SURVEY REPORT ON AFLATOXIN PREVALENCE AND INCIDENCE IN UGANDA



SUBMITTED TO FEED THE FUTURE (FtF) UGANDA AGRICULTURE RESEARCH ACTIVITY

November 2022

Contents

EXECUTIVE SUMMARY 4
Methodology 4
Key findings 4
Gaps and challenges of aflatoxin management in Uganda 6
Conclusion 6
ACRONYMS 8
1.0 INTRODUCTION 10
1.1 Background 10
1.2 About the Feed the Future (FtF) Uganda Agriculture Research Activity 11
2.0 ABOUT THE TASK 11
2.1. Objectives 11
2.2 Terms of reference 11
3.0 METHODOLOGICAL APPROACH 12
3.1 Desk reviews 12
3.2 Sampling of maize, groundnuts, cassava, sorghum and livestock feeds 12
3.4 Development of a matrix of key stakeholders addressing aflatoxin contamination in Uganda 16
3.5 Documentation of interventions, gaps and challenges in aflatoxin management 16
4.0 RESULTS AND DISCUSSION 16
4.1 Desk review 16
4.1.1. Prevalence data on aflatoxins in food and feed commodities 16
4.1.2 Aflatoxin exposure in Uganda 23
4.1.3 Health impacts of aflatoxins 24
4.1.4. Trade impacts of aflatoxins 27
4.2. Aflatoxin levels in Food and Feed 28
4.3 Stakeholders involved in aflatoxin control/management 30
4.4 Gaps and challenges of aflatoxin management in Uganda 39
5.0 CONCLUSIONS AND RECOMMENDATIONS 41
5.1 Conclusions 41
5.2 Recommendations 41
6.0 REFERENCES 42
7.0 List of annexes 44
7.1 Letter from Kenya's Agriculture and Food Authority banning maize imports into Kenya 45

7.2 Aflatoxin contamination in maize from different districts of Uganda 45
7.3 Aflatoxin contamination of groundnuts from different districts of Uganda 46
7.4 Aflatoxin contamination of cassava from different districts of Uganda 46
7.5 Aflatoxin contamination in sorghum from different districts of Uganda 46
7.6 Aflatoxin contamination of animal feeds from different districts of Uganda 47

EXECUTIVE SUMMARY

Introduction

Uganda has made considerable efforts to ensure food security of its population. However, the safety of food in the country is still a major issue due to aflatoxins produced by the fungi *Aspergillus flavus* and *A. parasiticus* that contaminate inadequately dried foodstuffs including maize, groundnuts, sorghum, cassava, spices and fish. Once produced, the toxins remain in the commodity for the subsequent parts of the value chain until consumption. This has great impact on food security, health and trade. Although several studies have been conducted on aflatoxin incidence and prevalence in Ugandan food products, the full extent of impact from exposure has not yet been documented. For these reasons, Feed the Future (FtF) Uganda Agriculture Research Activity conducted a rapid assessment of aflatoxin prevalence and incidence in Uganda during the period August-November, 2022 with three objectives;

1. Understand the prevalence and incidence of aflatoxin contamination for the selected (commodities maize, groundnuts, livestock feed, dried cassava and sorghum) in the key commodity markets in Uganda;
2. Develop a holistic model for addressing the aflatoxin challenge encompassing research and innovation, value-chain handling, and policy and enforcement
3. Collaborate with lead consultant undertaking the aflatoxin socio economic study in developing sustainable solutions in managing the aflatoxin challenge

Methodology

The study followed the guidelines given by USAID Uganda Feed the Future Agriculture Research Activity and also used standard procedures where appropriate. Desk reviews were conducted on published articles in refereed journals and books as well as in the form of grey literature presented as Government reports, donor reports, policy documents and media reports, amongst others, on interventions for the selected commodities (maize, groundnuts, livestock feed, cassava, sorghum and animal feeds). In order to determine aflatoxin contamination of the selected commodities, the food and feed samples were obtained from farmers and markets in the regions where these are produced and consumed most in the country. The samples were analysed for aflatoxins using the ELISA technique. In order to develop a matrix of key partners, key informant interviews (KII) were conducted with the actors at different stages of susceptible commodity value chains. The actors were categorized into eight groups and in each group, the stakeholders involved were identified and their activities addressing aflatoxins were documented. The information obtained from desk reviews and matrix of key stakeholders, was used to document gaps and challenges in aflatoxin management in the country.

Key findings

Desk review

Aflatoxins studies in Uganda started in 1965 and have continued to-date. However, there were no studies conducted during the period 1972-1989 due to political instability that led the researchers at that time leave the country. Most serious studies have been conducted during the period 2005-2022 and the majority have concentrated mainly on determining aflatoxin levels in foods and feeds. Results from most of the studies indicate that aflatoxin contamination in staple foods is wide spread across the country and a large proportion of the samples contained aflatoxin levels that were above the national limit of 10 ppb. Exposure studies to the toxins in humans have been limited due to inadequate laboratory infrastructure to quantify the aflatoxin biomarkers in blood. For the few studies done, human exposure to aflatoxins are high, including exclusively breast-fed children.

The current review further indicates that only one study conducted by PACA in 2014 estimated the impact of aflatoxins on trade of maize, sorghum and peanuts using the CGE Model. Using the financial year 2013/14 as a reference point, the study findings indicated that failure to sell aflatoxin contaminated grains resulted into loss of US$ 7.48 million (Ugx 27.7bn) and in the same year, sales of the health sector goods and services to households and Government increased by 0.48% (US$ 1.86) to finance medical costs associated with aflatoxin related illnesses. The information reported by PACA have some inaccuracies due to informal trade that goes on between Uganda and neighbouring countries that is not documented, some or all the grains rejected due to aflatoxin contamination may be channeled in the domestic or regional markets and, there is no disparity between prices of aflatoxin contaminated foods and aflatoxin-free foods. Furthermore, during the period 2013-2021, there has been rejection of Ugandan maize by Kenyan Government leading to loss of billions of Uganda shillings. For these reasons, a further study on the economic impact of aflatoxins to Uganda needs to be conducted.

Aflatoxin contamination along the animal feed value chain is not well documented in Uganda. During the current study, the consultant was only able to access two published studies on aflatoxin contamination in animal feeds in Uganda; one assessed both ingredients for poultry feeds and the final products among small scale and large scale processors and the other on the levels of aflatoxins in ingredients and locally processed commercial fish feeds. It is important to note that for both studies, most of the samples contained aflatoxin levels above the national tolerable of 20 ppb for animal feeds. Given that there is limited regulation among the livestock feed sub-sector in the country, the problem of aflatoxin contamination could be much bigger than revealed by these two studies.

Aflatoxin levels in foods and feeds

Majority of the samples (above 76%) of maize, groundnuts, cassava and sorghum during the current study, had detectable aflatoxins. Groundnuts had the highest (90%) incidence of aflatoxins followed by sorghum (83%). Groundnuts recorded the highest mean aflatoxin level (32.93 ppb) and highest level of aflatoxin (460 ppb). Apart from cassava whose overall mean aflatoxin contamination levels were 9.94, the rest of the foodstuffs had their mean levels above the UNBS/EAC regulatory limit of 10 ppb. For maize, groundnuts and sorghum, more than 50% of the samples would not be fit for trade and human consumption as these were above 10 ppb.

For animal feeds, the majority (above 76%) had detectable aflatoxin levels with Layer's mash recording the highest (100%) incidence of aflatoxins. Sow and weaner meal had the highest mean (30.58 ppb) aflatoxin content followed by cattle feeds (30.43 ppb). Cattle feeds recorded the highest proportion of samples with aflatoxin levels above the UNBS/EA limit (20 ppb) for animal feeds. Overall, dog feeds had the lowest aflatoxin levels possibly because majority were imported.

Stakeholders involved in aflatoxin control/management

A total of eight (8) categories of stakeholders were identified. These were Government Ministries & Departments (including Regulatory Agency), Research and Innovation Institutions, Academia, NGOs/CBOs/Companies, Testing services, Suppliers of Mycotoxin testing equipment and supplies, RECs and Development Partners. Based on the activities being done, it appears academia takes a lead in addressing issues of aflatoxins. These stakeholders need to be coordinated in the country to streamline work and avoid duplication of activities.

Gaps and challenges of aflatoxin management in Uganda

The gaps and challenges were obtained through interaction of the consultant with various stakeholders during KII, in coming up with the matrix, during literature review and also during the Annual Performance Review Meeting of Feed the Future Uganda-Agricultural Research Activity held November 14 -18, 2022. The following are the identified gaps and challenges (not in order of priority) and have been explained in details in the report.

1) Inadequate aflatoxin awareness, advocacy and management strategies
2) Weak coordination among the stakeholders involved in aflatoxin management
3) Inadequate implementation and enforcement of standards for aflatoxin prevention and management
4) Research gaps in the areas of aflatoxin management/control, alternative use of contaminated foods, iinadequate data on aflatoxin health-related issues in humans and animals; no comprehensive countrywide food analysis and exposure assessment have been done, inadequate uptake of research results by the end users as well as mapping aflatoxin contamination of food in the country correlating it with food consumption, cancer and other aflatoxin-related health challenges.
5) Limited availability and application of recommended appropriate technologies
6) Inadequate investment in aflatoxin testing infrastructure
7) Failure for the country to put into action the Uganda Aflatoxin Mitigation Action Plan of 2018/19-2023/24
8) No budget allocation from Government for aflatoxin management:
9) Lack of a Food Safety Law

Conclusion

Results of the current rapid assessment of aflatoxin prevalence and incidence indicate that aflatoxin is still a major problem in this country for both food and feed commodities as attested by the high percentage of samples above the regulatory limits. Although a number of stakeholders are currently

involved in addressing the problem, these need to be coordinated. There are gaps and challenges that need to be immediately tackled to reduce the aflatoxin health and economic impacts. This requires a holistic approach involving all stakeholders in the value chains of the susceptible commodities, Government of Uganda should take the lead.

ACRONYMS

ACDP	Agricultural Cluster Development Project & Agricultural Value Chain Development Project
AFA	Agriculture and Food Authority
AFB	Aflatoxin B group
AFM	Aflatoxin M group
ATWG	Aflatoxin Technical Working Group
CBO	Community Based Organization
COMESA	Common Market for East and Southern Africa
DALYs	Disability Adjusted Life Years
DFTN	Department of Food Technology and Nutrition
EAC	East African Community
ELISA	Enzyme-linked Immunosorbent Assay
FAO	Food and Agriculture Organization
FtF	Feed the Future
CGE	General Equilibrium Model
DGLV	Dark Green Leafy Vegetables
GAP	Good Agricultural Practices
GHP	Good Hygienic Practices
GMP	Good Manufacturing Practices
GPC	General Population Cohort
GSP	Good Storage Practices
HPLC	High Performance Liquid Chromatography
IARC	International Agency for Research on Cancer
IEC	Information Education and Communication
IITA	International Institute of Tropical Agriculture
KII	Key informant Interviews
LC-MS	Liquid Chromatography Mass Spectroscopy
MAAIF	Ministry of Agriculture Animal Industry and Fisheries
MOH	Ministry of Health
MTIC	Ministry of Trade Industry and Cooperatives
NaCRRI	National Crops Resources Research Institute
NARO	National Agricultural Research Organization
NaSSARI	National Semi-Arid Resources Research Institute
NGO	Non-Government Organization
NDP	National Development Plan
OPM	Office of The Prime Minister
PACA	Partnership for Aflatoxin Control in Africa
PMB	Produce Marketing Board
PPB	Parts Per Billion
RCCS	Rakai Community Cohort Study
REC	Regional Economic Community
SAM	Social Accounting Matrix

TGCU	The Grain Council of Uganda
UBOS	Uganda Bureau of Statistics
UMMSC	Uganda mycotoxins Mitigation Committee
UN COMTRADE	United Nations Import and Export Statistics
UNBS	Uganda National Bureau of Standards
USAID	United States Agency for International Development
WHO	World Health Organization
WFP	World Food Programme
UMFSNP	Uganda Multisectoral Food Security and Nutrition Project

1.0 INTRODUCTION

1.1 Background

Uganda has made considerable efforts to ensure food security to its population. The overarching 3rd National Development Plan (NDP) 2020/21-2024/25 sets out 18 programmes with agro-industrialisation providing the main thrust alongside human capital development, natural resources management, community mobilisation and mind-set change. Accelerating the development of value chains that are competitive and have high returns on food security, incomes and nutrition is critical at this juncture of Uganda's development. However, these efforts are consistently threatened by food safety concerns as a result of a number of hazards that contaminate food. Amongst these hazards are aflatoxins.

