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Full Length Research Paper

Towards a successful management of aflatoxin contamination in legume and cereal farming systems in northern Nigeria: A case study of the groundnut value chain

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Abstract

Aflatoxin is reported to be a major challenge of many agricultural commodity value chains groundnut, with potential negative impacts on nutrition, food safety, human health and foreign trade. This paper presents multiple pre-emptive management measures in the management of Aflatoxins in the groundnut value chain in Nigeria. These measures include: the organization of Training of Trainers (ToT) workshops, development of aptitudes in the detection and quantification of aflatoxin levels, demonstration of integrated crop management (ICM) practices, production of pedagogic materials to support awareness raising engagement of media organs to sustain awareness on the challenges of aflatoxin contamination, and evaluation and promotion of *Aspergillus flavus* resistant groundnut varieties. Alongside these measures which target behavioural corrections, samples of groundnut and groundnut-based are being collected to establish the prevalence and distribution of aflatoxin contamination in groundnut kernel and groundnut-based products in Northern Nigeria.

Keywords: Aflatoxin, pre-emptive measures, groundnut, Northern Nigeria, policies.

INTRODUCTION

Nigeria is the largest groundnut producing country in West and Central Africa (WCA), accounting for about 51% of the total production in the region and third leading producer in the World after China and India. In 2012, Nigeria ranked 11th in the World's production of groundnut with 3.071 million MT and 5th by value estimated at 130 million US Dollars (27). The pods and haulms are important cash income earning sources for many urban and rural households in the Northern States of Nigeria.

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It accounts for about 21% of farm-family annual cash incomes. In terms of employment, the crop is an important source of paid and unpaid employment for smallholder farmers, women, youths and children. Groundnut continues to play a central role in nutrition and food security of a majority of rural farm-families providing the much needed protein and cooking oil as well as raw materials for small-scale cottage processing dominated by women in the predominant groundnut producing states of Nigeria. Finally, groundnut is an important component of the farming systems in the Sudan, Sahel and Derived Savannah agro-ecological zones of Nigeria. These agro-ecological zones are spread across fifteen (15) out of the nineteen (19) States of Northern Nigeria particularly Kano, Katsina, Kaduna, Jigawa, Sokoto, Zamfara, Kebbi, Adamawa, Bauchi, Yobe, Taraba, Borno, Benue, Plateau, Nasarawa, Federal Capital Territory (Abuja), Kogi, Niger and Kwara (NAERL, 2011).

In-spite of its local and national importance, groundnut and groundnut-based products are exposed to the global challenges of Aflatoxin contamination. In effect, Aflatoxin contamination in groundnut and groundnut-based products reduce their values and potentials for human and livestock consumption, as well as for export. Contaminated groundnut and ground-based products that are consumed, sold or exported pose serious public health challenges. Unfortunately, awareness about aflatoxins and other mycotoxins in agricultural value chains in Nigeria is very low (7, PACCA, 2017)). In 2015, ICRISAT embarked on the implementation of a USAID funded multi-country groundnut technology up-scaling project in Mali, Ghana and Nigeria. A key output of this project is to raise awareness on aflatoxins, develop capacities in the detection and quantification of its inherent aflatoxins, and advise value chain actors on aflatoxin contamination and options for their adequate management. This paper summarises actions and emerging outcomes on the management of Aflatoxins during the active period of the project. The project is being implemented in five groundnut producing States of Nigeria namely Kano, Katsina, Jigawa, Sokoto and Kebbi (Figure 1).

Global Concerns about Aflatoxins

Aflatoxins are a group of 20 closely related secondary metabolites produced by *Aspergillus flavus* and *Aspergillus parasiticus* (10, 19). These fungi are ubiquitous, air-borne and soil-inhabitants, and also found in crops and foods, including food storage facilities (24, 22, 6, 26, 2, 9). Aflatoxins display a wide array of biological effects on humans and have been confirmed to induce liver cancer in persons with Hepatitis C (10). The consumption of high doses of aflatoxins can be fatal, while regular exposures to small quantities of Aflatoxins can lead to liver cancer and liver cirrhosis (26, 20). Aflatoxins are reported to retard growth especially in children (8) and are potential immune-suppressors (18).

