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A REVIEW OF PAST AND PRESENT RESEARCH ON AFLATOXIN IN UGANDA

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ABSTRACT

Uganda is a landlocked country located in Eastern Africa covering an area of about 241,000 km^2. Its climate is tropical, with most parts of it receiving bimodal rainfall of 500 to 2000 mm per annum, and an average temperature of 25 ^{o}C. These temperatures and the humid environment are optimum for growth of *Aspergillus flavus/parasiticus* and subsequent production of aflatoxins in the produce. The country was among those in the world where aflatoxin studies were first conducted following their discovery, in the 1960s and, during that time, hepatoma frequency was related to aflatoxin content of food. The objective of this paper is to review the past and present status of aflatoxin research in Uganda by considering the epidemiology, measurement, research, promoting factors, control strategies and problems associated with this toxin in the country. It is revealed that aflatoxin contamination has been studied mainly in maize and groundnuts, and aflatoxin B_1 is the most prevalent in the country. More studies have been done on foods sampled at the market level than on-farm level. There is more aflatoxin contamination of foods in markets, than those stored by farmers, with some having levels above the FDA/WHO recommended limits of 20 ppb. However, no strategies for controlling aflatoxin contamination of food and food products in Uganda have been reported. It is concluded that aflatoxin contamination of agricultural produce is a big problem in the country, and this is attributed to inadequate research, lack of proper sampling and analytical procedures; poor legislation and lack of awareness of the problem by farmers, traders, processors and consumers. Therefore in order to reduce the potential hazard of aflatoxins, government of Uganda through the Ministries of Health, and Agriculture, Animal Industry and Fisheries; together with the Uganda National Bureau of Standards, should put into place information dissemination and training programs for farmers, traders and consumers on proper pre- and post-harvest aflatoxin management strategies. To reduce further this potential hazard, regulations for monitoring susceptible produce from buying points to retail markets should be put in place and strict measures on the quality of food at both household and market levels be enforced by all policy makers.

Key words: Uganda, aflatoxin, contamination, maize, groundnuts

FRENCH

RÉSUMÉ

L'Ouganda est un pays enclavé situé en Afrique orientale, qui couvre une superficie de près de 241.000 km^2. Son climat est tropical, la plupart de ses régions reçoivent des pluies bimodales de 500 à 2000 mm par an, et la température moyenne est de 25 ^{o}C. Ces températures et l'environnement humide sont optimaux pour la culture et la croissance d'Aspergillus flavus/parasiticus et la production subséquente d'aflatoxines dans ses produits. L'Ouganda compte parmi les premiers pays du monde où des

études sur les aflatoxines ont été menées aussitôt après la découverte de ces dernières dans les années 1960. A cette époque, la fréquence de l'hépatome a été associée à la teneur en aflatoxine dans les aliments. L'objectif du présent document est d'évaluer l'état des recherches passées et actuelles sur l'aflatoxine en Ouganda en considérant l'épidémiologie, les mesures, les recherches, les facteurs de promotion, les stratégies de contrôle et les problèmes associés à cette toxine dans le pays. Il a été révélé que la contamination par aflatoxine a été étudiée principalement dans le maïs et l'arachide, et l'aflatoxine B_1 est la plus prévalente dans le pays. Des études ont été effectuées sur les aliments pris comme échantillons plus au niveau du marché qu'au niveau des champs. Il y a plus de contamination par aflatoxine dans les aliments exposés au marché que dans les aliments conservés par les cultivateurs, certains aliments ayant des niveaux supérieurs aux limites de 20 ppb recommandées par l'OMS/FDA (organisme gouvernemental de contrôle pharmaceutique et alimentaire). Cependant, aucune stratégie de contrôle de la contamination par aflatoxine d'aliments et de produits alimentaires en Ouganda n'a été rapportée. La conclusion est que la contamination des produits agricoles par aflatoxine est un grand problème qui se pose dans le pays, et ceci est dû à des facteurs tels que des recherches inadéquates, le manque d'échantillonnage approprié et de procédures analytiques; une mauvaise législation et aussi parce que les agriculteurs, les commerçants, les agents de la transformation industrielle et les consommateurs ne sont pas au courant du problème. Par conséquent, pour réduire les possibilités des dangers présentés par les aflatoxines, le Gouvernement de l'Ouganda, par le biais des Ministères de la santé, de l'agriculture, de l'industrie animale et de la pêche, conjointement avec le Bureau National de vérification des Normes en Ouganda (Uganda National Bureau of Standards), devrait mettre en place des programmes de diffusion d'informations et de formation à l'intention des cultivateurs, des commerçants et des consommateurs sur des stratégies de gestion de l'aflatoxine avant et après la récolte. Dans le souci de réduire davantage ce danger éventuel, des règlements visant à contrôler des produits sensibles depuis les points d'achat jusqu'aux marchés de vente en détail devraient être mis en place et des mesures strictes relatives à la qualité des aliments aussi bien au niveau des ménages qu'au marché devraient être mises en application par tous les décideurs.