Aflatoxins are highly toxic poisons produced mainly by the moulds *Aspergillus flavus* and *A. parasiticus*. The moulds infect the crop pre and post-harvest and can produce aflatoxins when moisture and temperature conditions are favourable. Aflatoxins frequently contaminate several crops including maize, groundnuts, tree nuts, herbs, chilies and spices, and once produced, the toxins remain in the crop for the subsequent parts of the value chain until consumption. The Food and Agriculture Organization (FAO) of the United Nations estimates that 25% of the food produced worldwide is contaminated with aflatoxins, Uganda being one of the countries where this menace has been reported.

The impacts of aflatoxins on food security, health and trade have been extensively documented and include: direct loss of food commodities, leaving vast populations exposed to hunger; immunosuppression, stunting and cancer as long-term health consequences; and acute consequences that include death; and lost opportunities in trade that translate to lost livelihoods. Due to the increasing recognition of the impact of aflatoxins on human health and trade, food regulatory authorities in the East African Community (EAC) countries have set and enforced limits for aflatoxins in traded food. If a partner state is not able to enforce aflatoxin regulations, contaminated foods which do not meet export standards cannot be traded across borders and, Uganda has had considerable volumes of maize rejected because of high levels of contamination by these toxins.

Although several studies have been conducted on aflatoxin incidence and prevalence in Ugandan food products, the full extent of impact from exposure has not yet been documented partly due to inadequate data on impact of aflatoxins on trade as a result of lack of proper records as well as rampant informal trade across porous borders. During the period 2014-2016, Uganda conducted the Country-led Situation Analysis for Mitigation of Aflatoxins supported by the Partnership for Aflatoxin Control in Africa (PACA) and came up with an Action Plan. However, this action plan has never been implemented and now it has been overtaken by events. The aflatoxin negative impacts have continued to affect the country requiring a comprehensive, systematic and integrated approach, involving Government and private companies in agricultural value chains of affected commodities, farmers, development partners, and research organizations to invest in a holistic and integrated approaches to better manage the mycotoxin challenge in Uganda.

1.2 About the Feed the Future (FtF) Uganda Agriculture Research Activity

The FtF Uganda Agriculture Research Activity is both a research and a development initiative implemented by NARO that aims to promote use and commercialization of improved crop and livestock technologies with yield and nutrition enhancing characteristics.

The Activity seeks to achieve three specific objectives; i) Facilitate the release and commercialization of varieties, ii) develop improved crop and animal production and management technologies in response to emerging threats and market demand and iii) align research with market needs, and mobilize additional domestic resources to support agricultural research.

In line with objective ii, and iii above; the activity seeks to identify, validate and scale-up aflatoxin management options for improved grain standards and food safety. However, for this to be realized, there is need to understand the magnitude of the mycotoxin challenge and engage key stakeholders implementing various aflatoxin management interventions in order to develop holistic and integrated approaches to better manage the menace.

It is against this background that USAID Feed the Future Uganda Agriculture Research Activity conducted a survey on aflatoxin prevalence and incidence in Uganda, identified the stakeholders involved in addressing this problem and the gaps/challenges associated with .

2.0 ABOUT THE TASK

The task was conducted countrywide during the period July-October, 2022 and targeted relevant stakeholders in the value-chains of maize, groundnuts, cassava, sorghum and animal feeds in Uganda.

2.1. Objectives

The task had the following specific objectives;

1. Understand the prevalence and incidence of aflatoxin contamination for the selected (commodities maize, groundnuts, livestock feed, dried cassava and sorghum) in the key commodity markets in Uganda.
2. Develop a holistic model for addressing the aflatoxin challenge encompassing research and innovation, value-chain handling, and policy and enforcement.
3. Collaborate with lead consultant undertaking the aflatoxin socio economic study in developing sustainable solutions in managing the aflatoxin challenge

2.2 Terms of reference

The task had six (6) terms of references namely;

1. Develop a data collection protocol including tools and appropriate time frame;

2. Conduct a rapid assessment of aflatoxin contamination in the selected commodities including its occurrence;
3. Conduct a desk study on aflatoxin interventions for key commodities: maize, groundnuts, livestock feed, dried cassava and sorghum. The study shall include previous and ongoing efforts in areas of interventions such as research, testing services and communication;
4. Develop a matrix of key partners, detailing their current activities in aflatoxin management. The matrix shall be categorized into research and innovation, capacity building, supportive services such as testing, and information dissemination /outreach;
5. Document interventions, gaps and challenges in aflatoxin management.
6. Prepare a report of the findings of the study;
7. Develop a joint report collaboratively with lead consultant undertaking the aflatoxin socio-economic study.

3.0 METHODOLOGICAL APPROACH

The study followed the guidelines given by USAID Uganda Feed the Future Agriculture Research Activity with modifications where standard procedures were required.

3.1 Desk reviews

Desk studies were conducted to review aflatoxin interventions for the selected commodities (maize, groundnuts, livestock feed, cassava and sorghum). Information was reviewed from published articles in refereed journals and books; as well as in the form of grey literature presented as government reports, donor reports, policy documents and media reports, amongst others. The Information documented through desk reviews included;

- Factors responsible for aflatoxin contamination
- Previous and ongoing efforts in areas of intervention/control including research, testing services and communication
- Prevalence data on aflatoxins in food and feed commodities.
- Health impacts, including exposure assessment, mortalities (deaths), chronic and acute toxicity (aflatoxicosis)
- Economic impacts including effects on trade

3.2 Sampling of maize, groundnuts, cassava, sorghum and livestock feeds

Food samples

The food samples were obtained from farmers and markets in the regions where these crops are produced and consumed most in the country based on the Uganda Annual Agricultural Survey of 2018 (UBOS, 2020). In order to be more focused, sampling took place in one or more districts in a region. The sampling protocol used was according to IARC (2014) that specifies sampling and sample

preparation methods for determining concentrations of mycotoxins in foods and feeds. A total of 155 samples were obtained from the districts as indicated in Table 1.

Table 1. Food samples collected from markets in selected districts

Crop	District/No of Samples									
	Mubende	Iganga	Mbale	Kiryandongo	Lira	Kumi	Soroti	Amuria	Apac	Kampala
Maize	20	5	5	20	-	-	-	-	-	5
Groundnuts		5	-	10	5	5	5	-	-	5
Cassava	5	-	-	5	5	-	5	-	10	-
Sorghum	-	-	-	-	5	5	5	10	5	-

Description of food samples

Maize samples: At least 2 kg of each sample were purchased in a shelled form from farmers and traders (stockists, retailers, bulking centers, wholesalers and processors). Most of the maize sampled was of the previous season (June-July 2022). Some farmers who provided the samples indicated that maize was dried on bare ground and indeed, some samples from traders were visibly dirty/soiled; while some farmers indicated that they dry on tarpaulins but maize takes long to dry. Storage conditions at bulking centers were generally poor as large volumes are handled; better conditions were observed at retail level given smaller volumes. Traders reported that they did not determine moisture content of maize grains before purchasing from farmers rather, they use subjective methods hence chances of purchasing wet grains. Only one stockiest in Kumi had a moisture meter and was strict on purchasing grains with moisture content below 15%.

Groundnut samples: Most samples were collected from the retailers and central markets (for processors and wholesalers); a few from stockists. There was visible poor handling of groundnuts before and during sorting by heaping the unsorted nuts on bare ground in the markets. The broken, shriveled, mouldy and dirty groundnuts were being used for making peanut products (paste, powder, and butter among others) and these products were also sampled. At least 2 kg of each product was sampled. Some of the stockists put peanut bags on pallets and others put the bags directly on bare ground. No efforts to check moisture content were observed in all stakeholders handling groundnuts.

Cassava samples: At least 2 kg of dry cassava were sampled from retail shops, processors and bulking centres. A lot of cassava in northern Uganda is used for both food and brewing local gin “lira lira”. Significantly large amount of dried cassava chips in Apac are outsourced from Tanzania through Mutukula. Some of the cassava from Mubende and Busoga sub regions is first fermented then sun dried on bare ground or sometimes on tarpaulins; this is preferred for brewing and mixing in the paste due to the desired fermented flavour and taste by the local consumers. Apac district also has a company that uses “flush” drying of peeled and grated cassava which is milled into clean white flour compared with the fermented, sun dried one. The flour produced from this kind of “flush” dried cassava is white in colour and used as composite flour in baking as well as for food. Very poor handling

conditions of cassava were witnessed during fermentation and sun drying processes leading to considerable moulding and soiling.

Sorghum samples: In all the districts, sorghum samples, each 2 kg, were purchased from retail shops and local markets. In retail shops, some bags where the samples were taken, were on pallets while others they were on bare ground. In markets, most of the representative samples were drawn from tarpaulins and mats undergoing further drying. Two edible varieties (the deep red and light red) were purchased. "Epuripur" meant for brewing, was not on market at the time of sampling.

Animal feed samples

The animal feeds vary a lot depending on the type and age of the animal. According to previous studies in Uganda), the poultry production sector is the most important in utilizing animal feeds and, has been significantly affected by aflatoxin contamination (Nakavuma et al., 2020). Therefore, in this study, majority of the samples were poultry feeds with a few for cattle, pig, rabbit and dog. Feed samples were obtained from the feed manufacturers in four districts, that is, Wakiso, Jinja, Kampala Capital City and Mukono putting into consideration both small and large manufacturers. The districts were chosen because they have high number of farmers using animal feeds. The number of samples obtained from each district are summarised in Table 2.

Table 2. Sampling of animal feed from Kampala, Mukono, Wakiso and Jinja districts

Feed Type	District/Number of samples				
	Kampala	Mukono	Wakiso	Jinja	Sub-Total
Chick Mash	5	5	5	5	20
Layers' Mash	5	5	5	5	20
Broiler Starter	5	5	5	5	20
Cattle feeds	5	5	5	5	20
Sow and weaner meal/feed	5	5	5	5	20
Rabbit pellets	5	5	5	2	17
Dog food (puppies)	5	5	5	2	17
Dog food (adults)	5	5	5	2	17
Total					**151**

Description of animal feed samples

Animal feed samples were purchased from different retail points/agents of the big manufacturing companies and other local feed makers in the districts. Absolutely poor manufacturing practices

including handling and storage were witnessed for the local feed mixers. Poultry feeds purchased included chick mash, layers' mash and broiler starter while samples of rabbit pellets included starters and growers. Samples for the dog foods were purchased from the imported sources and the local manufacturers and included dog porridge and pellets as well. There were reports of poor quality dog food (Pellets) from one local company that had caused death to dogs; that's why most traders don't want to stock/retail it even after some improvements. The quality of some samples of locally made dog porridge was doubted basing on the way they were being handled and the storage conditions. Fewer samples of rabbit and dog feed were purchased from Jinja than what had been planned previously because of unavailability.

Summary of key points considered during sampling of food and feeds

- Storage period/current or previous season
- Mode of storage/packaging
- Type of store: House, traditional structure, market, warehouse
- Mode of drying: on bare ground, tarpaulin, stabilized structures

All samples (both food and feed) were stored in a cool place, protected from light in order to avoid mould growth and subsequent aflatoxin production.

3.3 Aflatoxins analysis

The samples were analysed for aflatoxins using the ELISA technique (R-Biopharm, Darmstadt, Germany).

Preparation of Samples for analysis

All reagents and samples were brought to room temperature (20 - 25 °C) before use and sample preparation was performed at room temperature. A representative sample of each commodity was ground and thoroughly mixed prior to proceeding with the extraction procedure. Approximately 2 g of the ground sample were weighed and homogenized into a suitable container and 10 ml of 70% methanol (HPLC Grade) was added. The mixture was stirred for 10 minutes at room temperature using a shaker and the extract was filtered through a Whatman No. 1 filter. About 100 µl of the filtrate was diluted with 600 µl distilled water and 50 µl of the diluted filtrate was used per microwell in the test. The microwells had already been prepared to handle the filtrate and the subsequent procedures followed the recommendations of the test method. The absorbance was measured at 450 nm within 30 minutes after addition of stop solution. The sample dilution factor of 1 was used and the detection limit was 1.75 µg/kg.

