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Review Article

Prevalence, Perception and Participatory Management of Aflatoxins in Groundnut with Emphasis on Northern Ghana

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Abstract

Groundnut is ranked as the most important legume crop in Ghana due to its versatile role as sources of cash, dietary protein, industrial oil, complementary animal feed, and in soil fertility restoration. However, food safety risk in relation to aflatoxins remains a daunting challenge among smallholder farmers due to poor production practices and weak food safety regulation and compliance. One critical concern requiring attention is that close to 60% of Ghanaian food dishes are prepared from maize and groundnut, both are highly susceptible to aflatoxins. In general, the tropical climate across Ghana is ideal for the growth the fungi in susceptible commodities, both in the field and at storage. This review highlights the risk of aflatoxins in groundnut, and identifies integrated management approaches that can be employed to reduce pre-and post-harvest contaminations. This study recommends regular tracking of aflatoxins in food products to facilitate early warning and necessary interventions of regulatory institutions.

Keywords: Aflatoxins; Consumption; Production Practices; Food Safety; Integrated Management

Introduction

About aflatoxins

Aflatoxins are one of the most potent toxic substances that occur naturally. These toxins are secondary metabolites produced by fungi in the genus *Aspergillus*; mainly *A. flavus, A. parasiticus* and *A. nomius* [1-3]. These fungi grow naturally on food products and can be toxic to vertebrates, including humans. There are four generally recognized dietary aflatoxins, designated B1, B2, G1 and G2 (AFB1, AFB2, AFG1 and AFG2, respectively). The metabolites, M1 and M2, are also found in milk. The order of toxicity is B1 greater than G1 greater than G2, greater than B2. Aflatoxin M1 (AFM1) has been identified in milk of dairy cattle consuming AFB1-contaminated feeds. In addition to aflatoxins, *Aspergillus* spp. produce ochratoxin A (OTA), *Penicillum* spp. produce ochratoxin A (OTA), and *Fusarium* spp. produce deoxynivalenol (DON), zearalenone (ZEA), fumonisins (FB), HT-2 and T-2 [4]. Unfortunately, their effects on health are seriously overlooked in developing countries.

Across sub-Saharan Africa, aflatoxin contamination in grain maize and groundnut remains a major challenge among smallholders [5-7]. Chronic dietary exposure to low doses of aflatoxins has been identified as a risk factor for liver cancer which, could affect protein metabolism and immunity thereby worsening infectious diseases and malnutrition [2]. Ingesting highly contaminated prod¬ucts results in severe, acute hepatitis known as aflatoxicosis; symptoms include vomiting, jaundice and abdominal pain, and can lead to fulminant liver failure and death. Some studies suggest that 60 to 85% of consumers in developing countries are not protected by commercial food safety regulations [8]. They often lack the capacity to protect crops against aflatoxin contamination, and awareness about risk of aflatoxins is poor. A report by the International Institute of Tropical Agriculture suggests that aflatoxin contamination in maize and groundnut remains a major non-tariff barrier to international trade since agricultural products that exceed the permissible levels are banned [9]. About $1.2 billion in commerce is lost annually due to aflatoxins, with African economies losing $450 million each year.

Socio-economic importance of groundnut in Ghana

Groundnut is considered the most important legume crop in Ghana due to its versatile role as sources of cash, dietary protein, industrial oil, complementary animal feed, and in soil fertility restoration [10,11]. Although the crop is grown throughout the country, the most intensive production zone is northern Ghana. In these areas, about 20% of farmers consider groundnut among their two most important crops. National per capita groundnut consumption is estimated at 0.61 kg/week [12]. According to Jolly., *et al.* [13], 80% of Ghanaians consume groundnut or peanut products at least once a week, and 32% at least three times a week. Women, in particular, are intensively in engaged in production, processing and trading to generate food and income to sustain the family. Women directly benefit from potential productivity increases resulting from improved technologies and value addition options. Nonetheless, a report by SPRING [14] revealed that most agricultural extension services were in favour of high value crops such as rice, maize and soybeans. As a result, the technologies, inputs and production practices employed in groundnut production and processing have trailed relative to these crops. Other production constraints include abiotic stresses (drought, high temperatures, poor fertility, low soil pH and Ca deficiency) and biotic stresses (rust, leaf spot, chlorosis, aflatoxin contamination, pod borers, aphids, thrips, millipedes and mites) [10,11]. Other production constraints include access to land, use of farmer saved seed, high cost of certified seed and non-supportive small scale agricultural policies.