According to Partnership for Aflatoxin Control in Africa (2013), countries lying between latitudes 40°N and 40°S, are highly susceptible to aflatoxin contamination; this includes all of Africa. Though aflatoxins contaminate a wide range of crops and their products, groundnut is the most common host of aflatoxins world-wide. This crop is largely grown by resource-limited farmers under rainfed conditions. It is a core component of farming systems, source of employment and cash incomes in the major producing states of the Northwest, Northeast and North-central regions of Nigeria. It can be consumed raw, boiled, roasted, processed and/or incorporated into other foodstuffs. Groundnut cake (*Kuli kuli*) is commonly consumed as a snack, while both the cake and haulms are used as feed to livestock. Aflatoxin contamination in these crops have been reported to occur above safe levels specified for many countries; Europe (4 ppb) and USA (20 ppb) and 20 ppb for Nigeria (25, 12). The occurrence of afflatoxins above acceptable levels pose serious health challenge. Indeed, Aflatoxin related health challenges are reported to be more severe amongst the rural poor, many of whom survive on unprocessed legume-and cereal-based diets (23). Apprehensions about food quality have been increasing globally given that food safety can be influenced by consumer perceptions and policies (23).

Challenges of managing Aflatoxins using bio-control measures

Aspergillus flavus is the most common species of aflatoxin in agricultural crops (4, 3). The incidences of aflatoxin contamination in agricultural crops are more common between latitudes 40°N and 40°S (tropical and sub-tropical regions) of the world (15). Also present in the soil, it has been detected in a number of agricultural value chains, but it is most common in groundnut, maize and sorghum (15). Unpredictable changes in climate that result in spells of drought are also susceptible to outbreaks of aflatoxins. Also, aflatoxin contamination are more prevalent at high temperatures which may stress the host plant thereby favouring the growth of aflatoxin producing fungi (16, 14, 11, 13).

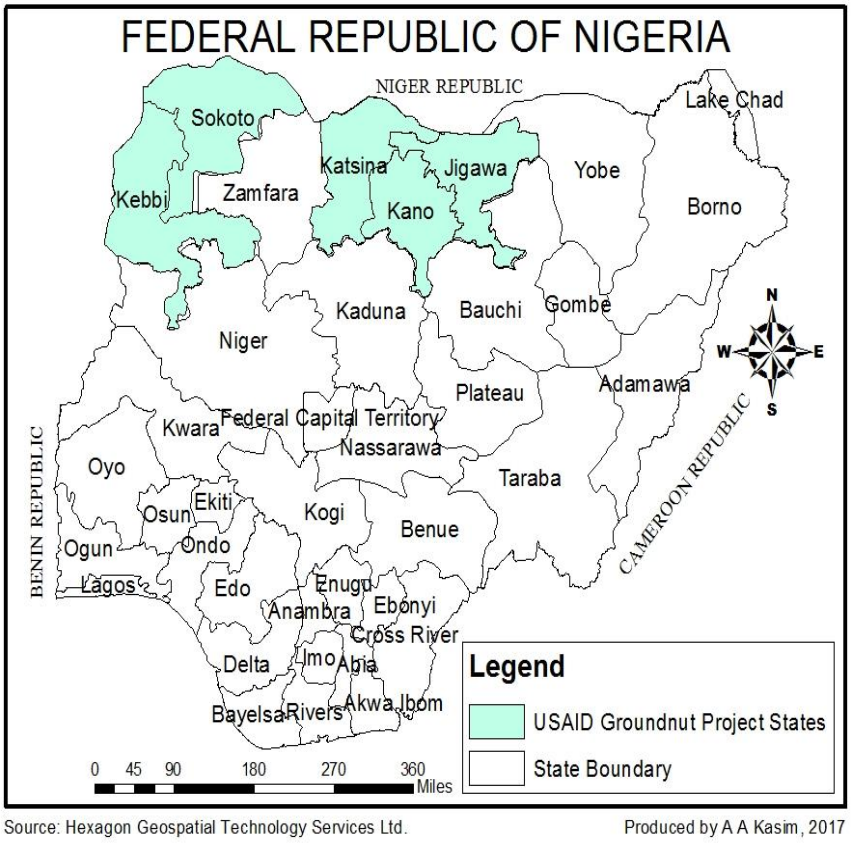

Figure 1. Map of USAID Groundnut Upscaling Project Sites in Nigeria.