Since groundnuts have a lot oil, the procedure for analyzing aflatoxins in these food samples was slightly different from that used to analyse cereals, cassava and animal feeds. About 2 g of sample was weighed and homogenized into 50 ml centrifuge tube, 8 ml of N-hexane was added followed by 10 ml of 70% methanol. The mixture was shaken thoroughly for approximately 5 minutes and centrifuged at 4000 r/min for 10 min at room temperature. The upper liquid was discarded and 0.5 ml of the lower

liquid was mixed thoroughly with 0.5 ml of 35% methanol. 50 µl of the mixture per well was used in the test and proceeded with test procedure as described for cereals and feeds. However, the sample dilution factor used was 10 and the detection limit was 1.75 µg/kg.

All results of food samples and animal feeds were reported in µg/kg (ppb).

3.4 Development of a matrix of key stakeholders addressing aflatoxin contamination in Uganda

In order to develop a matrix of key partners, key informant interviews (KII) were conducted with the actors at different stages of susceptible commodity value chains. The actors were categorized into eight groups and in each group, the stakeholders involved were identified and their activities addressing aflatoxins were documented. The following were the identified categories of aflatoxin actors in the country;

1. Government Ministries & Departments (including Regulatory Agency)
2. Research and Innovation Institutions
3. Academia
4. NGOs/CBOs/Companies
5. Testing services
6. Suppliers of Mycotoxin testing equipment and supplies
7. Regional Economic Communities (RECs)
8. Development Partners

3.5 Documentation of interventions, gaps and challenges in aflatoxin management

The information obtained from desk reviews and matrix of key stakeholders above, was used to document gaps and challenges in order to come up with concrete recommendations and sustainable aflatoxin management solutions in the country.

4.0 RESULTS AND DISCUSSION

4.1 Desk review

4.1.1. Prevalence data on aflatoxins in food and feed commodities

Food products

The first study on aflatoxin contamination in Uganda was conducted in 1965-1966 on peanuts (Lopez and Crawford, 1967). The study revealed that majority of the peanut samples collected from retail shops were contaminated with aflatoxins in the range 0.1->10 mg/kg (Table 3). The study findings further revealed that aflatoxin contamination was spread across all the 12 months of the year. However, the highest levels of aflatoxins (>10 mg/kg) were recorded in the period between May-August which coincides with at least two months of crop storage according to the peanut production cycles in Uganda.

Table 3. Aflatoxin Content in Peanuts in Uganda (1965-1966)

Month	Total number of samples	Number of samples contaminated with aflatoxin B1 (mg/kg)			
		0-0.1	0.1-1	1-10	>10
January/February	12	10	2	0	0
March/April	15	11	3	1	0
May/June	15	8	4	3	1
July/August	15	11	2	2	1
September/October	12	10	2	0	0
November/December	15	11	4	0	0

Source: Lopez and Crawford, 1967

The second aflatoxin study was conducted between September 1966 and June 1967 (Alpert, 1971). The study collected and analysed 480 food samples from household granaries and markets from across the entire country. The study findings indicated that about 30% of the samples were contaminated with aflatoxin levels above 1 µg/kg of aflatoxins while 3.7% of the samples contained more than 1 mg/kg of aflatoxins. The study reported several forms of aflatoxins including B1, B2, G1 and G2 with B1 and B2 the most prevalent (Table 4).

Table 4. Aflatoxin contamination in food staples 1966-1967

Food	Number of samples			Total Aflatoxin contamination (µg/kg)			Number of samples containing aflatoxin			
	Assayed	+ve	% +ve	1-100	100-1000	>1000	B1	B2	G1	G2
Beans	64	46	71.9	30	11	5	15	42	11	1
Maize	49	22	44.9	13	9	-	19	11	14	4
Sorghum	69	26	37.7	19	5	5	16	11	13	1
Peanuts	152	27	17.8	11	8	8	24	16	17	7
Millet	55	9	16.4	9	-	-	6	4	2	1

Peas	19	3	15.8	3	-	-	2	1	1	-
Cassava	34	4	11.8	-	2	2	2	4	2	-
Rice	11	0		-	-	-	-	-	-	-
Other grains	11	2	18.2	-	1	1	2	2	2	-
Grain mixtures	16	3	18.7	2	-	-	2	2	2	1
Total	480	142		87	37	18	88	93	64	15
% of Total			29.6	29.6	7.7	3.7	18.3	19.4	13.3	3.1

Source: Alpert, 1971.

The study findings in Table 5 further indicated that the proportion of positive samples from village markets (31%) was slightly higher than that from home (27%). However, no marked differences were observed between home grown (27.5%) and market sourced samples (28.3%).

Table 5. Aflatoxin content according to source of food (1966-1967)

Source	Number of samples			Total Aflatoxin contamination (µg/kg)			Number of samples containing aflatoxin			
	Assayed	+ve	%+ve	1-100	100-1000	>1000	B1	B2	G1	G2
Sampling site										
Home	266	71	27.1	46	14	11	39	34	32	12
Village market	197	61	31	34	20	6	47	47	32	2
Other	17	10	29.6	7	3	1	2	10	-	1
Total	480	142	29.6	87	37	18	88	93	64	15
Original source										
Home grown	193	53	27.5	41	8	4	25	37	20	2
Market	180	51	28.3	30	14	7	35	31	24	7
Unknown	107	38	35.8	16	15	7	28	25	20	6
Total	480	142	29.6	87	37	18	88	93	64	15

Source: Alpert, 1971.

In terms of geographical distribution, two sub-regions namely; Karamoja and Toro reported large numbers of samples with the highest frequency of aflatoxin contamination. Samples from other areas such as Masaka district (60.5%), Teso sub-region (66.7%) and Kigezi sub-region (79.3%) reported higher rates of contamination, but the numbers of samples analyzed were not sufficiently large to permit firm conclusions(data not shown).

Storage in grass thatched structures was reported to have lower proportion of aflatoxin positive samples (24%) compared to storage inside the house (32%). The proportion of positive samples increased with storage time. The proportion of aflatoxin positive samples was 25% for samples stored for one month compared to 38% for samples stored for a period of 6 months (data not shown).

In 1990, another study was conducted in Uganda (Sebunya and Yourtee 1990). The study samples consisting of maize, peanuts, soybean and poultry feeds were obtained from food and feed stores of the Produce Marketing Board (PMB), Kampala and the Animal Feed Mill at Jinja. The study findings reported high occurrence of aflatoxin producing fungi in both food and feed samples. However, only 4 samples (1 feed and 3 food) were found with detectable aflatoxins. Two samples (1 feed and 1 food) had more than 20 µg/kg. The low proportion of contaminated samples reported in this study could be attributed to use of thin layer chromatography which has very low sensitivity. Studies on ability of the *Aspergilus* strains isolated from the samples revealed that majority of the species were able to producing aflatoxin B1, B2, G1 and G2.

Since 1990 to date, a number studies have been undertaken to quantify the levels of aflatoxins in staple foods (Table 6). The studies mainly focused on peanuts (Kaaya et al, 2006a, Baluka et al, 2017, PACA 2017), maize (Kaaya et al, 2006b, PACA 2017, Omara, 2019 and Sserumaga et al, 2020) and sorghum (PACA 2017, Kitya et al, 2010). The other staples that have been reported to be contaminated with aflatoxins include dried cassava chips (Kaaya and Eboku, 2010), rice (Candia and Masette, 2012), *Eshabwe* (Kitya et al, 2010) and imported baby foods (Mady et al, 2008).

Results from most of the studies indicate that aflatoxin contamination in staple foods is wide spread across the country and a large proportion of the samples contained aflatoxin levels that were above the national limit of 10 µg/kg.

Table: 6. Summary of studies that quantified aflatoxin contamination in staple foods from 2005-2020

Sub-region/District/Agro ecological zone	Product	Type of aflatoxin	Mean Aflatoxin levels (µg/kg)	Reference
Busoga Farming System	Pre-harvest maize kernels	Total	4.4 ± 9.7	Sserumaga et al, 2020
Eastern Highlands			1.8 ± 3.5	
Eastern Savannah			9.7 ± 33.0	
Lake Albert Crescent			66.5 ± 493.5	
Lake Victoria Crescent			1.7 ± 1.4	
Northern Farming System			7.4 ± 29.5	
South Western Highlands			145.5 ± 428.3	

Western Range Lands			1.7 ± 0.8	
Mubende	Maize kernels	Total AF	9.6±4.20	Omara, 2019
Ibanda			10.1±3.10	
Jinja			9.1±4.35	
Hoima			11.0±3.01	
Mayuge			10.6±1.63	
Buikwe			6.5±0.60	
Mpigi			3.8±1.30	
Masindi			7.2±1.99	
Bugiri			8.5±2.56	
Kioga plains				
Soroti	Sorghum grains	Total AF	170.1(98.25-65.5)	PACA, 2017
Tororo	Sorghum grains		61.14 (4.0-215)	
Iganga	Maize grains		25.36 (4.5-77.0)	
Soroti	Maize grains		70.9 (4.5-179.5)	
Tororo	Maize grains		35.5 (7.0-86.0)	
Iganga	Peanuts grains		221.12 (2.5–450)	
Soroti	Peanuts grains		31.16 (3–31.16)	
Tororo	Peanuts grains		7.25 (3.5–11)	
North-eastern Savannah Grasslands				
Gulu	Sorghum grains	Total AF	70.5 (5.5-119.5)	PACA, 2017
Amuria	Sorghum grains		11.5 (28.5-472)	
Lira	Sorghum grains		102.27 (27.5-227)	
Gulu	Peanuts grains		4.75(4.0-5.5)	
Amuria	Peanuts grains		5.3 (2.1-17)	
Lira	Peanuts grains		7.5 (2.5-21)	
Western Savannah Grasslands				
Mubende	Maize grains	Total AF	75.2 (3.5-247.5)	PACA, 2017
Kamwenge	Maize grains		26.56 (3.25-04.5)	
Masindi	Maize grains		45.99 (3.05-510)	
Mubende	Peanuts grains		7.0(3.0-13)	
Kamwenge	Peanuts grains		8.82 (5.5-12)	
Masindi	Peanuts grains		88.35(2.5-174.5)	
Kampala markets (Nakawa, Bukoto, Kalerwe, and Owino/St. Balikudembe)	Peanuts grains	AFB1	0-540	Baluka et al, 2017
		AFB2,	0-141	
		AFG1	0-213	
		AFG2	0-36	
Eastern region (Butaleja district)	Paddy rice	Total AF	10.08	Candia and Masette, 2012
	Milled rice		11.0	
Western region (Hoima district)	Paddy rice		12.25	
	Milled rice		104	
Central region (Nakaseke)	Paddy rice		9.78	
	Milled rice		9.6	
	Paddy rice		18.0	

Lira Northern region (Lira district)	Milled rice		19.4	
Kumi district				
Ngora county	Dried Cassava chips	Total AF	0.633 (0-3.5)	Kaaya and Eboku, 2010
Kumil county			0.412 (0-2.5)	
Bukedea county			0.5 (0-4.5)	
South western Uganda	*Eshabwe* sauce	Total AF	18.6 ± 2.4	Kitya et al, 2010
	Groundnuts flour		11.5 ± 0.43	
	Cassava flour		16.0±1.66	
	Millet flour		14.0±1.22	
	Sorghum flour		15.2 ± 0.2	
Sampled from Kampala markets	Heinz mixed cereal	Total AF	(0-20)	Mady et al, 2008.
	Cerelac		ND	
	Cornflakes		(1-20)	
	Weetabix		(1-10)	
	Porridge oats		(1-20)	
Iganga	Peanuts[1]	Total AF	12.4 ± 5.31	Kaaya et al, 2006a
Mayuge	Peanuts[1]		10.5 ± 6.15	
Mubende	Peanuts[1]		9.8 ± 4.32	
Mid-Altitude (moist)	Maize kernels (stored for 2 months)	Total AF	20.54 (0–32)	Kaaya et al, 2006b
Mid-Altitude (dry)			18.02 (18.02)	
Highland			12.35 (0–15)	
Mid-Altitude (moist)	Maize kernels (stored for more than months)		30.2(0–50)	
Mid-Altitude (dry)			22.5 (0–45)	
Highland			12.8 (0–18)	
Mayuge district	Maize kernels at Physiological maturity	Total AF	0.72 (0–2.5)	Kaaya et al, 2005
	Maize kernels: 1 week delayed harvest		0.79 (0–5.8)	
	Maize kernels: 2 weeks delayed harvest		1.95 (0–8.5)	
	Maize kernels: 3 weeks delayed harvest		2.96 (0–10)	
	Maize kernels: 4 weeks delayed harvest		5.53 (0–12)	

Numbers in parentheses = Range

[1] Samples obtained from farmers

ND=Not detected

Animal feeds

Aflatoxin contamination along the animal feed value chain is not well documented in Uganda. Despite the little attention given to the quality and safety of animal feeds in Uganda, farmers have on several occasions reported incidences of poor animal health, reduced productivity and sometimes death among livestock fed on cereal-based feeds.