Groundnut production

Production of groundnut in Ghana is mainly carried out by small-scale farmers of whom majority are women. The production levels in Ghana have not been consistent; however, there is an indication of increasing production particularly in Northern Ghana. Opinions vary as whether the groundnut production is increasing or stagnated [15]. In general, the demand for groundnut products may be influenced by a number of factors. Two important contributors are population growth and availability of close substitutes. Groundnut oil and other meals must compete directly with oils from soybean, sunflower, palm and cotton, and even with other cereal-based products. Output of groundnut in these regions increased from 150,000 to 193,000 MT in the 1990s. Since 2004, annual production usually hover at 400,000 to 520,000 MT [16]. For several decades, the commonly cultivated varieties are Virginia and Spanish/Valencia. In rural areas of northern Ghana, access to improved varieties is still a limiting factor due to challenges of groundnut seed systems. However, in recent years, demand for improved varieties has increased due to increased participation of donor agencies and programmes.

Access to improved varieties

Seed security (availability, access and quality) is critical to increasing farm level productivity of smallholder farmers [17]. Increased yield and farmers' income are directly linked to the availability and access to quality seed of improved varieties. It is well documented that that initial quality of seed determines the final crop productivity and subsequent benefits such as yield and income. Peculiar to most parts of Africa, national seed system of groundnut are bedevilled with challenges of high cost, poor distribution and weak quality assurance systems. The groundnut seed sector in Ghana is supported by the formal and informal institutions. However, the informal sector supplies most of the groundnuts seed, an observation that is common in most parts of SSA. The informal supplies close to 90% of smallholder seed requirements through the informal farmer-to-farmer exchange and through social intervention programmes; due to cost of certified seed of improved varieties.

Assessment of access to improved seed showed that 'China' variety was the most cultivated by the farmers in the Northern Ghana [18]. The relative occurrence was China (76.5%) 'Agric' (20%), Obolo (1.5%) and Otuhia (0.5%). Similar trends were observed in the Upper East Region and Upper West Region with the local China being cultivated by 99.5% and 96.5%, respectively (Figure 1). Two recently released varieties with large seed size (Obooshie and Yenyawoso) were not cultivated in the Northern region. Majority (73.3%) of groundnut farmers mentioned high yield (73.3%), ease of harvesting (46.5%) and drought tolerance (32.67%) as key traits for choosing a groundnut variety. Other important traits were disease tolerance, oil content and storability.

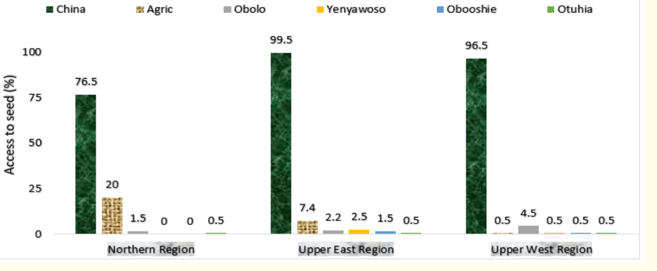

Figure 1: Access to improved seed of groundnut varieties in Northern Ghana.

Source: Oppong-Sekyere., *et al.* [18].

Over the years, research interest has focused on developing varieties for high yield, earliness, drought tolerance and resistance to biotic stresses such as rust, leaf-spot disease and rosette disease. Consumer preference traits include seed/pod size, seed colour, seed number per pod, oil yield, ease of shelling, nutrient value and overall confectionery properties. Due to growing market for fresh groundnut, the importance of pod size and ease of shelling have recently emerged as critical. Some description and characteristics of common varieties developed mainly by the Council for Scientific and Industrial Research (CSIR) of Ghana and their partners over the years was provided (Table 1). Albeit, access to these varieties remains woefully poor in communities across the regions of Ghana; due weak national seed systems and policy.