Mots-clés: Ouganda, aflatoxine, contamination, maïs, arachides

INTRODUCTION

Aflatoxins are poisonous, carcinogenic by-products of the growth of the molds *Aspergillus flavus* and *Aspergillus parasiticus*, and are the most studied and widely known mycotoxins. There are four major groups of aflatoxins: B_1, B_2, G_1 and G_2. Aflatoxin M1, a metabolite of Aflatoxin B1 in mammals, may be found in the milk of animals eating feeds contaminated by Aflatoxin B1 [1-3]. Aflatoxins B_1, B_2, G_1 and G_2

are classified as Group 1 human carcinogens whereas M_1 is classified as Group 2B probable human carcinogen [4].

Aflatoxins are of economic and health importance because of their ability to contaminate human food and animal feeds, in particular cereals, nuts and oilseeds [5, 6]. Cheese, almonds, figs and spices have been also associated with aflatoxins [7]. The economic impact of aflatoxins is derived directly from crop and livestock losses due to flatoxins and directly from the cost of regulatory programs designed to reduce risks to human and animal health [7]. The Food and Agricultural Organisation (FAO) estimates that 25% of the world's crops are affected by mycotoxins, of which the most notorious are aflatoxins. Aflatoxin losses to livestock and poultry producers from aflatoxin-contaminated feeds include death and more subtle effects of immune system suppression, reduced growth rates, and losses in feed efficiency [8]. Other adverse economic effects of aflatoxins include lower yields for food and fibre crops [9].

The aflatoxin problem has been reported to be more serious in tropical and subtropical regions of the world where climatic conditions of temperature and relative humidity favour the growth of *Aspergillus flavus/parisiticus*. Uganda is a landlocked country in Eastern Africa and its climate is tropical, with most parts of it receiving bimodal rainfall of 500 to 2000 mm per annum, and an average temperature of 25^{o}C. These temperatures and the humid environment are optimum for growth of *A. flavus/parasiticus* and subsequent production of aflatoxins in the produce.

In Uganda, maize (*Zea mayis* L.) and groundnuts (*Arachis hypogaea* L.) are the two commodities most researched as far as aflatoxins are concerned, and, both have been reported to be contaminated. These two crops are major staple foods for the majority of people in the country. Groundnuts are the second most important legume and total production has been estimated at 140,000 MT grown on 175,000 ha, mainly in eastern parts of the country. Maize on the other hand, is the most important cereal and its production is more than 750,000 MT on 560,000 ha. In 1999, Uganda exported 23,163 MT of maize valued at US $ 5,291,000 [10]. Thus, the crop is ranked third of the Non-traditional Exports in the country. Besides human consumption, maize is also a major ingredient in animal feeds. Therefore, contamination of the produce by aflatoxins puts consumers at high-risk health hazards and reduces the export potential of the country.

Aflatoxin research on food crops in Uganda started in the sixties and continued in the early seventies [11-14]. The results of these studies indicated that the populace was exposed to consumption of aflatoxin-contaminated foods. These studies also linked cases of liver cancer with high levels of aflatoxin in Ugandan foods.

There is no aflatoxin research reported in Uganda between 1971 and 1989. This could be attributed to the fact that all earlier researchers were foreigners. They left the country during the periods of political insecurity and thus little or no aflatoxin research continued until the end of that era. From 1990 to date, aflatoxin research has been going on, by studying produce stored both at the farm and market levels [15, 16]. Little work has been done in the area of pre-harvest contamination of produce and a lot is still required in designing management and control programs for proper follow up of aflatoxin contamination of different produce from field through post-harvest period. The objective of this paper is to give a review of the past and present research on aflatoxin in Uganda by considering studies on epidemiology, measurement of aflatoxin and the fungi involved, factors promoting contamination, current control strategies, problems affecting research and the needs to control aflatoxin contamination of foods in the country.