During the current study, we were only to access two published studies on aflatoxin contamination in animal feeds in Uganda. The first study by Nakavuma et al, 2020 assessed both ingredients for poultry feeds (Table 7) and the final products (Table 8) among small scale and large scale processors. The results indicate that all the raw materials were contaminated with aflatoxins. Generally, raw materials sampled from small scale processors recorded higher levels of aflatoxins compared to those from small scale processors. Maize bran from small scale processors recorded the highest level (103.25 µg/kg) of aflatoxins.

Table 7. Aflatoxin concentration in different poultry feed ingredients from large- and small-scale processors

Processor's scale of production	Aflatoxin concentration Mean ± SD (µg/kg)				
	Mukene	Maize bran	Soybean	Cotton seed	Sunflower seed
Large Scale	8.75 ± 3.18	22.25 ± 6.01	16.75 ± 7.42	20.25 ± 6.71	17.00 ± 7.78
Small Scale	19.25 ± 5.30	103.25 ± 22.98	52.75 ± 0.35	67.25 ± 22.98	62.25 ± 2.47

Source: Nakavuma et al, 2020

The study results further indicate that all the feeds assessed by the study were contaminated with aflatoxins (Table 9). Feeds from small scale processors recorded higher levels of aflatoxins compared to those from large scale processors with broiler finisher recording the highest (185.25 µg/kg).

Table 8. Aflatoxin concentrations in different poultry feed types from large- and small-scale processors

Processor's scale of production	Aflatoxin concentration Mean ± SD (µg/kg)				
	Chick mash	Growers Mash	Broiler Finisher	Layers mash	Broiler mash
Large Scale	26.75 ± 11.85	86.5 ± 116.54	46.50 ± 23.23	40.40 ± 31.50	24.75 ± 13.99
Small Scale	69.38 ± 16.24	125.87 ± 96.74	185.25 ± 42.03	98.38 ± 79.08	105.37 ± 25.34

Source: Nakavuma et al, 2020

The second study assessed the levels of aflatoxins in ingredients and locally processed commercial fish feeds (Magala et al, 2022). The results indicate that all the samples analysed in the study were contaminated with aflatoxins. Samples collected from farmers (24.63 µg/kg) recorded the highest level of aflatoxins (Table 9).

It is important to note that for both studies, most of the samples contained aflatoxin levels above the national tolerable of 20 µg/kg for animal feeds. Given that there is limited regulation among the livestock feed sub-sector in the country, the problem of aflatoxin contamination could be much bigger

than revealed by these two studies. There is thus need to undertake further studies to cover a representative portion of the value chain actors and assess all the ingredients and livestock feeds available on Ugandan markets.

Table 9. Aflatoxin contamination in ingredients and locally processed commercial fish feeds

Point of sampling	No. of samples analyzed	No. of positive samples	% of samples beyond acceptable levels (20 ppb)	Aflatoxin levels (µg/kg)		
				Low	High	Mean ± SE
Farmers	20	20	65	4.8	45.9	24.63±2.67
Processors	20	10	30	5.9	37.5	17.68±3.07
Traders	20	10	60	10.6	34.1	23.10±2.47
Landing site	2	2	50	29.3	31.0	21.15±8.15

Source: Magala et al, 2022

4.1.2 Aflatoxin exposure in Uganda

Aflatoxin exposure in humans can be assessed at the individual level through two approaches namely; i) Food consumption estimates and laboratory analysis of food samples, ii) Determining the aflatoxin–biomarkers in urine and blood. However, the use of food consumption data and aflatoxin contamination levels in food may not be accurate due to errors associated in estimating the exact amount of food consumed by an individual and the extent to which individuals respond to aflatoxin exposure (Groopman et al., 2005). The use of biomarkers that are able to provide a realistic estimate of the amount of aflatoxins or its metabolites in the body fluids is therefore considered to be more accurate.

The most commonly used aflatoxin biomarkers include; AFM1 and AFB1-N7-guanine adducts, which are excreted in urine and are usually used in acute aflatoxin exposure (Mupunga et al, 2016). Serum AFB1-lysine adduct which has a longer half-life of approximately 2–3 months (Turner et al, 2000) and melanin which has been reported to be a primary binding site for aflatoxins in hair are used in assessing chronic exposure (Ropero-Miller et al, 2000).

Despite several studies that have been done in Uganda to determine the levels of aflatoxins in food, a few have been done to assess exposure to the toxins in humans. This has been attributed to limited laboratory infrastructure to quantify the aflatoxin biomarkers in blood.

The first detailed aflatoxin exposure assessment in humans was a pilot cross-sectional survey conducted, in Kalungu District, South-western Uganda (Nunn et al, 1994). The study collected serum samples and dietary information from selected individuals living the targeted areas. Dietary information was collected from the adults (or from the parent or guardian of a child) using a food frequency questionnaire (Asiki et al, 2014). All serum samples were analysed for aflatoxin–albumin (*AF-alb*) at the University of Leeds, UK using ELISA assay.

The study findings indicated that *AF-alb* was near-ubiquitous among the study population. The respondents whose depended mainly on *Matoke* had about half of the aflatoxin-albumin aduct (AF-alb) compared to those who did not eat it. The study reported that all five children reported to be exclusively breastfed at the time of the survey had detectable AF-alb. This is confirmation that the children were exposed to aflatoxins through their mothers' breast milk. The study findings further indicated that children who fed on *posho* and soy beans had higher *AF-alb* than their counterparts.

The study by Asiki et al. (2014) was preceded by another study by Kang et al, (2015) which was also conducted in South western Uganda. In this study, AFB1–lysine (AFB-Lys) adduct levels were determined via HPLC fluorescence for a total of 713 serum samples from the General Population Cohort (GPC), covering eight time periods between 1989 and 2010. AFB-Lys adduct levels were also measured in a total of 374 serum samples from the Rakai Community Cohort Study (RCCS), across four time periods between 1999 and 2003.The study findings indicated that in both populations, aflatoxin exposure persisted and had not significantly changed over time.

Another study by Zitomer et al, 2020, a subsample of 985 serum specimens selected among HIV-negative participants from 10 survey-defined geographic regions were analysed for serum aflatoxin B1-lysine (AFB1-lys) using isotope dilution LC-MS/MS. The study findings indicated that serum AFB1-lys was higher in males (GM: 1.57; 95% CI: 1.38–1.80) vs. females (GM: 1.12; 95% CI: 0.97–1.30) (P = .0019), and higher in persons residing in urban settings (GM: 2.83; 95% CI: 2.37–3.37) vs. rural (GM: 1.10; 95% CI: 0.99–1.23) (P < .0001). Gender, age, occupation, distance to marketplace, and number of meals per day were the major predictors of aflatoxin exposure among the study population.

The findings of these three studies conducted in Uganda are in agreement and highlight the widespread burden of aflatoxin exposure throughout the country. However, it is important to note that all the three studies were not originally designed to collect data on aflatoxin exposure and thus the findings may not paint a true picture on the ground. Therefore, there is need to undertake specific aflatoxin exposure assessment studies across the country in which specific individual information on: age, weight, food consumption patterns (frequency of consuming aflatoxin prone foods and amount consumed), levels of aflatoxin in foods consumed and the predisposing factors such as alcohol consumption, Heptatis B infection, smoking among others. Such data will be helpful in estimating the actual aflatoxin exposure and estimation of the overall aflatoxin burden in the entire country.

4.1.3 Health impacts of aflatoxins

Aflatoxins pose health effects in both humans and domestic animals that may be acute or chronic. Acute toxicity is as a result of taking in very high doses of aflatoxins that triggers acute illness and subsequent death while chronic toxicity is characterized by low-dose exposure over a prolonged period of time, resulting in cancer (Bennett & Klich, 2003), nutritional and immunologic consequences (Williams et al., 2004). The linkage between aflatoxin contamination and health effects in both humans and livestock is summarised in Figure 1.

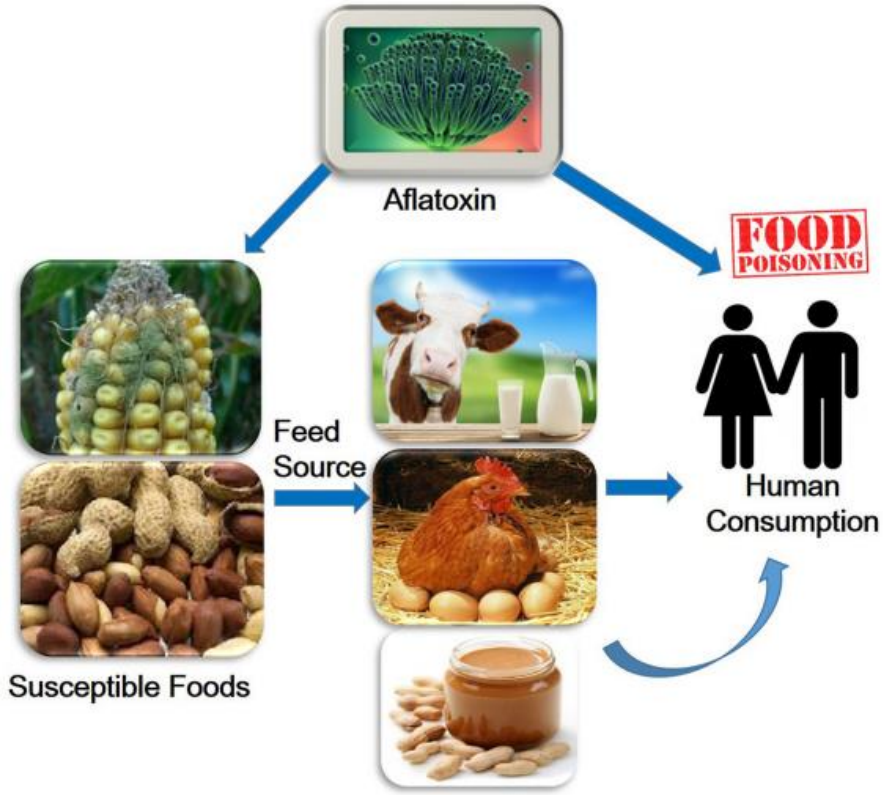

Figure 1: Overview of the health effects of aflatoxins on humans and animals

Source: Kumar et al, 2017

Information in Figure 1 illustrates that both humans and domestic animals can be exposed to aflatoxins through consumption of contaminated produce. Due to bioaccumulation in livestock, humans can also be exposed to aflatoxins through consumption of contaminated animal products such as milk and eggs. Humans can also be exposed to aflatoxins through consumption of processed products such as peanut butter, cornflakes and other products processed from contaminated raw materials.

In humans, acute exposure to aflatoxins causes immediate death as has been reported in Kenya (Azziz-Baumgartner et al, 2005) and Tanzania (Kamala et al, 2016). Chronic exposure to aflatoxins causes a range of severe diseases, including cancer, immunosuppression, teratogenicity, mutagenicity, cytotoxicity, and estrogenic effects in mammalians (Klvana and Bren, 2019). Aflatoxins have also been reported to be involved in nutritional disorders, such as kwashiorkor and growth faltering due to interfering with the absorption of micronutrients such as zinc, iron, and vitamins, protein synthesis, and metabolic enzyme activities (Williams et al, 2004; Turner, 2013).

