in 44.4% of market samples exceeded 10ppb. The level of aflatoxin contamination was associated with the type of cereals and grains ($p<0.05$). There was no difference in mean level of aflatoxin in cereals from the study areas ($p>0.05$). Furthermore, there was no difference in mean level of aflatoxin in the cereals and grains collected from the markets and households ($p>0.05$). Majority of the farmers (84.7%) were aware of aflatoxin. However, detailed information on its management was scanty and inconsistent. Awareness creation on aflatoxin contamination to all stakeholders in the cereals value chains is needed for their concerted efforts in its control. Recognition of these barriers together with the opportunities for aflatoxin containment, the researcher hoped to improve the knowledge on aflatoxin management, health, and economic well-being of households and by extension the national food security.

Key Words: *Aflatoxin, Contamination, Food Security, climate-related, Staple Foods*

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1.0 Introduction
Tharaka-Nithi is a county of great geographic, ethnic and cultural wealth and diversity, yet it faces significant social, economic, and environmental challenges. Given the excessive temperatures and humidity experienced in the county, cereals structure are ideal substrates for aflatoxin-

producing fungi. Several strategies for preventing this aflatoxin menace have been proposed in the county, but the implementation uptake among the farmers is very low. Principal prerequisite for entry into the food markets globally and even access to the high-value local markets in the growing nations currently is food safety (Ashraf et al., 2009).

At the same time mycotoxins excert a substantial health burden in the growing nations especially among the poor populations (Leroy et al., 2015). Epidemiologic investigations shows that contamination is predominant in Kenya, affecting mainly maize which is the main staple food. Consumption of aflatoxin contaminated foods has been shown to have negative impacts on health and loss of life if utilized in high doses. Chronic sub-lethal doses have been linked to cancer with limited studies showing an association between aflatoxin exposure and stunting in children (Strosnider et al., 2006).

In spite of the fact that this contamination is a significant problem, developing countries no longer frequently test the main foods for aflatoxins, leading to the consumption and sale of unsafe food (IFPRI, 2011). In Kenya, aflatoxicosis outbreaks have been reported in Eastern Kenya, which is a renowned global aflatoxin hotspot. Epidemiologic investigations have linked aflatoxicosis outbreaks to consumption of poorly stored locally produced maize (Daniel et al., 2011). The explanations for the absence of consistent efforts to eliminate this contamination in growing nations is multifaceted. A multi-sectoral approach which is needed to recognize the potential risks of aflatoxin contamination is lacking in the developing countries (Wild, 2007).

In Tharaka-Nithi, sorghum and millet are grown on 45% of the cultivated land. Of the 45,000 sorghum producing farmers in Kenya, 17,000 farmers (37.8%) are from Tharaka-Nithi County (MOALF, 2017). Regrettably, these cereals are susceptible to aflatoxin contamination. Poor infrastructural support and lack of awareness hinder mitigation of aflatoxin contamination in the county (MOALF, 2017).

The complex and interconnected nature of aflatoxin contamination facing the county requires a holistic, multi-sectoral approach that promotes system-wide collaboration and innovative solutions leveraging available resources to get an all-encompassing perspective on challenges and to collaborate on aflatoxin control. This will catalyze public-private partnerships and leverage system-wide investments creating a pathway for smallholder farmers to reap the benefits from access to markets, infrastructure, and inputs. For a county where approximately 80% of the population is engaged in agricultural activities and depends on agriculture for food, income and livelihoods, partnerships in agriculture and nutrition are extremely important (MOALF, 2017). Through the process, stakeholders agree on actions to collaboratively reduce inefficiencies and barriers in the value chain by taking actions that promote adoption of cost-effective aflatoxin management practices and efficient technologies.

Given the progressively stronger proof that aflatoxins are both a food safety and public health issue, the researcher in this study aims to analyze aflatoxin levels in cereals used as staple foods, and to evaluate households' awareness on the overall management of aflatoxin, and identify factors contributing to aflatoxin contamination in the county. The purpose is to not only provide context-specific information on aflatoxin occurrence but to also make recommendations to mitigate this menace by encouraging the county government to engage all the stakeholders to create awareness on aflatoxin management, and to provide resources required in its control. The study findings recommend the use of multi-sectoral approach to drive the engagement process.