EPIDEMIOLOGICAL STUDIES OF AFLATOXIN IN UGANDA

Uganda was among the first countries in the world where aflatoxins and attendant primary liver cancer studies were carried out following the discovery of aflatoxins [17]. In 1967, one of the earliest cases was reported. Aflatoxin B_1 was circumstantially associated with death of a 15-year old boy in Uganda [13]. His younger brother, and his sister became ill at the same time; the younger sibling survived, but the older boy died two days after admission to the hospital with symptoms resembling the victims in the Taiwan outbreak in which 26 persons were poisoned following consumption of moldy rice containing up to 200 ppb aflatoxin B_1 [18]. An autopsy revealed pulmonary edema and diffuse necrosis of the liver. Histology demonstrated centrolobular necrosis with a mild fatty liver. A sample of the cassava eaten by these children contained 1700 ppb of aflatoxin which was reported to be lethal if such a diet is consumed over three weeks [19]. This estimate was based on the acute toxicity of 220 ppb aflatoxin B_1 in African monkeys [19]. The current total maximum aflatoxin level limits in foods for human consumption recommended by United States Food and Drug Administration (FDA) is 20 ppb [20, 21, 23]. Maize containing aflatoxin levels of 20 ppb or more should thus not be consumed by humans, young poultry and swine [20].

Aflatoxin content of food has been associated with hepatoma frequency in Uganda. In one study, aflatoxin levels were determined in 480 food samples including beans, maize, sorghum, groundnuts, millet, peas, cassava and rice [14]. These foods were collected from different parts of the country during the nine month period, from September 1966 to June 1967. It was found that the frequency of aflatoxin contamination was particularly high in provinces with a high hepatoma incidence, or where cultural and economic factors favoured the ingestion of mouldy foods (Table 1). These observations suggested that aflatoxin exposure may account for the high incidence of hepatoma in Uganda and perhaps elsewhere.

AFLATOXIN MEASUREMENT AND FUNGI INVOLVED IN FOODS AND FOOD PRODUCTS OF UGANDA

The pioneering effort in the survey of aflatoxin content of foods and food products in Uganda was undertaken in early 1966 [11]. The content of aflatoxin was estimated in groundnuts sold for human consumption in the country. About 15% of the samples examined contained more than 1 ppm of aflatoxin B_1 and three percent contained more than 10 ppm. The level of contamination seemed to be highest at the end of the rains and before the new crop was harvested.

In a study conducted between September 1966 to June 1967 in which 480 different food samples were analysed for aflatoxin, it was found that 29% contained between 1 –100 ppb, eight percent contained between 100-1000 ppb while four percent had more than 1000 ppb aflatoxin [14]. Aflatoxins occurred most frequently in beans, followed by maize and sorghum, whereas groundnuts, millet and cassava were contaminated least frequently (Table 2). However, there was no aflatoxin detected in rice.

In 1990, 25 of 54 samples from food and feed stores of the Produce Marketing Board (PMB), Kampala, and those of the Animal Feed Mill at Jinja, consisting of corn, peanuts, soybean and poultry feeds, were screened for aflatoxin content [15]. Four samples tested positive and of these, two (one from poultry feeds and the other from corn) contained detectable levels of 20ppb aflatoxin B_1. Further more, the ability of isolates of *Aspergillus flavus* to produce aflatoxins revealed that aflatoxins B_1, B_2, G_1 and G_2 were detected in the samples. Peanuts were the most extensive host for aflatoxigenic fungi with varied capacity to produce aflatoxigenic types. Aflatoxigenic isolates from the various sample types seemed to produce qualitatively similar patterns of mycotoxins. For example, isolates from peanuts often produced the B_1, G_1 pattern, while fungal isolates from corn and animal feed produced B_1 only.

In 1991 and 1992, over 100 maize, groundnut and cassava samples from Kampala markets were qualitatively screened for aflatoxin content using the Holladay Minicolumn Technique, and over 50% tested positive [23]. However, there was no quantification to establish the actual levels or the types of aflatoxins in these samples.