In domestic animals, exposure to high aflatoxin doses results into acute toxicity while sub-lethal doses have been reported to induce impaired productivity and reproduction, increased susceptibility to diseases, and reduced quality of the foods they produce (WHO, 2017). The current study did not come across studies done to document the health impacts of aflatoxins in domestic animals in Uganda.

With respect to humans, the first and only fetal case related to aflatoxin poisoning in Uganda is of a 15-year-old boy that was admitted at Mulago Hospital, Kampala in 1967 (Serck-Hanssen, 1970). The patient presented with a history of abdominal pain and swelling for four days. The patient was given digoxin and mersalyl sodium but his condition deteriorated and died within 2 days of admission to the hospital. A macroscopic examination revealed, pulmonary edema, a dilated flabby heart, and diffuse centrilobular necrosis of the liver. Domestic follow up indicated that the family had been feeding on mouldy cassava at the time the boy feel sick. Upon analysis, the cassava was found to contain 1.7 mg/kg .Given that studies undertaken in 1966-1967 had also documented high prevalence of aflatoxins in Ugandan staple foods, the cause of death was suspected to be aflatoxin poisoning.

The first research report that linked high incidences of hepatoma to aflatoxin contamination was undertaken between 1965-1966 (Alpert et al, 1971). The study collected 480 food samples from randomly selected native homes and markets across the entire country. The study also calculated hepatoma incidence from the total number of hepatoma patients diagnosed in the entire country during the 3-year period 1963-1966. The findings of this study indicated that the distribution of aflatoxins in foods stored for consumption correlated with the pattern of incidence of liver cancer in Uganda at the time. Incidence of liver cancer was highest in areas such as Karamoja that reported highest aflatoxin contamination. However, the findings of these studies could not be conclusive since agents liver cancer are many in addition to other predisposing factors such as parasitic infections and viral diseases especially hepatitis B.

Since the first study conducted in 1966-1967, no further epidemiological studies have been conducted in Uganda on the relationship between aflatoxin contamination and cancer incidence. The only study that has been done to estimate the number of liver cancer cases attributed to aflatoxin contamination used the Disability Adjusted Life Years (DALYs) approach (PACA, 2017). The study estimated the total primary liver cancer cases attributed to consumption of aflatoxin contaminated foods using aflatoxin contamination data obtained from a survey that was conducted in 2014 in four agro-ecological zones known to be major producers of maize, peanuts and sorghum. The study findings indicated that about 3,700 liver cancer cases per year were attributed to consumption of aflatoxin contaminated maize, peanuts and sorghum. The estimated total liver cancer cases represented approximately 0.011% of the total population of 34,856,831 (UBOS, 2014) at that time. The liver cancer cases were quite high compared to the 1,292 liver cancer cases reported for Uganda by the International Agency for Research on Cancer (IARC, 2012). Considering that the WHO/IARC estimates are based on data of HCC cases available in health facilities, which are often underreported, and that majority of the number of cancer patients die without visiting the hospital, the estimated DALYs of 3,700 estimated for Uganda in 2014 indicated that more efforts towards safeguarding the health of Ugandans from aflatoxin exposure is imminent.

The current literature search reveled that there is one documented report on the effect of aflatoxin exposure and birth outcomes (Lauer et al, 2018). The prospective cohort study investigated the association between maternal aflatoxin exposure during pregnancy and adverse birth outcomes (primarily lower birth weight) in a sample of 220 mother–infant pairs in Mukono district, Uganda.

Maternal aflatoxin exposure was assessed by measuring the serum concentration of AFB1-lysine (AFB-Lys) adduct at 17.8 ± 3.5 -week gestation using high-performance liquid chromatography. The study findings indicated that all the 220 maternal serum samples were positive for AFB-Lys adduct, indicating widespread dietary exposure to AFB1 in pregnant mothers. The study findings indicated that elevated maternal AFB-Lys levels were significantly associated with lower infant birth weight and smaller head circumference.

4.1.4. Trade impacts of aflatoxins

The current review indicates that there is paucity of information on the impact of aflatoxins on trade in Uganda. Only one study conducted by PACA in 2014 estimated the impact of aflatoxins on trade of maize, sorghum and peanuts using the Computable General Equilibrium (CGE) Model. The data used information extracted from the 2009/10 Social Accounting Matrix (SAM); secondary micro- and macro-data, and primary data on aflatoxin contamination levels in maize, peanuts and sorghum collected in 2014 from 3 agro-ecological zones that are the major producers of the most aflatoxin prone crops.

Using the financial year 2013/14 as a reference point, the study findings indicated that failure to sell aflatoxin contaminated grains resulted into loss of US$ 7.48 million (Ugx 27.7bn) (PACA 2017). The study findings further indicated that in the same year, sales of the health sector goods and services to households and government increased by 0.48% (US$ 1.86) to finance medical costs associated with aflatoxin related illnesses.

The information reported by PACA have some inaccuracies due to the following reasons;

i. There is a lot of informal trade that goes on between Uganda and neighbouring countries that is not documented. As such, estimation of the total value of exports for grains that are vulnerable to aflatoxin contamination could have been underestimated
ii. Some or all the grains rejected due to aflatoxin contamination may be channeled in the domestic or regional markets
iii. There is no disparity between prices of aflatoxin contaminated foods and aflatoxin-free foods

Apart from the PACA study, the media has attempted to estimate the impact of aflatoxins on trade by estimating the value of produce that fails to meet the existing regional aflatoxin standards.

In 2013, there were media reports that more than 600,000 tons of maize worth Uganda shillings 10 billion destined for export to neighbouring Kenya was rejected because the aflatoxin levels were above regulatory limits (10 µg/kg). In 2018, Uganda signed an agreement with Kenya to export maize into the Kenya to the tune of 600,000MT per year. However, this target was not met due to failure of the maize to comply with standards and the country lost over 180 billion shillings

In early 2021, Kenya's Agriculture and Food Authority (AFA) placed a ban on maize from Tanzania and Uganda citing non-compliance with regulatory thresholds for aflatoxins (See annex 1). The borders have since been opened but Ugandan traders lost unspecified amounts of money.
There are also reports that Uganda maize has been severally denied access to the Rwandan markets over the concerns of high level of aflatoxins. However, there are no official records on the quantity of produce rejected and its value.

While focus is mainly put on export markets, the local traders also usually lose money through;
i) Failure to comply with requirements of the exporters and institutions/companies such as World Food Programme (WFP) and the brewing industries that pay premium prices, ii) Failure to sell their produce or selling at lower prices due to mould infestation.

The regional markets also monitor aflatoxins in milk, eggs and animal feeds or their raw materials such as maize, bran and dried cassava chips. In 2019, Kenya banned milk exports from Uganda. Ugandan eggs as well as animal feeds have in the recent past faced challenges accessing the Kenyan market despite the existence of the East African Community common market protocol. However, it was not clear whether milk, eggs and animal feeds was due to aflatoxin contamination or protection of the local industry.

Given the gaps highlighted above, there is need for a detailed study to document the impact of aflatoxins on trade. The study should consider both formal and informal trade across the borders of the neighbouring countries and engage all the value chain actors in the country. The results of such a study will be invaluable in designing interventions for promoting trade across the region and reduction of aflatoxin related negative socioeconomic impact.

4.2. Aflatoxin levels in Food and Feed

This section presents detailed aflatoxin contamination of food and feed samples obtained from the different districts in Uganda during the current study. Overall mean for each category of commodities (maize, groundnuts, cassava, sorghum and animal feeds), percentage (%) samples above 10 ppb (for food) and 20 (ppb for feeds) and the highest aflatoxin levels for each category of commodity have been computed to establish the occurrence and prevalence.

Food

The results on aflatoxin contamination in staple foods (Maize, groundnuts, cassava and sorghum) are summarised in Table 10. The results indicated majority (above 76%) of samples had detectable aflatoxins. Peanuts had the highest (90%) incidence of aflatoxins followed by sorghum (83%). Results in Table 10 further indicate that groundnuts recorded the highest mean aflatoxin level (32.93 ppb) and highest level of aflatoxin (460 ppb). Apart from cassava whose overall mean aflatoxin contamination levels were 9.94, the rest of the foodstuffs had their mean levels above the UNBS/EAC regulatory limit of 10 ppb (Table 10).

For maize, groundnuts and sorghum, more than 50% of the samples would not be fit for trade as these were above 10 ppb and not safe for human consumption. This has a direct implication on the economic impact as well as nutrition security and health where a considerable amount of money and calories would be lost if the aflatoxins standards were enforced. According to UN COMTRADE (2013), if 45% of maize samples have aflatoxin levels above 10 ppb, Uganda would lose USD 12,037,050 and 11.1% calories. However, it is now ten years since COMTRADE published this information. This implies the value of maize lost could be more than double today due to the increase in production volumes and the price of maize.

The findings from this study are comparable with those from other studies conducted in Uganda that have reported high levels of aflatoxins in groundnuts (PACA, 2017; Baluka et al, 2017; Kaaya et al, 2006a), maize (Sserumaga et al, 2020; Omara, 2019; PACA, 2017; Kaaya et al, 2006b), sorghum (PACA, 2017) and Cassava (Kaaya and Eboku, 2010; Kitya et al, 2010). The major factors promoting aflatoxin contamination reported by these researchers included among others, leaving the produce to partially dry in the field, drying produce on bare ground, high moisture content of dried foods and stored foods, inadequate storage structures and containers and failure to manage insect infestation among others. All these factors were observed during sampling of produce in the current study.

Table 10. Levels of aflatoxins in staple foods

Commodity	No of samples	% of samples with detectable aflatoxins	Aflatoxin content (ppb)		
			Mean	Highest level	% Above 10 ppb
Maize	55	76.4	28.82	97	56
Groundnuts	40	90.1	32.93	460	55
Cassava	30	76.7	9.94	22	27
Sorghum	30	83.3	13.42	35	53

Animal feeds

The results of aflatoxin contamination in animal feeds are presented in Table 11. The majority (above 76%) of the animal feed samples had detectable aflatoxin levels with Layer's mash recording the highest (100%) incidence of aflatoxins. Sow and weaner meal/feed had the highest mean (30.58 ppb) aflatoxin content followed by cattle feeds (30.43 ppb). Cattle feeds recorded the highest proportion of samples with aflatoxin levels above the UNBS/EA limit (20 ppb) for animal feeds. Overall, dog feeds (mean of 8.50 ppb for puppies and 6.45 ppb for adult dogs) had the lowest aflatoxin levels possibly because majority were imported. Not many studies have been done on animal feeds in Uganda. However, the findings of this study are in agreement with those the only documented study by Nakavuma et al, 2020.

The high incidence of aflatoxins in animal feeds could be attributed to the fact that the major ingredients include dried grains such as maize which is vulnerable to aflatoxin contamination. There is a misconception among the animal feed value chain actors that there is no need for strict controls in production and handling of animal feeds including the nature of the ingredients used. As a result, the majority of the value chain actors use poor quality and cheap ingredients like rotten and discoloured maize bran, rotten silver fish and wet, rotten and insect infested maize grains in the production of animal feeds. Furthermore, while there is a UNBS/EA standard

for aflatoxins (20 ppb) in animal feeds, there is no general standard for animal feeds and as such, the no regulation of the animal feed value chain. The value chain actors are operating in a non-regulated space. This calls for interventions to regulate the animal feed industry to save farmers from spending money on animal feeds that affect the production and productivity of livestock.

Table 11. Levels of aflatoxins in animal feeds

Feed type	No of samples	% of samples with detectable aflatoxins	Aflatoxin content (ppb)		
			Mean	Highest level	% Above 20 ppb
Chick Mash	20	90	18.15	40	40
Layers' Mash	20	100	17.95	56	25
Broiler Starter	20	95	18.55	59	25
Cattle feeds	20	95	30.43	77	45
Sow and weaner meal/feed	20	95	30.58	44	40
Rabbit pellets	17	88.2	12.55	35	29
Dog food (puppies)	17	76.5	8.50	28	6
Dog food (Adults)	17	76.5	6.45	12	-

4.3 Stakeholders involved in aflatoxin control/management

The results of the stakeholders involved in aflatoxin activities in the country are presented in Table 12. A total of eight (8) categories of stakeholders were identified. Based on the matrix established and the activities being done, it appears academia takes a lead in addressing issues of aflatoxins. The country is blessed for having a good number of development partners and RECs interested in addressing aflatoxin issues. The UMMSC of MAAIF should be revived to take a lead in coordinating these activities to avoid duplication as well as prioritize and do resource mobilization from development partners and RECs in order to come up with sustainable solutions in aflatoxin management.