2.0 Materials and Methods

Study Design

The study was an analytical cross-sectional design. Cereals and grains samples were collected in September 2019 for aflatoxin analysis. During the sample collection, observations were also done to provide insights on the storage and post-harvest management practices. The collected facts comprised of the views gathered from discussions at every household on pre-harvest and post-harvest technologies together with collected samples for laboratory testing.

Field of Study

Tharaka-North and Tharaka-South Sub-counties constituted the study areas. The two Sub-counties have three Wards (Marimanti, Gatunga, and Mukothima) with a total of 24 Sub-locations. The size of the two Sub-counties is 1,569 Km^2 out of a total of 2,409.5 Km^2 which is approximately 65% of the county's geographic area. The estimated number of residents in the two Sub-counties is 136,036 (KNBS, 2019 Estimates).

The population living in this area are at the highest risk of aflatoxins exposure. The study area was relevant because they are the two-major grain producing areas of Tharaka-Nithi County.

Sample Size and Sampling Technique

Villages that cultivated the crops and households that had some stock of the crops of interest were listed. One village was selected from each Sub-location. Four households per village were randomly selected for sample collection among all the eligible households which could be sampled based on the study protocols. A total of 24 sorghum samples, 24 pearl millet samples, and 24 maize samples were collected. To ensure collection of a realistic amount of samples, sampling was carried out shortly after harvesting. Three major open-air markets within the two study areas were also selected based on size. Sample quantities of 1kg of each cereal type were obtained from each market. The researcher therefore had 72 samples from the households and 9 samples from the markets. During the collection of the samples, questions pertaining to the source of cereals and grains currently being utilized in the households were asked. In addition, questions were asked about the awareness of aflatoxin contamination. Sampling site GIS coordinates, date of collection, and precise sample identifier were included on the sample labels. Hermetic sealed paper carriers were used to transport the samples to the laboratory for analysis.

Data Analysis

Analysis for Aflatoxin levels was conducted using the ELISA Kit model STAT FAX 4700 Microstrip reader**.** ELISA method used is centered on direct enzyme-linked immunosorbent assay. This method permits direct ascertainment of the levels of mycotoxins in samples. In this method, the magnitude of contamination is compared to a recognized concentration of a control sample. To extract total aflatoxins from the ground sample, 70% methanol solution is used. Free aflatoxin and conjugate contest for antibody binding sites when the removed sample and HRP-conjugated aflatoxin are combined and transferred to antibody coated microwells. Substrate is added after a wash step and colour changes as a result of the presence of the bound conjugate. The levels of aflatoxins in the sample is inverse to the resultant color concentration.

The data obtained during the household interviews was subjected to statistical analysis using SPSS version 22 to evaluate the farmers' farm and crop management practices to minimize aflatoxin contamination. To establish the existence of relationship between the types of cereals and grains and the levels of aflatoxin contamination, Chi-square test for association was applied. To determine if there was a difference between the mean level of aflatoxin in the cereals and grains sourced from the two study regions, t-Test for Equal Means was used.

Ethical Considerations

The Kenya Methodist University Scientific and Ethics Review Committee (SERC), National Commission for Science, Technology and Innovation (NACOSTI), and the County Departments of Agriculture, Health and Education provided the required study ethical review and ethical approval. All the research respondents approved of their participation by giving a verbal consent and signing the consent form.

3.0 Results and Discussions

Social Demographic Factors

The data in table 1 illustrates the socio-demographic characteristics of sex and educational levels of the study respondents. There were more women (64%) than men (36%) among the study respondents. Since socio-economic characteristics are known to have effects on the levels of aflatoxin contamination, we assessed the study respondents' educational levels to establish their knowledge on aflatoxins contamination. Attending primary school only was considered as low level of education. Majority of the farmers (56.9%) in the region have low education. Higher educational level increased the chances of the farmers to have heard about aflatoxins.