Aflatoxins prevalence in Ghana

Occurrence, prevalence and health risk

The occurrence, perception, prevalence and health risk of aflatoxins in Ghanaian foodstuffs have been extensively reported in Ghana [6,7,11,13,19]. Albeit, most of such have concentrated on prevalence, consumer risk and perception surveys. Aflatoxins risk is particularly a problem in groundnuts and maize grain and their food products, although other food commodities are at risk too. The tropical climate in Ghana is ideal for the growth and development

Variety	Seed coat colour	Maturity period (days)	Yield potential t/ha	Production ecology
Chinese	Reddish brown	95-100	1.8	Sahel, Guinea and Sudan Savannah
Manipintar	Red and white	115-120	2.2	Guinea and Sudan Savannah
F-mix	Brown-cream	120	2.5	Guinea and Sudan Savannah
Sinkarzei	Red	102	2.2	Guinea and Sudan Savannah
Nkatiesari	light tan	110	2.2	Guinea and Sudan savannah
Edorkpo - Munikpa	dark tan	90	2.0	Guinea and Sudan savannah
Kpanieli	red	120	2.5	Guinea savannah
Jusie Balin	brown	100	2.0	Guinea savannah
CRI-Nkosour	slightly dark brown	90-94	2.3	All Agro ecologies
CRI-Adepa	light brown	91-94	2.5	Forest and Coastal Savannah Transition zone
CRI- Jenkaar	light brown	90-95	2.5	Forest- Savannah Transition zone
CRI-Azivivi	light brown	98-93	2.9	All agro ecologies in Ghana
Obolo	Brown	105-110	2.7	Savannah, forest- savannah transition, semi deciduous forest
Yenyawo so	Dark red	90	2.7	Savannah, forest- savannah transition, semi deciduous forest
Otuhia	Brown	115-120	2.4	Savannah, forest- savannah transition, semi deciduous forest
Oboshie	Brown	105-110	2.6	Savannah, forest- savannah transition, semi deciduous forest

Table 1: List and characteristics of common varieties developed in Ghana.

Note: Information provided in this table was collated from different secondary sources, with varying degree of accuracy.

of these fungi, particularly in susceptible products [20,21]. Other practices that favour the aflatoxins contamination are poor agricultural practices during planting, harvesting, drying, transportation and storage of the product. In the developed countries, the levels of aflatoxins are presumed to be lower in processed foods, due to standard quality control systems applied by the industry, but this may not apply to processed foods in developing countries such as Ghana.

In a study, Jolly., *et al.* [13] measured the levels of aflatoxin B_1 (AF-B_1) albumin adducts in blood and aflatoxin M_1 (AF-M_1) metabolite in urine of consumers in major groundnut and maize consuming regions. High AF-B_1 albumin-adduct levels were found in plasma (0.89 ± 0.46pmol/mg albumin) and high AF-M_1 levels in urine (1,800.14 ± 2602.01pg/mg creatinine) of the participants. Socio-demographic factors such as educational level, ethnic group, community, household size, and number of children in the household attending secondary school were found to be significantly associated with AF-B_1 albumin-adduct levels. Another study on aflatoxin B_1-Lysine (AF-ALB) adduct levels among pregnant women showed a range of 0.44 pg/mg to 268.73 pg/mg albumin [19]. Approximately, 25% of the women had AF-ALB levels of >5.0 to ≤10.0 pg/mg albumin and 15% had AF-ALB >25.0 pg/mg albumin. In this study too, AF-ALB as well as the percent of women having high AF-ALB levels (>11.34pg/mg) were inversely associated with indices of higher socioeconomic status, namely, higher education and income, being employed and having a flush toilet.

An extensive evaluation of aflatoxin levels in groundnut and groundnut based in Ghana was conducted [7] (Table 2). This study found that fresh harvested groundnuts, even if contaminated, contain low, allowable levels of aflatoxin. However, because groundnuts are stored after harvest, the level of contamination rises with time and significantly exceeds the allowable level. The highest level of contamination was found in rejected kernels (288.8ppb) being sold local markets. The rejected nuts included discoloured, moulded, or split groundnuts sorted out of a batch of raw groundnuts. Among the processed products sold by the cottage industry, the level of contamination varied, and unacceptably high contamination was recorded in groundnut paste (on average, 42.5ppb, about 10 times higher than the threshold for entry to the EU markets. Moreover, very high contamination was recorded in kulikuli (76.9ppb) due to inadequate processing. It is worth to note that whereas rejected kernels are likely to be eaten by the poor, the paste, kulikuli and kulikuli zim are consumed by both the poor and high income consumers. Grounded paste or kulikuli zim is often used to garnish roasted meat which is mainly purchased by high income groups. A sample of commercial products showed some weaning mix that contained groundnut flour to have unacceptably high aflatoxin levels. Commercially manufactured salted, roasted groundnuts contained 25 times more total aflatoxin than the allowable limit.