Table 12. Stakeholders involved in aflatoxin control/management and their roles

CATEGORY	STAKEHOLDER	WHAT IS BEING DONE
Government Ministries & Departments		
	Ministry of Agriculture Animal Industry and Fisheries (MAAIF)	• Coordinates activities of aflatoxin management in the country and EAC level including hosting the Uganda Mycotoxin Mitigation Committee (UMMC) • MAAIF guided development of the multisectoral Action Plan for aflatoxin prevention and control interventions in the country and is planning to review/update it at the end of its expiry period in 2023. • I.E.C materials for advocacy & sensitization on aflatoxin were also developed for all value chain players. • Developed a handbook for Aflatoxin Management for Extension Officers in the country. • MAAIF is planning to fast track the review of the Food and Nutrition Policy 2003 with a food systems lens and possibly launch it by the end of 2023. As part of a food systems lens, food safety including aflatoxin control will be the core aspect of this policy document. • MAAIF is working closely with Office of the Prime Minister (OPM) to develop a food systems transformation roadmap for Uganda that will inevitably emphasize food safety including aflatoxin control in the country. • Organizes refresher courses for agricultural extension staff. For example, on the ground more than 1000 extension officers in over 50 key production districts have been sensitized (Under Agricultural Cluster Development Project & Agricultural Value Chain Development Project, ACDP) and their capacity built on aflatoxin control and prevention. Postharvest Handling Infrastructure for aflatoxin control is also being installed through a private public partnership in the high production (under ACDP). • Under the Uganda Multisectoral Food Security and Nutrition Project (UMFSNP) more than 20 districts with high levels of stunting and poor dietary diversity have been targeted for mass nutrition campaigns over the last six years. Aflatoxin management will form part of the agenda plus emphasis on production of Dark Green Leafy Vegetables, fruits, Vitamin A rich Sweet Potatoes and Iron Rich Beans. Over 10000 DGL Vegetable, Fruits, Biofortified Crops demonstration gardens have been put in place in 1500 schools and surrounding communities.

	Ministry of Trade Industry and Cooperatives (MTIC)	• Departments of Internal Trade (DIT) and External Trade (DET) address issues of market negotiations, technical barriers and Non-tariff barriers to trade including those related to aflatoxins; DIT has come up with a Project titled: Aflatoxin Control testing Infrastructure Capacity Enhancement Project • Department of Business Development Quality Analysis addresses issues of GMP, GHP as well as capacity building across value chains of grains and aflatoxins are also addressed; through The Standards and Trade Development Facility (STDF) has written a concept titled "Aflatoxin control in the maize value chain for Uganda's sustainable trade" • Coordinates activities supported by COMESA on Trade barriers where aflatoxin issues are addressed • Uganda National Bureau of Standards (UNBS) is involved in aflatoxin Standards development and harmonization across EAC as well as enforcement in Uganda; their laboratory is accredited for testing aflatoxin • Uganda Export Promotion Board facilitates the development and growth of export trade in Uganda and, through the Division of Management Information Systems, Trade Promotions and Public relations addresses quality control and assurance of export produce including aflatoxin contamination • Uganda Warehouse Receipt Authority facilitates farmers to store and access markets by selling their produce later when prices are high. In this way, they address issues of quality and safety including aflatoxin contamination
	Ministry of Health (MOH)	• Have the Department of Environmental Health that handles aflatoxin contamination issues • Are members of the UMMC • Compilation of data on health effects of aflatoxins (prevalence of liver cancer, Hepatitis B Virus and malnutrition etc.)
	Ministry of Local Government (MoLG)	• Establishment of ordinances regarding postharvest handling of aflatoxin-prone produce especially maize • Implementation of standards and ordinances about aflatoxins locally
Research Institutions		
	National Agricultural Research Organization (NARO)	• Under their Grant Programme, NARO has supported a number of projects addressing aflatoxin management in the country. For example, the project "Development of an aflatoxin-binder prototype for enhanced productivity of

		intensive poultry and dairy production systems in Uganda" was supported and has just ended. The prototype aflatoxin binder is ready for commercialization • NARO Scientists are conducting research on aflatoxin tolerant maize (NaCCRI) and groundnut varieties (NaSSARI some of which have already been released to farmers. • Has been working on aflasafe project including isolation of atoxigenic *Aspergillus flavus* strains. Together with IITA, they are in the final process of commercializing aflasafe specifically for Uganda conditions, later planning to scale it out for bio-control of aflatoxin along the whole value chain. • Currently working on development of an aflatoxin biosensor with College of Health Sciences, Makerere University
	International Institute of Tropical Agriculture (IITA)	• Linkage with NARO to development of aflatest product and make it available to the market • Together with The Grain Council of Uganda (TGCU) and with support from AGRA, they have developed aflatoxin awareness materials and have also participated in radio for campaigns
	Uganda Industrial Research Institute (UIRI)	• Have been involved in aflatoxin analysis in their laboratory. The Lab is recognized by UNBS
Academia		
	Makerere University College of Agricultural and Environmental Sciences (CAES)	• The Department of Food Technology & Nutrition (DFTN) has four courses that address issues of aflatoxins: Postharvest Technology (taught to undergraduates of BSc Agriculture, BSC Food Science & Technology, BSc Human Nutrition & Bachelor of Agribusiness), Postharvest Technology & Small Scale Agroprocessing (Taught to Bachelor of Agricultural & Rural Innovations), Postharvest Technology of Plant Products (Taught to MSc. Food Science & Technology/MSc Applied Human Nutrition) and Food Toxicity and Allergenicity (Taught to MSc Food Safety) • The DFTN is currently implementing 3 projects addressing aflatoxins: (I) Enhancing nutritional benefits and safety of maize to improve the health of Africans where nixtamalization process has been used to decontaminate maize of aflatoxins; the project has also designed simple IEC materials and translated them into selected local languages. This Project is funded by Nestle Foundation, (II) Aflatoxin Exposure and Risk Assessment among Peri-urban Low Income populations in Kampala Capital City, Uganda, funded by Carnegie Corporation of New York and; (III) Exposure assessment and analysis of health risks associated with consumption

		of aflatoxin contaminated staples in Uganda, funded by Government of Uganda (Mak RIF) • The DFTN collaborates with NARO and IITA on the Aflatest Project • Prof. Kaaya from DFTN chairs the Technical Working Group on Aflatoxins in Uganda and is a member of the Uganda Mycotoxin Mitigation Committee • DFTN has a laboratory for testing aflatoxins and isolation of moulds with microbiology section recognized by UNBS • The Department of Agricultural Sciences (DAP) has just completed a Project on use of local clay (bentonite) as aflatoxin binders in animal feeds.
	Makerere University College of Health Sciences	• Department of Medical Biochemistry collaborates with several institutions outside Uganda to address aflatoxin effects including liver cancer and HBV • Focusing on the health aspects of aflatoxin, including bringing forward the health effects of aflatoxins including a recent study on a case control study to establish the relationship between food consumption and liver cancer. Also they are working with NARO and USAID to develop a rapid on-site aflatoxin testing kit.
	Makerere University College of Natural Sciences	• Department of Chemistry, has a project on determining aflatoxin in herbal medicine (powders, syrups, liquids. The project is supported by Government of Uganda, Mak RIF
	Makerere University College of Veterinary Medicine, Animal Resources and BioSecurity (COVAB)	• Department of Biomolecular Resources and Biolaboratory Sciences has been working on evaluation of microbiological binders of aflatoxins in poultry feeds; and conducting aflatoxin awareness among animal feed processors in Uganda • Work hand-in-hand with Soroti University to develop an aflatoxin rapid detection technology comprised of a rapid diagnostic strip and a mobile app
	Soroti University	• Together with COVAB, Makerere University, they are the PIs on a project aiming to develop an aflatoxin rapid detection technology comprised of a rapid diagnostic strip and a mobile app
	Gulu University	• They have a Project on Holistic approach to combat mycotoxins in Uganda. The project has developed control mechanisms to suppress aflatoxin producing fungi. Mycotoxin assessment is on grains; sorghum, maize, groundnuts and millet. • PhD work on assessment of aflatoxins in the flour and grains of millet, sesame and soy by Ms. Eunice Achiro. The assessment is done on the raw material, processed composite flour and also under storage.

		• Faculty of Medicine has a Project on Assessment of mycotoxins in herbs prepared for children. • Networks with Lira University on the DINU-CHASE Project
		• Together with Gulu University, they have the DINU-CHASE Project that involves Analysis of aflatoxin in grain-based (Sorghum, maize, soy) composite flour for children with moderate acute malnutrition and patients of nodding disease in Northern Uganda. Coordinator at Lira University is Dr. Bernard Omech and at Gulu University is Dr. Solomon Olum
	Mbarara University of Science and Technology	• Department of Biology, Faculty of Science, has just completed work on fungal contamination and aflatoxin occurrence along production stages of Ajono (local brew) from Soroti district, eastern Uganda (MSc student accomplished u1a2020)
	Kyambogo University	• Department of Food Science and Technology has a number of taught Diploma and undergraduate courses addressing aflatoxins • Co-supervising a PhD student from Busitema University working on use of enzymes to decontaminate the aflatoxin in maize and groundnuts
NGOs/CBOs/Companies		
	Sasakawa Africa 2000	• Design and distribution of Postharvest technologies (dryers, shellers, threshers, cleaners, tarpaulins etc.) that can help to mitigate aflatoxins • Capacity building of farmers to manage aflatoxins • Advocacy and awareness campaigns on aflatoxin management
	Uganda Grain Council (UGC)	• Capacity building of grain traders on aflatoxin management • Development of simple IEC materials on aflatoxins • Linking grain traders to the market where aflatoxins are included as safety issues
	Eastern Africa Grain Council (EAGC)	• Training of smallholder farmers, warehouse operators, traders, and processors on aflatoxin detection, testing and control, and other related grain storage best practices. • Conducting surveillance on the levels of aflatoxin maize contamination. They have collected over 50 samples of maize from different regional markets and grain handling and processing facilities and are conducting tests for aflatoxin and additional EAS quality standards parameters to determine the levels of quality compliant maize in the markets.