Table 1

Social Demographic Characteristics and Awareness of Aflatoxin Contamination

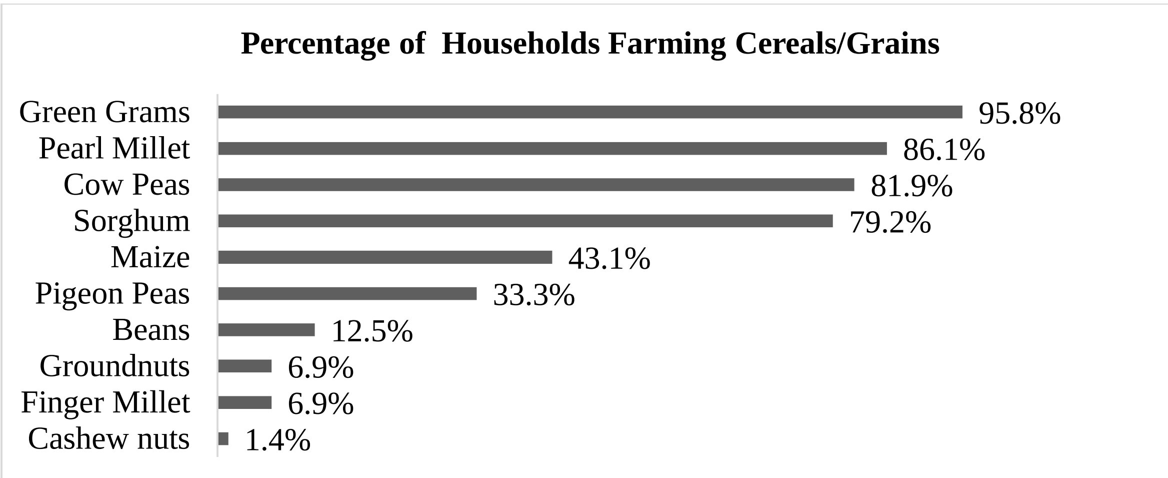
				Have You Heard About Aflatoxin			
				Yes		**No**	
Characteristics (n=72).	**Categories**	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**
Sex	Male	26	64	25	96.2	1	3.8
	Female	46	36	36	78.3	10	21.7
Educational Level	Primary	41	56.9	33	80.5	8	19.5
	Secondary	18	25	16	88.9	2	11.1
	College	8	11.1	8	100	0	0
	Vocational	2	2.8	2	100	0	0
	Other	3	4.2	2	66.7	1	33.3

Type of Cereals and Grains Farmed

Data on type of cereals farmed by the study respondents reveal that green grams (95.8%), pearl millet (86.1%), cow peas (81.9%), and sorghum (79.2%) are the type of cereals and grains commonly farmed in the study area and constitute the main staple foods (Figure 1).

Figure 1

Type of Cereals and Grains Farmed



Analysis of the data for the source of cereals and grains eaten at home reveal that majority of the households (98.6%) were consuming homegrown cereals and grains (Table 2), but they were also purchasing other cereals and grains not produced in the study area from the markets for households' consumption.

Table 2

Source of Cereals and Grains Eaten at Home

Source of Cereals	Number of Households	Percent of Households
Homegrown	71	98.6
Markets	67	93.1

The Levels of Aflatoxin in Cereals

A total of 72 samples were collected from households together with 9 samples from the markets (n=81). Overall, aflatoxin contamination in 25.8% of sampled cereals was above the legal threshold of 10ppb Kenyan standards with 17.2% exceeding 20ppb (Table 3). The level of aflatoxin in the sampled cereals ranged from <1ppb to 30.79ppb. The findings indicated that pearl millet and sorghum were least affected by aflatoxin with maize being the most affected. From all the collected maize samples from the households and markets, 59% of the maize was not suitable for human or animal consumption.

Table 3

Total Aflatoxin Ranges of Cereals Sampled From Households and Markets

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

Table 4

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

Chi-Square Tests

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

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

Based upon Chi-Square test for association, it was evident that level of aflatoxin was associated with the type of cereals and grains ($p<0.05$). Therefore, cereals and grains levels of contamination differed as they were exposed.