One of the most promising strategies currently being used to manage pre-harvest contamination of crops liable to aflatoxin contamination is to introduce atoxigenic (biocontrol) *Aflatoxin flavus* into the crop environment. Whether or not bio-control measures, when introduced into crop fields are enough to mitigate aflatoxin contamination to acceptable levels is still a subject of research. Therefore, there are still challenges using bio-control measures to manage aflatoxins. First, the biology of *Aflatoxin flvus* is not well understood due, in part to *Aflatoxin flavus*'s diversity, its ability to form heterokaryotic reproductive forms, and its unknown ability to survive for prolonged periods. Second, biocontrol strains must be selected that are suitable for the environment, the type of crop, and the soils into which they are to be introduced. Third, there is a need to guard against inadvertent introduction of *Aflatoxin flavus* strains that could impose additional burdens on food safety and food quality. Fourthly, with global warming and accompanying inherent changes in soil nutrients and microbiome populations, biocontrol management options must be sufficiently flexible to adapt to inherent changes.

PROJECT-BASED APPROACHES TO THE MANAGEMENT OF AFLATOXIN CONTAMINATION

The USAID adopts three mutually inclusive approaches in the management of Aflatoxins contamination in groundnut and groundnut-based products. Each of these approaches are briefly described below.

Enhancing knowledge of groundnut value chain actors

Awareness creation meetings are being organized across the five States where the USAID Groundnut Upscaling Project is being implemented. Similarly, pre-harvest demonstrations are being established and field days carried out. Post-harvest management practices for aflatoxin control are systematically demonstrated for seed producers across the project states. Four Training

of Trainers (ToT) workshops have been organized for middle level personnel of institutions of National Agricultural Research Systems (NARS), the media and leaders of groundnut farmers' associations. The overall objective of these ToT workshops is to raise awareness and develop aptitudes and abilities in the detection of aflatoxin contamination in samples of groundnut and groundnut-based products. The contents of the ToT training workshops comprise basic science of aflatoxin, pre-harvest and post-harvest operations for aflatoxin management, and the detection and quantification of aflatoxins in groundnut and groundnut-based products. Alongside these capacity enhancement interventions, pedagogic materials have been developed both for step-down trainings and awareness raising events by project collaborators. In each of the states where the project is being implemented, the media is actively engaged to broadcast targeted messages on the different aspects of managing aflatoxin. Typical media messages comprise what aflatoxin is, the challenges of aflatoxins on human health and nutrition, on-farm and off-farm management of aflatoxins.

Sampling of groundnut pods and groundnut-based products for aflatoxin detection

A combination of purposive and random sampling procedures are being used to collect groundnut pods and groundnut-based products for the assessment of the distribution and spread of aflatoxins across the project site. Nearly 1250 samples of groundnut and groundnut-based products have been collected for the detection and quantification of the most popular strain of which is aflatoxin (AFB_1). These samples comprise improved groundnut varieties being promoted by the USAID funded Project and national partners through on-farm demonstrations, the most popular local varieties planted by farmers, promising breeding lines being evaluated for their performance and aflatoxin resistance. Samples of the groundnut-based products generally consumed, and/or sold in popular markets in Nigeria, with many of the markets habitually playing the role of aggregation centres.

Quantification of aflatoxin loads in the groundnut and groundnut-based samples collected

The groundnut and groundnut-based samples collected are being used to quantify the presence or absence of AFB_1, The presence or absence of AFB_1 are estimated using the *Indirect Competitive Enzyme Linked Immunosorbent Assay* (cELISA) method. The laboratory technique applied by Waliyar *et al.* (2015) involves immobilizing the antigen on the surface of an ELISA plate, followed by competition for antibody binding between the AFB1 present in the sample or standard. Later, the enzyme labelled secondary antibodies is used to detect aflatoxin specific antibodies.