In 1999, a study of fungi and aflatoxins in maize grains in five districts of Uganda (Kampala, Mpigi, Mubende, Luwero and Mukono) was conducted [24]. The samples were obtained from shops and markets and were monitored for five months. Thirty six fungal genera represented by 83 species were isolated and *Aspergillus flavus/paristicus* was among the most frequent species. Aflatoxin levels ranged from 0 – 50 ppb during the storage period with seven out of eight samples contaminated by aflatoxin B group. More than 30% of the samples had their aflatoxin levels above 20 ppb while 50% contained up to 10 ppb. The high aflatoxin levels were associated with high moisture content, in which 48% of the samples had moisture levels above 14%.

More studies were conducted in 1999 in which both baby foods imported (Heinz mixed cereal, Cerelac, Cornflakes, Wheetabix and Porridge oats) and locally manufactured (Baby soya, Kayebe, Mwebaza rice porridge, Jacinta millet and Mukuza) in Uganda were investigated for natural contamination by various types of fungi and aflatoxins [25]. The samples in each category were purchased from displayed items in shops and supermarkets in five towns (Kampala, Jinja, Mbarara, Masaka and Mbale) and had similar expiry date. They were stored and monitored on a monthly basis for six months. Imported foods had less fungal contamination than locally manufactured foods and for both categories *Aspergillus flavus* was among the predominant species. Total aflatoxin analysis showed that all locally manufactured foods were contaminated, with some in the range of 20 – 50 ppb. Kayebe with maize, soybean and fish as ingredients was the most heavily contaminated while the least contaminated was Jacinta, composed of whole millet. Cornflakes were the most aflatoxin-contaminated imported food with 10 – 20 ppb range levels, while no aflatoxins were detected in Cerelac. It was recommended that manufacturers of baby foods should avoid use of already contaminated ingredients.

It can be observed that studies on aflatoxin content of foods and food products by 1999 had mainly concentrated on stored produce in markets but less on farm-level stored food products. However, in the year 2000, the USAID sponsored Integrated Pest Management Collaborative Research Support Program (IPM CRISP) Uganda Site, included in its plans, a proposal to conduct on-farm research in the field of moulds and aflatoxins. The main objective was to establish aflatoxin levels and reduce contamination of maize and groundnuts at farm level in order to improve the export potential of these produce in the country. Aflatoxin research under this programme was started in March 2000, by collecting maize and groundnut samples from farmers in Mayuge and Kumi districts of Uganda. Their moulds and total aflatoxin contamination was studied [26]. Both maize and groundnuts are major staple food crops in Mayuge and Kumi districts [27, 28].

The results indicate that mycotoxigenic fungi and aflatoxin contamination in maize and groundnuts starts at farm level and contamination occurs in both pre and postharvest phases. In Kumi, 48% of the groundnuts stored by farmers up to seven months and 28% of those newly harvested tested positive for aflatoxin, with ranges of 0 – 22 ppb and 0 - 5 ppb, respectively. In Mayuge, 50% of the groundnuts and 40% of the maize stored up to five months were positive for aflatoxins, with 0 – 18 and 0 - 10 ppb respectively. The aflatoxin levels observed especially in samples stored for five to seven months were low compared to those earlier reported in samples from markets. This may have an implication on the storage systems of these commodities at market level.

In a different study, the types of aflatoxins in on-farm maize and groundnuts at harvest and five to six months of storage from Kumi and Mayuge districts were identified [16]. It was reported that the majority of groundnuts and maize had aflatoxin B_1 irrespective of the storage time and method (Tables 3 and 4).

From the findings of different researchers who have analysed aflatoxin content in food products of Uganda, it is evident that Aflatoxin B_1 is the most predominant. This type of aflatoxin is the most toxic in terms of carcinogenicity [(29-31]. Therefore, consumers are at a high-risk health hazard from consumption of aflatoxin contaminated food products in the country.

INSTITUTIONS CURRENTLY INVOLVED IN AFLATOXIN RESEARCH AND ANALYSIS IN UGANDA

Makerere University is the leading institution in aflatoxin research in Uganda. It has four Departments actively involved in aflatoxin surveillance and analysis, and these are: the Department of Food Science and Technology, Department of Botany, Department of Veterinary Parasitology and Microbiology, and the Institute of Public Health.

The Government Chemist Laboratories, located in Wandegeya, Kampala are one of the earliest established government laboratories and mainly carry out aflatoxin analysis in food samples for safety purposes at government level.