		• Promoting among smallholder farmers, the use of affordable hermetic storage technologies, post-harvest handling tools such as tarpaulins for drying maize. • Media engagement with the print, audio and visual media houses creating awareness about the dangers of Aflatoxin to health and trade. • Conducting agribusiness expo creating a platform for the private sector service providers for aflatoxin testing equipment and grain quality tools to show case and demonstrate how to mitigate, test, and control the aflatoxin contamination. • Providing aflatoxin testing services to private sector grain traders especially during the process of trade facilitation between the buyer and seller under the Gsoko trading system. They currently have the Reveal Q+ equipment for mobile testing and Elisa aflatoxin equipment.
	Catholic Relief Services (CRS)	• Runs programmes involving training on agriculture, nutrition and food safety including aflatoxin awareness and management
	PELA Commodities, Arapai, Soroti	• Have a facility for aflatoxin decontamination in grains using ozone (TOXI SCRUB) • Work with Private sector including grain exporters to remove aflatoxins from grains
Laboratories		
	CHEMIPHAR, Kansanga	• Accredited for analysis of aflatoxins using ELISA, GCMSMS (newest model) and have continued to get samples for aflatoxin analysis
	Govt analytical Lab (GAL), Wandegeya	• Not accredited but quite involved in toxin analysis on foods including aflatoxins using HPLC
	St. Michael, Bugolobi	• Not accredited but analyses aflatoxins (using ELISA)
	Chemical Laboratory,	• Not accredited but they analyse aflatoxins (using ELISA)
Suppliers of Mycotoxin testing Equipment and supplies		
	Mycoveria Scientific Limited	• All Mycotoxin testing equipment supplied
Continental/Regional Economic Commissions		
	African Union (AU)	• Supported the Partnership for Aflatoxin Control in Africa where Uganda was included among the 6 Pilot Countries; • Currently, AU has developed a Food Safety Strategy which focuses on increasing the performance of the food safety systems in Africa at large which will ensure that all food safety issues, including aflatoxins, are adequately addressed. The strategy also sets out to ensure that the capacity of the three key players in the management of food safety (governments, food business operators (the private

		sector) and consumers) are strengthen, thereby enabling these actors to play their roles adequately within the food safety system. The strategy was approved at the Fourth Ordinary Session of the Specialized Technical Committee (STC) on Agriculture, Rural Development, Water and Environment (ARDWE).
	EAC	• Established and launched policy briefs on aflatoxin control among EAC member countries Uganda inclusive • Establishment of an aflatoxin communication strategy which is with MAAIF
	IGAD	• The Post-Harvest Loss Reduction Strategy 2020 considers aflatoxin as a major cause of economic losses
	COMESA	• Has involved Uganda on a number of Projects addressing aflatoxins. For example, the Mutual Recognition Framework (MRF) pillars and Standard Operating Procedures (SOPs) under the COMESA-AGRA MRA programme; Harmonisation of regulatory limits for agricultural commodities of regional trade importance (established the Uganda National Task Force to generate data on aflatoxin contamination); Training on SPS, risk management, Prioritizing Investments and Leveraging Resources to Boost Agri-food exports in the COMESA Region Confirmation
Development Partners		
	USAID FtF	• Funding for aflatoxin surveillance and management in food and feed value chains • Funding on aflatoxin health and economic impact studies • Training of grain value chain actors in management of quality along the value chain • Advocacy on stakeholder aflatoxin management
	aBI TRUST	• The aBi Green Challenge Fund also addresses grain value chains where aflatoxins are key
	FAO	• Has supported identification of regional interventions or policies that have an impact on national postharvest loss management for Uganda where aflatoxins have been included • During the UN Food Systems Summit, FAO supported Action Track 1 on Ensuring Access to Safe and Nutritious Food for all where aflatoxins were strongly addressed as No. 1 causes of food safety. This support has continued at country level FAO now supporting the Food Systems Transformation in the country

	WFP	• Has been distributing hermetic storage facilities (PICS bags, Cocoons, Plastic silos etc.) for management of grain quality and safety including aflatoxins • Addresses issues of Postharvest handling of grains to supply safe products during emergencies • Screens maize for aflatoxins using rapid test prior to purchasing.
	UNICEF	• Addresses issues of child malnutrition where aflatoxins are considered as contributing factors
	WHO	• Supports studies on food borne illnesses including those related to aflatoxins • Sets SOPs and Regulatory standards including aflatoxins

4.4 Gaps and challenges of aflatoxin management in Uganda

This section summarizes gaps and challenges in management of aflatoxins established during the study. The gaps and challenges presented here were obtained through interaction of the consultant with various stakeholders during KII in coming up with the matrix, during literature review and also during the Annual Performance Review Meeting of Feed the Future Uganda-Agricultural Research Activity held November 14 -18, 2022.

These will be the basis for coming up with concrete and sustainable solutions for management of aflatoxins in the country. The following are the identified gaps and challenges (not in order of priority).

1. Inadequate aflatoxin awareness, advocacy and management strategies

   During the study, the consultant established that majority of stakeholders (farmers, traders, processors and consumers) are now aware of the aflatoxin problem in the country following rejection of Ugandan maize by Kenyan Government in 2021. Although most maize farmers and traders lost money, there is limited awareness of the health and economic impacts of aflatoxins. This is because there are inadequate aflatoxin awareness, advocacy and management strategies in place to educate stakeholders about the problem and also to change their mind and cultures that promote aflatoxin contamination of produce. This could be the reason for high levels of aflatoxins established during the current study. In addition, there is no particular institution that is charged with aflatoxin information dissemination/outreach in the country.

2. Weak coordination among the stakeholders involved in aflatoxin management

   As indicated in the matrix of stakeholders, a number of activities including research are going on to address the aflatoxin problem in the country. However, the coordination is quite weak. The Aflatoxin Technical Working Group (ATWG) and the Uganda Mycotoxin Mitigation Committee (UMMSC) established by MAAIF are inactive possibly due to lack of resources and support. These committees were established mainly to play a coordination role including prevention of duplication of activities among others.

3. Inadequate implementation and enforcement of standards for aflatoxin prevention and management

   Whereas the Government of Uganda (GoU) recognizes the importance of aflatoxins with respect to health, trade and food security and in a bid to protect the citizens against the harmful effects of aflatoxins, UNBS has developed aflatoxin standards for several food products including maize (US EAS 2:2013), groundnuts (US EAS 57-1), sorghum (US EAS 757:2013), and rice (US EAS 128) and animal feeds among others, implementation and enforcement of these standards is still inadequate in majority of the stakeholders. Inspection services to establish those not adhering to the standards are almost not there. Many products from aflatoxin-susceptible foods are on the market (including supermarkets) without certification. In addition, there is inadequate enforcement of Good Agricultural

Practices (GAP), Good Manufacturing Practices (GMP), Good Storage Practices (GSP) and, overall, Good Hygienic Practices (GHP) along the value chains of aflatoxin-susceptible food products.

4. Research gaps

Although there are a number of institutions conducting research on aflatoxins, most of the research is still concentrated on determination of aflatoxin incidence in food and feedstuff. There are research gaps in the areas of;

- aflatoxin management/control including coming up with rapid detection techniques that can be used by farmers and traders, research on resistant/tolerant varieties and biological control among others;
- alternative use of contaminated foods,
- Inadequate data on aflatoxin health-related issues; for example, what exactly are cancer cases related to aflatoxin in the country?; what is the status of aflatoxin exposure among the human population and domestic animals? No comprehensive countrywide food analysis and exposure assessment have been done etc.
- Inadequate uptake of research results by the end users is a strong gap because most of the generated data/information remains on the shelf.
- Mapping aflatoxin contamination of food in the country (which regions/subregions are more susceptible), correlating it with food consumption, cancer and other aflatoxin-related health challenges.

5. Limited availability and application of recommended appropriate technologies

Simple and appropriate postharvest technologies to be used by stakeholders to ensure quality and safety of produce are not available. Thus, majority of the farmers, traders and processors use rudimentary technologies during drying, threshing, shelling, transportation and storage. Where these technologies exist, they are not affordable by the majority of stakeholders. In addition, use of secondary processing technologies like ammonia, ozone, and animal feed binders that can decontaminate produce is limited to a few large scale exporters and manufacturers.

6. Inadequate investment in aflatoxin testing infrastructure

Very few labs are capable of analyzing aflatoxins due to lack of appropriate equipment and supplies. Very few labs are accredited for aflatoxin testing. In addition, there are very few suppliers of aflatoxin testing equipment and supplies in the country. There are no simple kits for analysis of aflatoxins. Due to these challenges, aflatoxin testing is quite expensive only affordable to a few large scale entrepreneurs especially exporters.

7. Failure for the country to put into action the Uganda Aflatoxin Mitigation Action Plan

The Uganda Aflatoxin Mitigation Action Plan (UAMAP) 2018/19-2023/24 was officially launched by H.E. The Vice President of Uganda on October 31, 2018 to be implemented by MAAIF for five years. This Plan has not been implemented yet it contained very informative strategies and recommendations for management of aflatoxin in the country. In addition, simple information, education and communication (IEC) materials developed and launched by Government together with UAMAP have not been adequately used. These materials were even translated into major local languages.

8. No budget allocation from Government for aflatoxin management:

There is no budget set aside for aflatoxin management in Uganda. This budget could be used to address the strategies suggested by the 2019-2023 UAMAP and several other challenges of aflatoxin in the country. The UAMAP came up with a budget on each action proposed which needs funds to be addressed. Government could borrow a leaf from Kenya and Tanzania governments which put a budget for aflatoxin management annually. Budget allocation would enable the Government to take the lead in implementation of the aflatoxin mitigation strategies alongside private sector, NGOs and development partners.

9. Lack of a Food Safety Law

The Food and Drug Act of 1959 is out dated and does not address contemporary food safety issues like aflatoxins. The new Food Safety Bill which has been in pipeline for several years is just being revived. This should contain information on how to address contemporary issues of food safety including aflatoxins in food and feeds.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Results of the current rapid assessment of aflatoxin prevalence and incidence indicate that aflatoxin is still a major problem in this country for both food and feed commodities as attested by the high percentage of samples above the regulatory limits. Although a number of stakeholders are currently involved in addressing the problem, these need to be coordinated. There are gaps and challenges that need to be immediately tackled to reduce the aflatoxin health and economic impacts. This requires a holistic approach involving all stakeholders in the value chains of the susceptible commodities, Government of Uganda should take the lead.

5.2 Recommendations

These could come after merging the document with the economic impacts study report

6.0 REFERENCES

1. Alpert, M. E, Hutt, M. S. R, Wogan, G. N. and. Davidson, C. S (1971). Association between aflatoxin content of food and hepatoma frequency in Uganda. Cancer, vol. 28, no. 1, pp. 253–260, 1971.
2. Asiki, G, Seeley, J, Srey, C., Baisley, K, Lightfoot, T et al. (2014). A pilot study to evaluate aflatoxin exposure in a rural Ugandan population," Tropical Medicine & International Health, 19, 5, 592–599.
3. Azziz-Baumgartner, E, Lindblade, K, Gieseker, K, Rogers, H.S, Kieszak, S, Njapau, H, Schleicher, R, McCoy, L.F, Misore, A, DeCock K, et al. (2005). Case-control study of an acute aflatoxicosis outbreak, Kenya, 2004. Environmental Health Perspectives. 13:1779-83.
4. Baluka, S.A, Schrunk, D. Imerman, P, Kateregga J.N, Camana, E, et al. (2017). "Mycotoxin and metallic element concentrations in peanut products sold in Ugandan markets," Cogent Food and Agriculture, 3, 1313925.
5. Bennett, J.W, Klich, M (2003). Mycotoxins. Clinical Microbiology Reviews 16(3): 497–516.
6. Candia, A and Masette, M 2012. Physical quality and safety assessment of selected varieties of local paddy and milled rice processed by cottage rice mills in Uganda. Uganda Journal of Agricultural Sciences, 13 (2): 127-138
7. Daily Monitor (2021). Aflatoxins can cause liver cancer. https://www.monitor.co.ug/uganda/oped/commentary/aflatoxins-can-cause-liver-cancer-3372204
8. Groopman J.D, Kensler T.W (2005). Role of metabolism and viruses in aflatoxin induced liver cancer. Toxicology and Applied Pharmacology 206: 131–137.
9. IARC (International Agency for Research on Cancer) (2012). GLOBOCAN 2012: Estimated Cancer Incidence, Mortality and Prevalence Worldwide in 2012 Lyon, France: WHO; 2016 [24th February 2016].: http://globocan.iarc.fr/Pages/fact_sheets_cancer.aspx
10. IARC (International Agency for Research on Cancer) (2014). Sampling and sample preparation methods for determining concentrations of mycotoxins in foods and feeds. Chapter 3. file:///C:/Users/Prof%20Kaaya/Downloads/IARC_SP158_Chapter%203-2.pdf
11. Ismail, M, Taligoola, H.K, and Nakamya, R (2008). Mycobiota associated with baby food products imported into Uganda with special reference to aflatoxigenic aspergilli and aflatoxins. Czech Mycol. 60(1): 75–89.
12. Kaaya, A.N and Kyamuhangire W (2006b). The effect of storage time and agro ecological zone on mould incidence and aflatoxin contamination of maize from traders in Uganda. International Journal of Food Microbiology, 110, 217–223.
13. Kaaya, A.N, Harris, C and Eigel, W (2006a). Peanut aflatoxin levels on farms and in markets of Uganda. Peanut Science, 33, 68–75.
14. Kaaya, A.N, Warren, L.H, Kyamanywa, S, Kyamuhangire, W (2005). The effect of delayed harvest on moisture content, insect damage, moulds and aflatoxin contamination of maize in Mayuge district of Uganda. Journal of the Science of Food and Agriculture 85, 2595–2599.