Promotion of pre-harvest management of Aflatoxins contamination

A core component of project intervention is the promotion of Good Agricultural Practices (GAP) – using the most appropriate seeds, timely planting, ensuring adequate farm sanitation (weeding when required), harvesting when crops are matured, adequate drying of crops after harvest, respecting basic hygienic condition during processing can keep away aflatoxin contamination. A minimum of 200 on-farm demonstrations are established yearly since 2015 to enable farmers and community members become aware of both improved groundnut varieties and appropriate crop management practices. Similarly, awareness creation on emerging bio-control methods to mitigate aflatoxin contamination are entertained where feasible. While a majority of Nigerian resource-limited farmers are willing, and able to implement farm-level measures, an inclusive approach to food safety and quality regulations remain supreme.

On-station and on-farm evaluations of aflatoxin resistant genotypes

Across the project site, there are several evidence of variability in climate and climatic change; declining length of the growing season, rising temperatures, etc. These effects expose groundnut and other crops to aflatoxin contamination. In the case of groundnuts, this implies that options for managing aflatoxin must include the development of cultivars that are both drought tolerant and resistant to aflatoxin contamination. Progressively, ICRISAT breeding interventions in Nigeria enlist the evaluation of eight genotypes for both yield performance and resistance to fungal invasion and proliferation. Cross country bio-technological approaches to increase host-plant resistance using anti-fungal and anti-mycotoxin genes are being enlisted.

EMERGING SALIENT RESULTS, DISCUSSIONS AND WAY FORWARD

Knowledge and capacities of Aflatoxin management impacted to value chain actors

Awareness creation meetings have brought together a total of 9,996 value chain actors the five states where the USAID Groundnut Upscaling Project is being implem-

ented. Similarly, a total of 345 pre-harvest demonstrations have been established and field days brought together a total of 3,861 curious groundnut value actors. A total of four Training of Trainers (ToT) workshops bringing together 227 participants. Using a questionnaire comprising 11 questions with multiple answers, beneficiaries of all ToT workshops confirmed having gained considerable knowledge on aflatoxins and different managing options of its management (Figure 2 and 3).

Note: Q1 – Q11 represent questions 1 – 11 used for testing the knowledge of beneficiaries on aflatoxins
Question 1: Is aflatoxin management one of the objectives of the groundnut up-scaling project in Nigeria?
Question 2: Crops associated with aflatoxin contamination
Question 3: knowledge in the quantification of aflatoxin in agricultural sector value chains
Question 4: Pathogen responsible for aflatoxin
Question 5: Techniques of detection and/or quantification of aflatoxins
Question 6: Sources of aflatoxin M1 and M2
Question 7: Techniques of managing aflatoxin production in the groundnut value chain
Question 8: Effective methods of preventing aflatoxin in groundnut in the groundnut value chain
Question 9: Health and nutritional hazards of aflatoxin contamination
Question 10: Actors who suffers most from aflatoxin contamination in the groundnut value chain?
Question 11: Major ways of reducing aflatoxin contamination in the groundnut value chain

The project and Nigerian partners will need to i) follow-up beneficiaries of these ToT workshops to ensure that the knowledge gained are passed onto other value chain actors particularly end-users of technologies during awareness raising events and step-down trainings, and ii) continue to provide technical support to awareness raising events and other step-down trainings. In collaboration with national project partners and other resource persons, the project has developed awareness raising and training support materials (Vabi et al., 2016). A mechanism has also been developed whereby trainers of the ToT could back-stop project partners in the organization of awareness raising events and step-down training workshops for other value chain. act actors. Similarly, trainers of the ToT could be invited as resource persons to aflatoxins learning events.

Building on, and expanding the scope of knowledge on the groundnut value chain

Out of the eight improved groundnut varieties recently released by the Institute for Agricultural Research (IAR), only the three most recent ones have been targeted for large-scale dissemination by the USAID Groundnut Upscaling Project; these are SAMNUT 24, SAMNUT 25 and SAMNUT 26. The core elements of the performance of these improved varieties have been presented by Ajeigbe et al. (2015) and Vabi et al (2016) However, these varieties can escape end of season droughts of the Sudan and Sahel agro-ecological zones due to their early maturity which is an important element of aflatoxin management. ICRISAT is intensifying support to national research partners for the release of other candidate varieties known to be resistant to aflatoxin contamination and which are also extra early maturing.