Households' Awareness on Suitable Conditions for Storage of Foods Regarding Aflatoxin Contamination

Since awareness is vital in encouraging farmers to plan suitable approaches for controlling the problem of aflatoxin contamination, the study sort to evaluate whether households were aware of aflatoxin and if poor storage practices increase the chances of contamination. The results indicate that 84.7% of the study respondents had knowledge about aflatoxins and that poor storage practices promote the presence of aflatoxins in foods. However, in-depth information on what aflatoxins are and the effects of their contamination was scanty and inconsistent. Regardless of the fact that most of the study respondents had heard about aflatoxins, only 26.8 % had attended training related to storage and safe handling of foods.

Table 5.

Knowledge on Aflatoxins

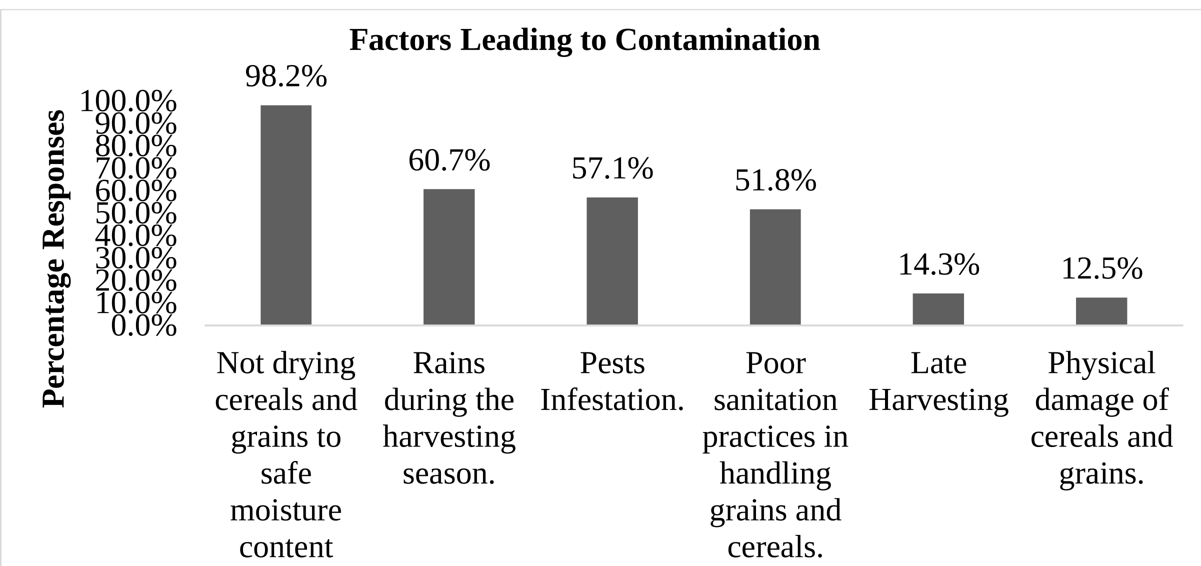
Variables	Responses	Frequency	Percentage (%)
Awareness of Aflatoxin	Yes	61	84.7
	No	11	15.3
Training Related to Storage and Safe Handling of Foods	Yes	19	26.8
	No	52	73.2
Do Poor Storage Conditions Promote the Presence of Aflatoxins in Foods	Yes	61	84.7
	No	11	15.3

Factors Contributing to Aflatoxin Contamination in Cereals and Grains

Good Agricultural Practices (GAP) are necessary for prevention of aflatoxin contamination. The main factor that encouraged contamination of aflatoxin was not drying cereals and grains to safe moisture content (98.2%) as shown in Figure 2. Other significant factors were: rains during the harvesting season (60.7%), pest infestation (57.1%), poor sanitation practices in handling grains and cereals (51.8%), late harvesting (14.3%), and physical damage of cereals and grains (12.5%). The households' interviews revealed that the farmers do not have adequate information on what encourages aflatoxins contamination. This is a great challenge since farmers' adoption of the good agricultural practices which includes ideal farm and crop management practices to minimize aflatoxin contamination is influenced by the farmers' enhanced awareness.