The National Agricultural Research Organization (NARO) through its Food Science and Technology Research Institute, Kawanda Agricultural Research Institute and Namulonge Animal and Agricultural Research Institute conducts research in control of storage insect pests and moulds which are promoters of aflatoxin contamination, and breeding maize varieties resistant to mycotoxigenic fungi. These institutes work hand in hand with Makerere University especially in the area of mould and aflatoxin analysis.

The Uganda National Bureau of Standards (UNBS) which is the Government body responsible for setting standards, works with all institutions conducting research and analysis of food produce for aflatoxins. The body has set aflatoxin limits in all Ugandan foods and feeds at 10 ppb and, certifies good quality produce intended for the export market.

FACTORS PROMOTING AFLATOXIN CONTAMINATION OF FOODS IN UGANDA

Drying

Drying techniques for various food crops in the country vary among different stakeholders. For instance, the majority of farmers dry maize and groundnuts on bare-ground, some on polyethylene sheets or mats while others leave the crop to dry in the field [32, 33]. These drying methods are slow and may support growth and development of fungi thus increasing the potential for aflatoxin production. Besides, during the first season of maize in some production zones, harvesting takes place during the months of August – September which are relatively wet. These conditions lead to inadequate crop drying. In order to minimize aflatoxin contamination of maize, it is recommended that the grain should be dried as soon as possible, within 24 to 48 hours to moisture content no greater than 14 percent to reduce infection, growth, and toxic production by *Aspergillus* [34]. Maize kernels dried at home on bare ground have been reported to be more contaminated with aflatoxin (41.7%) than those dried on polyethylene sheets/mats (25%) [33]. Both the samples dried on bare-ground and those dried on polyethylene sheets/mats tested positive with aflatoxin B_1 only [33].

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Storage

Storage systems of produce in Uganda have also been found to encourage aflatoxin contamination. Adequate storage facilities are not available especially at farm level. It has been reported that the majority of farmers and traders in Uganda store maize using woven polypropylene bags, which do not protect the grains against aflatoxin contamination [16]. Grains stored or heaped on the floor (unshelled) and those stored under the verandah had 100% aflatoxin contamination [16]. The only method that protected the grains against aflatoxin contamination was storage above fire racks but this method cannot be adopted for storage of large quantities of grains [16]. Additionally, some farmers use out-door storage practices for maize like granaries and silos which do not guarantee maize free from moisture pick-up, mould infection and insect infestation [35-37].

At the retail markets, produce is not properly protected from environmental influence during storage. Most of the produce is not properly packaged, always exposed, making it susceptible to infection by mycotoxigenic moulds. Maize flour, pounded/ milled groundnuts and shelled kernels are some of the produce suspected to be highly contaminated by aflatoxins due to their form [38].

Moisture content and insect damage

Moisture content and grain physical condition are major factors in moulds and mycotoxin contamination of grains [39] Despite slow drying processes and inadequate storage methods, the moisture content and insect damage of maize and groundnuts stored for three to seven months at farm level have been found to be low, within recommended levels. Average moisture content has been reported to be seven to nine percent for groundnuts and eight to 11% for maize [16, 26]. These grain conditions have been described as major factors in the low aflatoxin levels observed in on-farm produce compared to produce in the markets in which the majority of grains were found to have moisture content above 14% and insect damage three times that of on-farm produce [24, 33]. Maize stored by traders for six to seven months was reported to have mean aflatoxin levels of 107 ppb implying that these grains were not suitable for local nor export markets [33].

Physical damage

No relationship between physical damage and aflatoxin content of produce has been reported in Uganda. However, it appears physical damage of the produce may be one of the factors hastening aflatoxin contamination by promoting mould infection. The majority of farmers in Uganda shell or thresh maize by manual beating thus, inevitably damaging the grains and predisposing them to fungal infection. Groundnuts on the other hand, may be uprooted using hand hoes, which cause considerable damage to both the shell and kernels thus promoting fungal infection.

CURRENT STRATEGIES FOR CONTROLLING AFLATOXIN CONTAMINATION

No strategies for controlling aflatoxin contamination of food and food products in Uganda have been reported. However, the Department of Food Science and Technology, Makerere University in conjunction with Kawanda Agricultural Research Institute is studying the effect of Neem kernel powder and other botanicals on kernel mouldiness and aflatoxin production. Additionally, studies on solar and biomass drying techniques are evaluated for control of molds and aflatoxins in maize. These studies are funded by the USAID IPM CRSP but results are yet to be published.