Raw Groundnut	Average total aflatoxins content (ppb)
New-crop	1.65
Un-shelled	7.60
Unknown	8.86
Old crop	88.82
Rejects	288.78
Cottage industry processed	Peanut products
Roasted	1.02
Dawadawa	2.90
Nkati cake	7.60
Dakwa	10.85
Pounded raw Peanut	15.80
Peanut paste	42.49
Kulikuli	76.90
Manufactured	Peanut products
Crispy nut cracker	1.10
Uni-mix product 1	1.90
Burger(R)	5.00
Tom-brown	104.00
Uni-mix product 2	296.00

Table 2: Average total aflatoxins content in various groundnut products in Ghana.

Source: Florkowski and Kolavalli [7].

Exposure risk, knowledge and perception

Attempts to manage risk of aflatoxins remain a daunting challenge across sub-Saharan Africa. Several studies have established that socio-economic demographic factors such as age group, family income, family size, educational, employment status, number of children in school, access to water, access to household toilet and access to radio were associated with exposure to aflatoxins [13,19,22]. For instance, income status may affect aflatoxin exposure as low-income earners would patronize cheaply-sold foods that may have high aflatoxins contamination [19,22]. Amongst the less costly but widely consumed foods in Africa are maize and groundnuts that are known to be highly susceptible to mycotoxin contamination [5,23]. Most farmers, in dire need of money, turn to consume the defective or rejected grains while the more quality grain are sold. However, response from public regulatory institutions to protecting the poor remains slow and poorly appreciated in developing countries.

A study to assess knowledge and perception of aflatoxins in northern Ghana found that 78% of respondents were aware of risk of aflatoxins; although 68.1% did not perceive it as major health risk [6]. Only 23.9% of respondents ever encountered problems related to eating aflatoxin contaminated foods, a large majority (77.1%) either disagreed or were not sure. Many did not perceive aflatoxin as a major food mycotoxin and had no knowledge if aflatoxins have any adverse influence on maize trade (Table 3). In Nigeria, a study to assess knowledge of aflatoxin contamination in groundnut and associated risk among health workers found that 95% of respondents had awareness of aflatoxins, however class room lectures was the common source of information to 56% of respondents [22]. In that study, none of the health workers had ever discussed the risk of aflatoxins in food with their patients. In Tanzania, up to 97% of respondents were not aware of mould infection in stored produce such as cereals and groundnut [23]. Probably, agricultural produce bought from such farmers, to a large extent, may be contaminated with aflatoxins. Such farmers and their families may face a greater risk of aflatoxin exposure since they consume what they produce.

Previous knowledge and perception of aflatoxins	Strongly disagree (%)	Disagree (%)	Not sure (%)	Agree (%)	Strongly agree (%)
If respondents ever encountered health problems after eating aflatoxin contaminated food	28.3	28.3	19.5	18.1	5.8
Proportion of respondents who were aware of aflatoxin contamination	11	15.5	4	33.2	35.8
Proportion of respondents who agree that aflatoxin contamination is a serious problem in their community	11.1	22.1	35.9	9.9	11.1
Proportion of respondents who agree that aflatoxin contamination affects price	9.9	26.5	28	26.1	9.3
Proportion of respondents who have been trained on aflatoxin management	57.1	21.0	2.2	13.3	6.2
Proportion of respondents who will adopt aflatoxin management strategies or resistant genotypes	1.3	-	0.4	10.2	88.1

Table 3: Knowledge and perception of aflatoxins contamination in communities in northern Ghana.

Source: Sugri., *et al.* [6].

Ghana Quality standards for aflatoxin

The Ghana Standards Authority (GSA) published the Ghana Standards Gazette that has specifications for groundnut (GS 313:2001), code of practice for the prevention and reduction of aflatoxin contamination in groundnut (GS 1003:2009), and the determination of aflatoxins in foodstuffs (GS ISO 16050:2003). The options for certification under these standards are detailed in Table 4. The Code of Practice for the prevention and reduction of aflatoxin contamination in groundnut provides guidance in the production and handling of groundnut for entry into international trade for human consumption. All groundnuts should be prepared and handled in accordance with the recommended International Code of Practice-General Principles of Food hygiene, which is relevant for all foods being processed for human consumption. The code has two main parts: (a) recommended Good Agricultural Practices (GAP) and, (b) Good Manufacturing Practices (GMP). The GAP recommends guidelines in post-harvest, harvest, transportation, segregation of aflatoxin contaminated lots and storage. The GMP provides guidelines for receiving and shelling, sorting, blanching, packaging and storage of end products. The code recommends introduction in the future, a complementary management system that incorporates the Hazard Analysis Critical Control Point (HACCP) system in the effort to reduce aflatoxin levels to safe limits. The recommended maximum aflatoxin content for groundnut in-shell and kernels grade 1-3 are all 20ppb (20µg/kg).