Instigating evidence-based regulations on acceptable levels of aflatoxins

Food regulations are official decisions, endorsed by a government, businesses, or organizations specifying how food is produced, processed, distributed, purchased, protected and disposed of. Food regulations can operate at the global, national, state, regional, local and institutional levels. They can also be community or grassroots efforts. Using evidence provided by the project on groundnut, innovative approaches for raising awareness and advocating for changes in regulations on acceptable levels of aflatoxins in Nigeria have been engaged. Prominent actors in this process include the Nigerian Chapter of the African Groundnut Council, National Groundnut Producer, Processors and Marketers Associations of Nigeria (NGROPPMAN), All Farmers Association of Nigeria (AFAN), the Nigeria Association of Plant Protection and the Mycotoxicology Society of Nigeria (MSN). In the Nigerian context, instigating regulations at different levels are effective preludes to higher levels of food regulations, labeling and standards leading to those of the World Trade Organization which today influence global food protection and safety.

These notwithstanding, there is an absolute imperative for groundnut value chain actors to work closely with appropriate levels of government to ensure that aflatoxin in groundnut can be placed on local, national, regional and international markets. At LGAs, practical examples of consciousness of food regulations include though not limited to the following:

- Purchasing of aflatoxin free groundnut by market dealers;

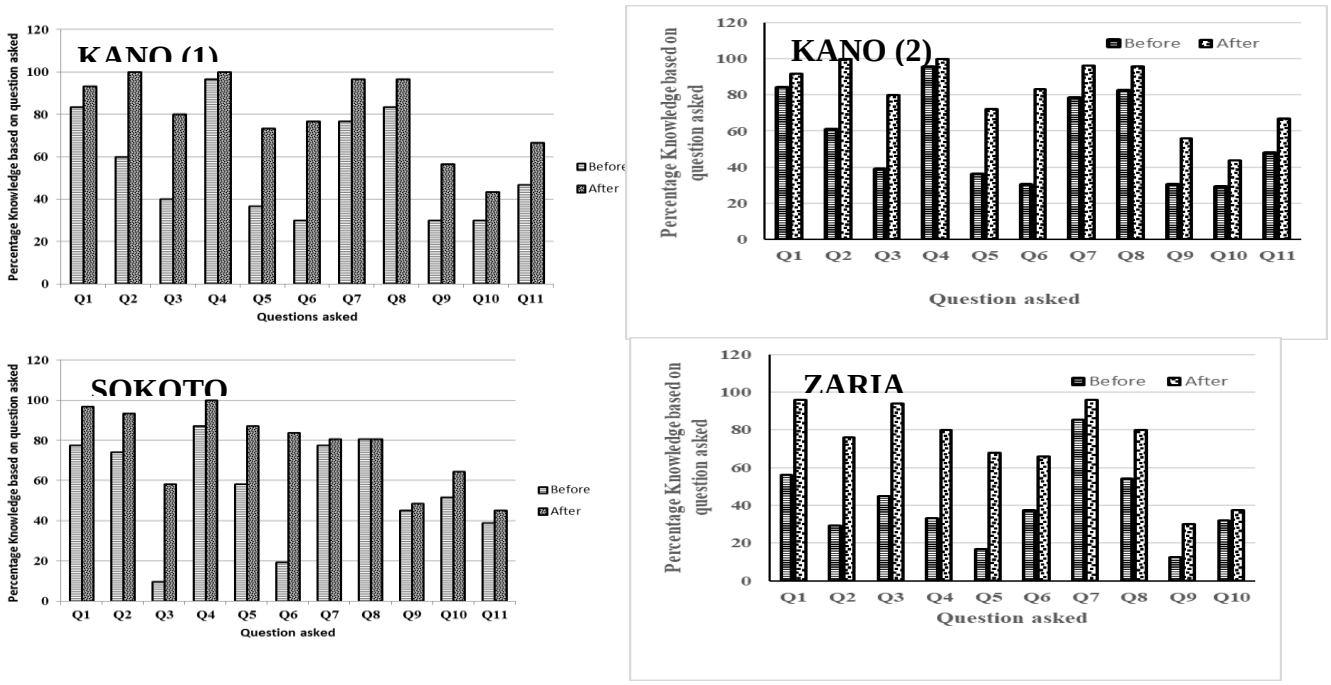

Figure 2. Assessment of participants' awareness levels of aflatoxin and its management during ToT Workshops organized in Kano, Sokoto and Zaria (Nigeria).