15. Kaaya, A.N, Warren, L.H., Kyamanywa, S., Kyamuhangire, W, (2005). The effect of delayed harvest on moisture content, insect damage, moulds and aflatoxin contamination of maize in Mayuge district of Uganda. Journal of the Science of Food and Agriculture 85, 2595–2599.
16. Kaaya, A.N. and Eboku, D (2010). Mould and Aflatoxin Contamination of Dried Cassava Chips in Eastern Uganda: Association with Traditional Processing and Storage Practices. Journal of Biological Sciences, 10: 718-729.
17. Kamala, A, Shirima, C, Jani, C. B, Bakari, M Sillo, et al. (2018). Outbreak of an Acute Aflatoxicosis in Tanzania during 2016. World Mycotoxin Journal 11, 3: 311–320. doi:10.3920/WMJ2018.2344
18. Kang, S. Nkurunziza, P, Muwanika R, Qian, G, Tang, L, et al. (2015). Longitudinal evaluation of aflatoxin exposure in two cohorts in South-Western Uganda. Food Additives & Contaminants: Part A, 32, 8, 1322–1330, 2015.
19. Kitya, D., Bbosa, G.S. & Mulogo, E, (2010). Aflatoxin levels in common foods of South Western Uganda: a risk factor to hepatocellular carcinoma. European Journal of Cancer Care 19, 516–521
20. Klvana, M, Bren, U, (2019). Aflatoxin B1–Formamidopyrimidine DNA Adducts: Relationships between Structures, Free Energies, and Melting Temperatures. Molecules, 24, 150
21. Kumar, P, Mahato D.K, Kamle, M, Mohanta, T.K and Kang, S.G (2017). Aflatoxins: A Global Concern for Food Safety, Human Health and Their Management. Frontiers in Microbiology. 7:2170.doi: 10.3389/fmicb.2016.02170
22. Lauer, J., Duggan C.P, Ausman L.M, Griffiths, J.K, Webb, P et al. (2019). Maternal aflatoxin exposure during pregnancy and adverse birth outcomes in Uganda. Maternal and Child Nutrition, 15, 2, Article ID e12701, 2019.
23. Lopez, A and Crawford, M.A (1967). Aflatoxin content of peanuts sold for human consumption in Uganda. Lancet, 2: 1351 – 1354
24. Magala, J, Kahwa, D, Nyatia, E, Kasule, T, & Natwijuka, F (2022). Aflatoxin Contamination and Rancidity in Locally Processed Commercial Fish Feeds and Ingredients along the Value Chain in Wakiso and Kampala Districts, Uganda. Food and Nutrition Sciences, 13, 619-637. https://doi.org/10.4236/fns.2022.137046
25. Mupunga, I, Christo I.D, Leshweni S.J and Katerere, D.R (2017). Aflatoxin biomarkers in hair may facilitate long-term exposure studies. Journal of Applied Toxicology, 37, 4, 395–399. doi:10.1002/jat.3422
26. Nakavuma, J.L, Kirabo, A, Bogere, P, Nabulime, M et al, (2020). Awareness of mycotoxins and occurrence of aflatoxins in poultry feeds and feed ingredients in selected regions of Uganda International Journal of Food Contamination, 7, 1. https://doi.org/10.1186/s40550-020-00079-2
27. Nunn A.J, Kengeya-Kayondo J.F, Malamba S.S, Seeley J.A & Mulder D.W (1994). Risk factors for HIV-1 infection in adults in a rural Ugandan community: a population study. AIDS 8, 81–86.
28. Omara, T (2019). Aflatoxigenic contamination of white maize (Zea mays L.) from some selected Ugandan districts. Peer J Preprints, vol. 7, Article ID e27888v1.
29. Partnership for Aflatoxin Control in Africa (PACA) (2017). Country-Led Aflatoxin and Food Safety Situation Analysis and Action Planning for Uganda: Final Report, PACA, African Union Commission, Addis Ababa, Ethiopia. http:// www.aflatoxinpartnership.org/uploads/Uganda_Aflatoxin_ Control_M.

30. Ropero-Miller, L.D, Goldberger, B.A, Cone, E.J, Joseph, R.E (2000). The disposition of cocaine and opiate analytes in hair and fingernails of humans following cocaine and codeine administration. Journal of Analytical Toxicology 24:496–508.
31. Sebunya, T.K and Yourtee, D.M (1990). Aflatoxigenic Aspergilli in foods and feeds in Uganda Journal of Food Quality, 13: 97 – 107.
32. Serck-Hanssen, A (1970). Aflatoxin-Induced Fatal Hepatitis? Archives of Environmental Health: An International Journal, 20(6), 729–731. doi:10.1080/00039896.1970.10665651
33. Sserumaga, J.P, Ortega-Beltran, A,. Wagacha, J.K. Mutegi, CK and Bandyopadhyay, R (2020). Aflatoxin-producing fungi associated with pre-harvest maize contamination in Uganda. International Journal of Food Microbiology. https://doi.org/10.1016/j.ijfoodmicro.2019.108376
34. Turner PC, Mendy M, Whittle H, Fortuin M, Hall AJ, Wild CP. 2000. Hepatitis B infection and aflatoxin biomarker levels in Gambian children. Trop. Med.Int. Health 5: 837–841.
35. Turner, P.C, 2013. The molecular epidemiology of chronic aflatoxin driven impaired child growth. Scientifica, 21.
36. UBOS (Uganda Bureau of Standards) (2014). National population and housing census 2014. The Republic of Uganda (www.ubos.org).
37. UN COMTRADE 2013. UN Comtrade database: The International Trade Statistics Yearbook: Volume I - Trade by Country and Volume II - Trade by Product
38. WHO (World Health Organization) (2017). Evaluation of Certain Contaminants in Food: Eighty-Third Report of the Joint FAO/WHO Expert Committee on Food Additives; World Health Organization: Geneva, Switzerland.
39. Williams, J.H, Phillips, T.D, Jolly, P.E, Stiles, J.K, Jolly, C.M and Agarwal D (2004). Human aflatoxicosis in developing countries: a review of toxicology, exposure, potential health consequences, and interventions. The American Journal of Clinical Nutrition. 80: 1106–1122.
40. Zitomer, N C, Obura, A, Widdowson, M, Daniel, J.H.; Sternberg, M.R et al. (2020). Human aflatoxin exposure in Uganda: Estimates from a subset of the 2011 Uganda AIDS indicator survey (UAIS). Food Additives & Contaminants: Part A, (), 1–12. doi:10.1080/19440049.2020.1825826

7.0 List of annexes

7.1 Letter from Kenya's Agriculture and Food Authority banning maize imports into Kenya



AGRICULTURE AND FOOD AUTHORITY

Tea House| Nairobia Road, Off Ngong Road,
P.O. Box 37962 NAIROBI – 00100.

5th March, 2021

Ref: AFA/MKT/1(40)

Mrs. Pamela Ahago,
Commissioner of Customs,
Kenya Revenue Authority,
P.O Box 40160- 00200,
NAIROBI.

RECEIVED
05 MAR 2021
MANAGING DIRECTOR'S OFFICE

Dear

RE: STOPPAGE OF MAIZE IMPORTS INTO KENYA

Agriculture and Food Authority is a State Corporation under the Ministry of Agriculture, Livestock, Fisheries and Cooperatives established through the AFA Act, 2013. The mandate of the Authority is to regulate, develop and promote scheduled crops.

The Authority has been conducting surveillance on the safety of food imports to Kenya. Test results for maize imported from Uganda and Tanzania have revealed high levels of mycotoxins that are consistently beyond safety limits. Mycotoxins, particularly aflatoxins and fumonisins are known to be carcinogenic. Over the years a number of acute and chronic aflatoxin related illness cases have been recorded in Kenya including deaths.

We wish to bring to your attention that Agriculture and Food Authority has stopped any further imports of the maize into Kenya with immediate effect. The Republic of Kenya is however committed to facilitating safe trade with her trading partners and look forward to working closely with all stakeholders to address the concern.

Yours

KELLO HARSAMA
AG. DIRECTOR GENERAL

Copy to:

Hon. Peter Munya, MGH,
Cabinet Secretary
Ministry of Agriculture, Livestock, Fisheries and Cooperatives,
Kilimo House,
P.O. Box 30028-00100,
NAIROBI.

Telephone: 3872421/3872497/3874445/6 || Mobile: 0722-200556/0734-600844
Wireless: 020-2536889/2536886 ||Telefax: 3862120/3876337

7.2 Aflatoxin contamination in maize from different districts of Uganda

District	Samples/AF contamination																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Mean
Mubende	ND	34	45	12	8	9	78	97	35	14	37	58	80	33	ND	ND	ND	90	ND	ND	45
Iganga	33	5	7	ND	46																22.8
Mbale	18	50	ND	27	ND																38.5
Kiryandongo	20	45	8	ND	ND	11	6	18	44	8	10	27	9	5	ND	ND	21	5	2	10	15.6
Kampala	28	18	25	50	15																27.2

ND=Aflatoxins not detected

7.3 Aflatoxin contamination of groundnuts from different districts of Uganda

District	Samples/Aflatoxin contamination										
	1	2	3	4	5	6	7	8	9	10	Mean
Iganga	29	11	6	8	45						19.8
Kiryandongo (Kigumba)	ND	15	8	226	460	12	ND	34	11	78	108
Lira	12	4	14	7	ND						9.25
Kampala	15	8	12	60	36	7	11	56	ND	40	27.2
Kumi	24	11	8	14	7						12.8
Soroti	8	ND	11	45	18						20.5

7.4 Aflatoxin contamination of cassava from different districts of Uganda

District	Samples/Aflatoxin contamination										
	1	2	3	4	5	6	7	8	9	10	Mean
Apac	18	ND	11	8	5	10	15	ND	ND	22	12.7
Mubende	5	12	ND	ND	4						7
Lira	12	ND	14	12	6						11
Soroti	8	ND	5	3	11						6.8
Kiryandongo	22	13	12	10	4						12.2

7.5 Aflatoxin contamination in sorghum from different districts of Uganda

District	Samples/AF contamination										
	1	2	3	4	5	6	7	8	9	10	Mean
Amuria	6	ND	ND	15	24	11	6	27	35	12	17
Kumi	12	18	11	7	10						11.6
Soroti	10	ND	14	9	5						9.5
Lira	18	22	8	17	ND						16.2
Apac	ND	14	6	11	20						12.8

7.6 Aflatoxin contamination of animal feeds from different districts of Uganda

Feed Type	Source/AF levels (Mean)			
	Kampala	Mukono	Wakiso	Jinja
Chick Mash	12, 17, 7, 30, 22 **(17.6)**	11, 16, 8, ND, 22 **(14.5)**	2, ND, 11, 15, 23 **(12.8)**	12, 40, 22, 32, 35 **(28.2)**
Layers' Mash	3, 11, 26, 18, 38 **(19.2)**	8, 23, 12, 14, 8 **(13)**	13, 11, 30, 4, 9 (13.4)	11, 34, 22, 56, 8 **(26.2)**
Broiler Starter	4, 13, 12, 17, 9 **(11)**	9, 28, 59, 33, 45 **(30.8)**	11, 45, 22, 16, 9 **(20.6)**	ND, 21, 8, 12, 6 **(11.8)**
Cattle feeds	28, 19, 44, 60, 18 **(33.8)**	12, 77, 28, 46, 20 **(36.6)**	15, 2, 5, 40, ND **(15.5)**	33, 32, 50, 21, 43 **(35.8)**
Sow and weaner meal/feed	181, 40, 22, 38, 11 **(58.4)**	21, 17, 44, 33, ND **(28.5)**	20, 12, 32, 6, 10 **(16)**	14, 18, 44, 10, 11 **(19.4)**
Rabbit pellets	19, 27, 11, 18, 35 **(22)**	22, 4, 25, 21, 8 **(16)**	ND, ND, 6, 2, 12 **(6.7)**	3, 8 **(5.5)**
Dog food (puppies)	ND 2, 11, 6, ND **(6.3)**	5, 8, 11, 4, 3 **(6.2)**	ND, ND, 28, 4, 10 **(14)**	4, 11 **(7.5)**
Dog food (Adults)	10, 12, 3, ND, 6 **(7.8)**	2, 9, 11, ND, 14 **(9)**	3, 8, 4, ND, ND **(5)**	5, 3 **(4)**
Total	**40**	**40**	**40**	**31**