IPM CRSP has also funded its lead scientists researching on moulds and aflatoxins in Uganda to prepare fact sheets and brochures on aflatoxin as a way of making awareness to the public about the danger and management strategies of aflatoxins. In addition, IPM CRSP also has plans to fund education programs on aflatoxin management in maize and groundnuts at the farm level through farmer field schools.

PROBLEMS AFFECTING AFLATOXIN RESEARCH AND THE NEED FOR CONTROLLING CONTAMINATION IN UGANDA

Analytical procedures

Aflatoxin analysis is expensive to conduct in Uganda thus, hindering routine analysis of food samples by individual farmers, traders and organizations handling susceptible foods. This is due to supplies and reagents that are costly and sometimes unavailable. Aflatoxin research in Uganda is of low priority therefore, very few companies import the appropriate supplies and reagents. Thus, most of the supplies and reagents have to be acquired expensively on special orders. Institutions analyzing aflatoxins thus charge high amounts of money per sample which discourages those involved in trade to have their foods analyzed.

There is a serious problem of inadequate up-to-date analytical equipment. The Department of Food Science and Technology, Makerere University is currently the only institution with the VICAM Aflatest® Fluorometer which can quantify aflatoxins in produce. The rest of the laboratories use qualitative or semi-quantitative methods. There is, therefore, need to upgrade laboratories with recently recommended aflatoxin analytical equipment like high pressure liquid chromatographs (HPLC), high performance thin layer chromatographs (HPTLC), gas chromatographs (GC) and simple presumptive or screening equipment which can predict aflatoxin presence in food samples. Means for maintenance of these equipment and acquisition of disposables like columns should be put in place to ensure that they are available for constant use.

In addition, there are no laboratories specifically constructed to handle aflatoxin analysis. Aflatoxin analytical equipment is installed together with other analytical equipment thus, putting analysts/researchers in danger. Simple protective devices like gloves, glove boxes, masks and head caps are sometimes lacking and therefore not used during aflatoxin analysis. Some laboratories lack functioning ventilated hoods, exhaust fans and waste disposal facilities. It is essential to safely handle all experimental materials associated with aflatoxin analyses following mycotoxin safety precautions as described by the International Agency for Research on Cancer (IARC) and the Association of Official Analytical Chemists (AOAC) [40].

Sampling

There are no proper sampling plans established for aflatoxin analysis in the country. Uganda being divided into five agroecological zones, there is a possibility of a non-homogenous distribution of aflatoxins. Therefore, differences in sampling could be the most important contributor to the variability of aflatoxin content in agricultural commodities so far tested. There is need to organize for proper sampling and analysis of commodities obtained from different climatic zones of the country, following recommended protocols, so as to rank zones in terms of aflatoxin contamination of produce like it has been done in countries like USA, India, Cyprus and others. The factors promoting aflatoxin contamination of commodities in each zone should subsequently be investigated and compiled. These will form the basis for designing aflatoxin control programmes in the country.

Legislation

At the moment, the established standards on aflatoxin contamination of food in Uganda are based on Kenyan standards, not on the actual aflatoxin content in Ugandan foods. There are no proper procedures put in place for aflatoxin control, monitoring, or supervision in the country. Susceptible produce like maize and groundnuts are not visually inspected by qualified personnel at buying points to separate good quality from contaminated produce. Thus, when the produce reaches the retail markets, sorting may be done but contaminated produce is sold to unsuspecting consumers at low prices. There is need for full participation of government through the Ministries of Health (MOH) and that of Agriculture, Animal Industry and Fisheries (MAAIF) together with the Uganda National Bureau of Standards (UNBS) to put into practice regulations for monitoring susceptible produce from buying points to retail markets. Strict appropriate post-harvest measures for drying, sorting, packaging, storage and proper handling of produce should be introduced and monitored.

Awareness of the problem by food handlers (farmers and traders) and consumers

Aflatoxins are not visible neither do they have a particular flavour. Therefore, it is not easy to convince consumers about their existence in food. The majority of farmers, traders and consumers in Uganda are not currently aware of the aflatoxin contamination of food. There is, therefore, need to disseminate information to these people, using simplified methods, about the dangers and management aspects of aflatoxins, and the susceptible produce. Since IPM CRSP has taken a lead in public awareness about aflatoxins at farm level, MOH and MAAIF should work with it and develop more effective and broad training programs to cover farmers, traders and consumers.