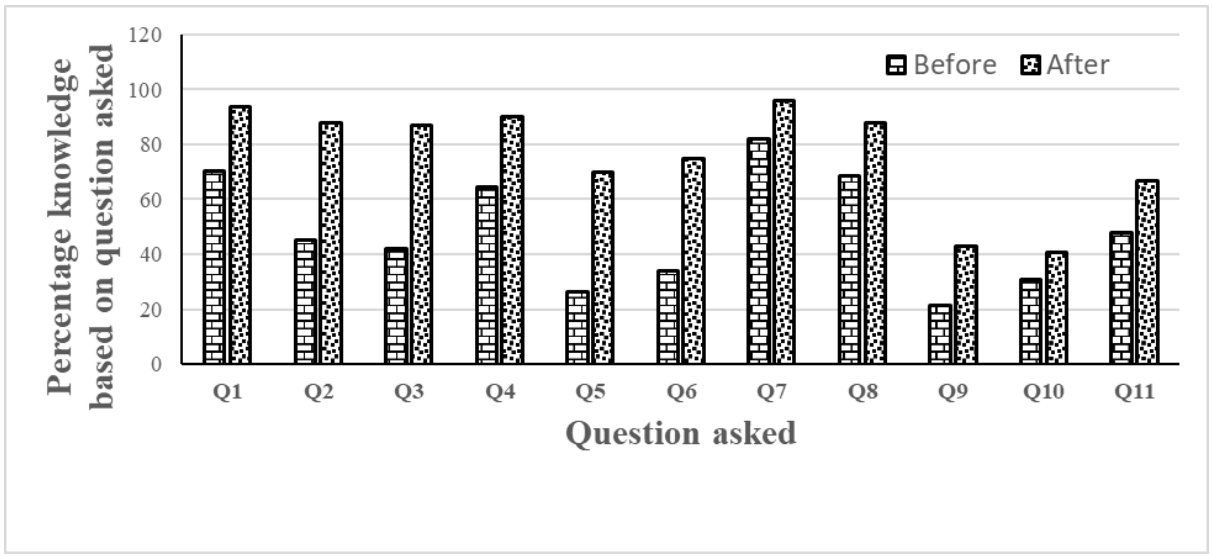

Figure 3. Mean percentage evaluations of awareness level of aflatoxin and its management among participants during ToT Workshops organized in Kano, Sokoto and Zaria (Nigeria).

- Requirements of school authorities not to allow aflatoxin contaminated groundnut and groundnut-based vendors into their school premises;
- Nutrition requirements that use groundnuts and groundnut-based products from known sources;
- Facilitating the acquisition of appropriate knowledge and capacities of national institutions to improve the effectiveness of compliance to existing food regulations.

It is known that when government and elected officials of political parties have the opportunity to meet and

interact with commodity value chain actors, a unique educational and networking opportunity could emerge. This can further illuminate the desire to comply to food safety regulations while opening up avenues for leveraging support and services.

CONCLUSION AND WAY FORWARD

Over the next couple of years, the Nigerian component of the groundnut upscaling project will be implemented in agro-ecological zones where the chances of pre- and post-harvest aflatoxin contamination remain high. Despite the invitation to consume groundnut in different forms by individuals and households, awareness and knowledge on the health and nutrition implications of aflatoxin contamination are almost inexistent amongst Nigerians. Through this project and similar interventions, ICRISAT, together with national partners and development partners in Nigeria, intensify efforts described in this paper to enhance awareness, knowledge and skills of agricultural sector value chain actors to manage aflatoxins while pursuing the development of genotypes that are most resistant to aflatoxin contamination.

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