Maximum allowable limits	Groundnut in Shell	Shelled grain		
		Grade I	Grade II	Grade III
Extraneous matter content (%)	2	1	3	5
Damaged pods/kernels (%)	0.5	0.5	1.5	3
Shriveled kernels (%)	3	3	3	3
Skinned kernels (%)	-	0.5	0.5	0.5
Broken and split kernels (%)	-	8	10	12
Empty pods (%)	2	-	-	-
Admixtures of other varieties (%)	5	5	5	5
Aflatoxin content (mcg/kg) (ppb)	20	20	20	20

Table 4: Ghana Standards Authority requirements for groundnut quality.

Source: Ghana Standards Authority: Nuts - Specification for Groundnut. GSB Ref. No. GS 313:2001. Accra: GSA, 2013.

Aflatoxin prevalence and management in northern Ghana

Prevalence in farm stores

A study on aflatoxin prevalence was conducted in 6 districts in northern Ghana to assess the influence of socio-economic factors, cropping systems, postharvest operations and knowledge gaps in relation to aflatoxins management [11]. Groundnut samples were obtained from farmer storage units: granaries, barns, bags and silos, and analysed for total aflatoxins using the indirect Enzyme Linked Immunosorbent Assay (ELISA) method. From this study, aflatoxin levels ranged from 0 to 1546 ppb with wide variations occurring within and across the communities and districts sampled (Table 5). Up to 92.9% of the samples could be classified as safe at a permissible level of 20 ppb. Total aflatoxins was below 20 ppb in 20 communities but some excessive levels were recorded in communities such as Baazu (25.7ppb) and Nimbare (75ppb) in Upper West Region, and Denegu (75ppb) and Bantanfarigu (252 ppb) in Upper East Region (Figure 2).

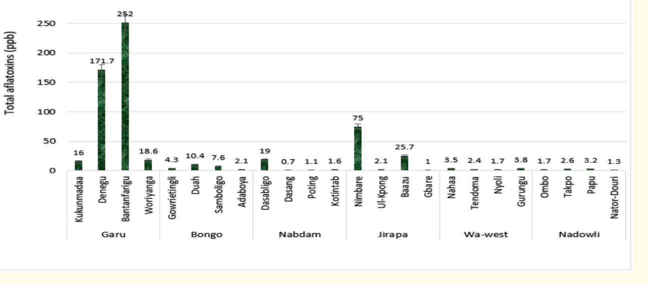

Figure 2: Total aflatoxins content in groundnut samples from 24 communities.

Source: Sugri., *et al*. [11].

Performance of advance genotypes for aflatoxin resistance

In this study, participatory on-farm evaluation was conducted in the Northern, Upper East and Upper West Regions to assess the performance of 10 groundnut genotypes for resistance to aflatoxins [25]. From this study, aflatoxin levels across locations showed that 98.7% of the samples were safe at a permissible level of 20 ppb (Table 6). Also, all 10 genotypes recorded aflatoxin levels of less than <15 ppb at 4 to 8 weeks after harvest. Genotypes: ICGV-94379 (0.6-38.7 ppb), farmer variety (0.92-22.6 ppb) and ICGV-91284 (0.4-19.9 ppb) may be susceptible compared to their counterparts.