Figure 2

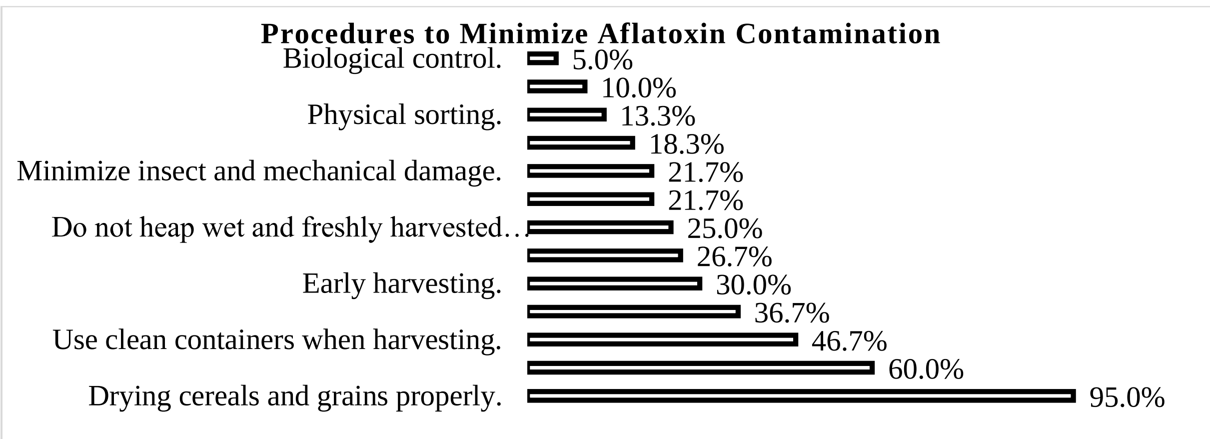
Factors Encouraging the Contamination of Aflatoxins in Foods



The study also assessed procedures to minimize aflatoxin contamination in food, and 95% of the respondents noted that drying of cereals and grains properly minimize aflatoxin contamination (Figure 3). Other significant methods supported included: harvesting of completely matured crops at recommended low moisture content (60%); use of clean and dry containers for collection and carrying harvested crops (46.7%); and avoiding contact of harvested crop with dirt, soil and other contaminants (36.7%). Discussions and observations made during the households' visits and assessment of the cereal bulking stores confirmed that the farmers do not have adequate information and do not practise Good Agricultural Practices (GAP) necessary for aflatoxin management.

Figure 3

Level of Knowledge on Procedures to Minimize Aflatoxin Contamination in Food



Awareness is vital in encouraging farmers to plan suitable approaches for controlling the problem of aflatoxin contamination (Marechera & Ndwiga, 2014). Socio-economic set-up of Tharaka Nithi County, which is resource constrained, makes it hard for majority of the residents to proceed to secondary education. Consequently, majority of the farmers had low education which compromises their awareness on aflatoxin contamination.

The findings concurs with another study in Lower Eastern Kenya on strategies to control aflatoxins which indicates that populations with higher educational levels have higher chances of being more aware of aflatoxin contamination than people with low educational levels (Marechera & Ndwiga, 2014). Farmers in the study area reportedly farm more of pearl millet and sorghum. The farmers prefer planting these cereals as part of their traditions, as their main food, ease of production, and because of their ready market. These crops are also drought resistant and give good harvests despite the region receiving low rainfall. Data for the source of cereals and grains eaten at home revealed that majority were homegrown, but households were also purchasing those not produced in the study area from the markets.

This stresses the need to control cereals and grains trading, and the marketing channels in the county to minimize aflatoxin contamination among all the stakeholders in the value chains. A similar study in Nandi and Makueni counties reported that homegrown maize was the main source of food for a majority of households (60-90%) in the two counties which is a major source of aflatoxin exposure (Kang'ethe et al., 2017).

Pearl millet and sorghum were least affected by aflatoxin, while maize was the most affected. This confirms analysis reports on maize collected from households during aflatoxicosis epidemics in Kenya, where extreme aflatoxin levels were detected. Notably, inappropriately warehoused maize was the cause of the 2004 severe aflatoxicosis epidemic in Eastern and Central Provinces of Kenya. The locally produced maize was found to be stored under damp conditions, hence, encouraging aflatoxin contamination during storage (Azziz-Baumgartner et al., 2005 & CDC, 2004).

Analysis of the aflatoxin levels in maize both at the households and market levels confirms previous studies done in Kenya to evaluate aflatoxin contamination of maize products found in markets. These studies reveal that most of the maize in the markets contain aflatoxin amounts greater than the Kenyan standards (Lewis et al., 2005).