CONCLUSION

In Uganda, aflatoxin contamination of agricultural produce is a big problem, with aflatoxin B_1 being the most prevalent. However, inadequate research has been done and most studies have concentrated mainly on maize and groundnut contamination without coordinated sampling protocols among different researchers. There is need to follow recommended sampling procedures and to widen research to include other commodities like beans and milk, which are important to peoples' diets, and animal feeds. Adaptive research on control and eradication of aflatoxins in food is necessary.

Since studies done in the sixties and seventies indicated a strong correlation between liver cancer and aflatoxin content of food in Uganda, there is a need for more epidemiological studies in the present era, as cancer is rampant in the country especially in the immunity-compromised individuals.

In order to strengthen the export potential of maize and groundnuts, and to protect consumers against aflatoxin contaminated foods, government through the Ministries of Health, and Agriculture, Animal Industry and Fisheries, together with the Uganda National Bureau of Standards, should put into place information dissemination and training programs for farmers, traders and consumers on proper pre- and post-harvest aflatoxin management strategies.

To further reduce this potential hazard, regulations for monitoring susceptible produce from farm level through buying points to retail markets should be put in place and strict measures on food quality at both household and market levels should be embraced and enforced by all policy makers.

TABLES

Table 1.

Comparison of Aflatoxin Contamination of Foods and Hepatoma Incidence in Uganda

Hepatoma Incidence		Aflatoxin contamination		
Tribe	Hepatoma (cases/100,000 per year)	*Province or district	No. samples assayed	% pos.
Bwamba	No data	Toro	29	79.3
Karimojong	15.0	Karamoja	105	43.8
Buganda	2.0	Buganda	149	28.9
Rwanda immigrants	3.0			
West Nile Tribes	2.7	West Nile	26	23.1
Acholi	2.7	Acholi	26	15.4
Soga	2.4	Busoga	39	10.3
Ankole	1.4	Ankole	37	10.8

Source: [14]

* Uganda is no longer divided into provinces and some names of districts have changed and new ones created since these data were published.

Table 2.

Aflatoxin Content of Food According to Type of Food

	Number of samples			Total aflatoxin concentration (ppb)		
Food	Assayed	Positive	% Positive	1-100	100-1000	> 1000
Beans	64	46	71.9	30	11	5
Maize	49	22	44.9	13	9	-
Sorghum	69	26	37.7	19	5	5
Groundnuts	152	27	17.8	11	8	8
Millet	55	9	16.4	9	-	-
Peas	19	3	15.8	3	-	-
Cassava	34	4	11.8	-	2	2
Rice	11	0	-	-	-	-
Other grains	11	2	18.2	-	1	1
Grain mixtures	16	3	18.7	2	-	-
Total	480	142		87	37	18
% of Total			29.6	29.6	7.7	3.7

Adapted from [14]

Table 3.

Aflatoxin contamination of different varieties of groundnuts at harvest and five to six months of storage

		Aflatoxin positive samples (%)			
Variety	No. of samples	B_1	B_2	G_1	G_2
At harvest					
Igola 1	15	13.3	0	0	0
Etesot	4	25	0	0	0
Erudurudu	3	100	0	33.3	0
Otiira	2	0	0	0	0
Serere Red	2	0	0	0	0
5 – 6 months after harvest					
Igola 1	14	35.7	0	0	0
Etesot	8	25	0	0	0
Erudurudu	4	100	0	50	0
Otiira	2	0	0	50	0
Serere Red	2	0	0	0	0

Adapted from [16]

Table 4.

Aflatoxin contamination of maize after two to seven days of harvest or two to three months of storage

Storage method	No. of samples	Aflatoxin positive samples (%)			
		B_1	B_2	G_1	G_2
2 – 7 days after harvest					
Polypropylene	16	37.5	0	0	0
Heaped on floor	3	100	0	0	50
Above fire rack	1	0	0	0	0
2 – 3 months after harvest					
Polypropylene	17	88.2	0	0	0
Heaped on floor	4	100	0	25	0
[a]Jerrican	2	50	0	50	0
[b]Verandah	2	100	0	100	0

Adapted from [16]

[a]Plastic container (20 L capacity) originally used for fetching water, now used as a storage facility.

[b]Samples were stored under the roof forming part of the verandah

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