Effects of soil amendments and improved varieties on aflatoxins

In this study, good production practices were out-scaled to smallholder farmers in the Bawku-West and Nabdam Districts of the Upper East Region of Ghana [25]. The production practices were sowing at optimum time, control of soil arthropods, nutrient amendments, appropriate plant density, use of improved varieties

District	Number of samples showing up to:					Total Aflatoxins (ppb)		
	0-4 ppb	4.1-15ppb	15.1-20Ppb	20.1 -100ppb	>100ppb	Min.	Ave. (± SD)	Max.
Bongo	26	12	-	2	-	0.4	6.1 ± 12.7	71.3
Garu-Tempane	3	18	6	9	4	1.6	114.6 ± 335.3	1546
Nabdam	39	1	-	-	-	0.0	5.6 ± 28.9	183
Jirapa	35	3	-	-	2	0.3	26.2 ± 120.9	737.0
Nadowli	38	2	-	-	-	0.4	2.2 ± 2.3	15.5
Wa-West	32	7	1	-	-	0.4	2.8 ± 3.1	17.3
Frequency	173	43	7	11	6			
Overall (%)	72.1	17.9	2.9	4.6	2.5	$P_{0.05}$= 0.0027, $LSD_{0.05}$= 4.03, CV (%)= 548		
Cumulative (%)	72.1	90.0	92.9	97.5	100			

Table 5: Total aflatoxins (ppb) in groundnut samples from six district in Northern Ghana.

Source: Sugri., *et al*. [11].

Genotypes	Number of samples showing up to:				Total Aflatoxins (ppb)		
	0 - 4.0 Ppb	4.1-15.0 ppb	15.1-20.0 ppb	>20 ppb	Min.	Ave. (± SD)	Max.
ACC-ICGV-91278	11	4	-	-	0.69	3.00 ± 1.89	6.40
ACC-ICGV-91279	14	-	1	-	0.50	2.34 ± 3.67	15.27
ACC-ICGV-91284	11	2	2	-	0.40	5.72 ± 7.16	19.90
ACC-ICGV-91315	14	1	-	-	0.65	2.19 ± 1.05	4.51
ACC-ICGV-91317	11	4	-	-	0.10	2.91 ± 2.28	9.50
ACC-ICGV-91324	14	1	-	-	0.00	1.14 ± 1.97	8.00
ACC-ICGV-93305	12	3	-	-	0.15	2.19 ± 2.40	7.10
ACC-ICGV-94379	12	1	1	1	0.60	6.03 ± 10.27	38.70
Nkatie-SARI	12	3	-	-	0.50	2.54 ± 3.13	12.40
Farmer variety	11	3	-	1	0.92	5.27 ± 6.31	22.60
Frequency	122	22	4	2			
Overall (%)	81.3	14.7	2.7%	1.3	$P_{0.05}$= 0.0014, $LSD_{0.05}$= 2.69, CV (%)= 113.3		
Cumulative (%)	81.3	96.0	98.7	100			

Table 6: Prevalence and levels of total aflatoxins (ppb) in peanut samples from on-farm research trials

Source: Sugri., *et al*. [11].

and weeding twice. Good postharvest operations such as prompt harvesting at maturity, reducing the cutting to thrashing intervals, prompt drying on tarpaulin, storage at safe moisture content and good storage were adopted. The treatments involved integrate use of 8 improved groundnut varieties and 4 soil amendments on yield and aflatoxins control. At harvest triplicate samples were analyzed for aflatoxins using the Afla-mobile assay procedure. Using up to 15 ppb permissible level, all samples were classified as safe for human use at 8 months after harvest. No significant difference (P<0.05) existed between the cultivars, and soil amendments. The study results suggest a tremendous opportunity to reduce aflatoxins contamination by adopting good agronomic and genetic strategies.

Effect of best production practices on aflatoxin levels

In a study, the effect best production practices on yield and aflatoxin contamination was assessed in 21 project districts in Northern Ghana [26]. Up to 140 field demonstrations were mounted to showcase 3 improved varieties (Yenyawaso, NkatieSari and Samnut 22) and improved agronomic practices. At harvest, pod samples (1kg) were collected from farmers and analysed for aflatoxin contamination using the Aflatoxin Mobil Assay (mReader) which employs Reveal Q+ test strips (Neogen Corporation). From this study, pod samples in 2015 had aflatoxin levels of 1.46-19.72ppb, with a grand mean of 6.51ppb. In 2016, aflatoxin levels was 3.95ppb and a range of 1 to13.59ppb (Figures 3A and B). All the improved practices showed lower levels of aflatoxin contamination when compared