Chi-Square test for association was used to establish whether a relationship exists between the types of cereals and grains and the levels of aflatoxin contamination. Based upon Chi-Square test, it was evident that level of aflatoxin was associated with the type of cereals and grains ($p<0.05$) and therefore, cereals and grains levels of contamination differed as they were exposed. The storage duration, kind of storage, temperatures during production and storage, type of soil, moisture, and composition of nutrients in the cereals and grains determine the level of contamination in different cereals and grains.

Majority of the respondents were aware of aflatoxins. However, the farmers' knowledge and skills on aflatoxin management was rather low. Therefore, heighten the gravity of aflatoxin contamination among farmers and provide a platform for the adoption of management practices that reduce aflatoxin contamination, there is need for continuous farmer-sensitization campaigns. Awareness creation and sensitizations to all the stakeholders in the cereals and grains value chains is needed to manage the contamination problem and increase the adoption of the recommended practices to improve the quality of food at home and in the markets.

Failure to dry cereals and grains to safe moisture content was cited as the main factor that encouraged contamination. Unpredictable weather nowadays is a concern because mature crops are usually rained on when ready for harvest and during drying; hence increasing the chances for aflatoxin contamination. Drying of the cereals and grains reduces the moisture content, consequently inhibiting the growth of fungi which leads to aflatoxin production and the resultant contamination. The physical damage to the cereals and grains increases the chances of the mycotoxins penetration thus the growth of fungi which leads to aflatoxin production. Poor sanitation practices when handling the cereals and grains leads to soiling of the crops resulting in fungal contamination and aflatoxin production (Moturi, 2008).

During discussions with the respondents, majority reported using tractor-propelled shelling machines. These shelling machines have the capacity to cause physical damage to the cereals and grains if not well calibrated to suit the different varieties. The resultant broken cereals provide routes for the penetration of aflatoxin-producing fungi. These observations were similar to the findings of a study on the situation analysis of the maize value chain in Kenya which recommended the standardization of these shelling machines for the farmers to effectively mitigate this problem (Kang'ethe, 2011).

Discussions and observations made during the households visits and assessment of the cereal bulking stores corroborated the findings that the farmers have limited awareness on food safety matters. Information on modern technologies e.g. the new biocontrol product called Aflasafe to fight aflatoxin contamination was lacking in almost all the interviewed farmers. This confirms the reports that nearly all farmers in Kenya are not aware of biocontrols recommended to protect the crops from the harmful effects of aflatoxin (Ngotho, 2019). This underlies the need for the government through the Department of Agriculture to conduct more sensitizations for the farmers on biocontrol technologies and subsidize the cost of aflatoxin chemicals.

4.0 Conclusion

Given that the staple foods in the county are contaminated with aflatoxins, the populations living in the county are chronically exposed to aflatoxins through their diets. This is of concern given the negative impact of chronic aflatoxin exposure on health; thus, the need for promotion of dietary diversity to reduce this exposure. Furthermore, there is need for stepping up farmers' sensitizations for improved households' awareness on better aflatoxin management techniques.

Multi-faceted issues require multi-stakeholder engagement. Aflatoxin contamination is a multi-sectoral problem which a single sector cannot address. For improved health, financial security and national food security, all the potential cereals and grains stakeholders; namely, government authorities, farmers, processors, millers, traders, and research institutes need to work together in the overall management of aflatoxin.

By engaging diverse stakeholders, the county will have great potential to minimize aflatoxin contamination risks and maximize returns for farmers. This cross-disciplinary collaboration catalyzes all the stakeholders across the sectors to envision a desired future and develop an action plan on the strategy to deal with aflatoxin contamination in Tharaka-Nithi County.

5.0 Recommendations

For sustainable impact, the national government needs to partner with the county government and other cereals and grains value chain players to reach all the farmers with support and information on aflatoxins management. This collaborative action will facilitate approaching the aflatoxin contamination challenges from multidisciplinary perspectives and with stakeholders from multiple sectors. This strategy will pave the way for collaboration between public and private sector while investing in smart and enduring solutions to problems which will bring about broad and sustained collective impact.

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