Treatment	Stover Yield (t/ha)	Pod Yield (t/ha)	Total Aflatoxins (ppb)
Control	0.98	0.81	5.05 ± 0.38
Fertisol (organic fertilizer)	0.95	0.96	5.05 ± 0.44
Triple super phosphate fertilizer (TSP)	1.23	1.45	5.18 ± 0.62
Fertisol+TSP	1.3	1.56	4.84 ± 32
Farmer variety 1 (Chinese)	1.02	1.02	5.08 ± 0.15
Farmer variety 2	1.14	1.14	5.05 ± 0.23
Kpanielli	1.10	1.10	4.43 ± 0.29
Obolo	1.17	1.28	5.15 ± 0.31
Oboshie	0.87	0.87	5.05 ± 0.44
Samnut 22	1.26	1.26	5.10 ± 0.28
Samnut 23	1.19	1.19	4.93 ± 0.32
Yenyawaso	1.12	1.12	5.45 ± 0.81

Table 7: Stover yield, pod yield and total aflatoxins as influenced by variety and soil amendments.

Source: Sugri., *et al*. [25].

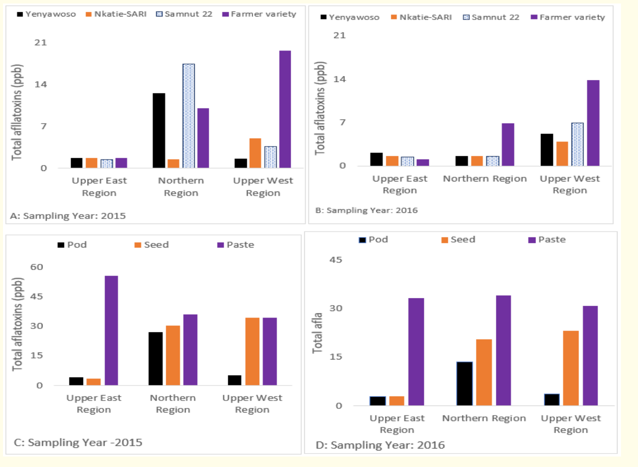

Figure 3: Total aflatoxins in different groundnut varieties and products sampled in 2015 and 2016.

Source: Tanzubil and Adam [26].

to farmers' variety and practices. Among the improved varieties, no consistent difference in aflatoxin contamination could be established over the two years across locations. The effect of location found that Upper East Region had significantly lower aflatoxin contamination than those from the Northern Region and Upper West Region. The observed differences may be attributed to weather variations among the regions. The Upper East Region with a Sudan savannah features usually has lower rainfall and relative humidity than the Northern and Upper West Regions which are largely situated in the Guinea savanna.

Aflatoxin levels in groundnut products

In Figures 3C and D, groundnut products (pods, kernels and paste) were collected from 21 districts in northern Ghana between November and January of 2015 and 2016 [26]. Aflatoxin levels in paste samples had the highest contamination (30-55ppb) across regions, followed by the kernels (3-34ppb) and pods (2.8-27ppb). The high aflatoxin levels in groundnut paste is a concern requiring attention as most families rely on this for the preparation of their household diets [7,26]. Commercial groundnut paste is usually produced from grain without grading in whole, shrivelled, broken and damaged grains, which may explain the unacceptable levels.

Integrated management of aflatoxins

Integrated management of aflatoxins should include: good agronomic practices, minimizing crop risk to moisture stress, effective management of moisture at harvest and good postharvest practices [27-30]. Some of the best management practices include, use of improved seed, timely planting, drought stress control, weed and pest control, early harvesting, good sanitation, drying to safe moisture content, proper cleaning and sorting should be greatly encouraged [28]. Combination of these practices help eliminate or reduce to the lowest degree conditions and factors that promote fungal infection.

Good agronomic practices

Good agronomic practices include choice of variety, plant population, time of planting, fertilization regime, weed control and pests and diseases control. For instance, crop rotation can reduce aflatoxin prevalence in crops by breaking the cycles and build-ups of toxin-producing microorganisms, and thus could be employed [27-30]. It is also important to ensure that pods are well formed through the application of fertilizer. Bleached pods due to termites and other soil arthropods are more susceptible to aflatoxins. Several on-farm studies have confirmed the potential of combining resistant varieties, cultural practices such as the use of soil amendments, and postharvest handling on yield and aflatoxin contamination.

Host plant resistance

Host plant resistance, when combined with pre- and post-harvest strategies, is often the most practical and effective approach. Over the past two decades, breeding groundnut varieties resistant to *A. flavus* infection has been a focus of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). A number of varieties with resistance to or tolerance of *A. flavus* infection and aflatoxin contamination have been released or are still being tested. Another trait of interest is reducing groundnut maturity periods to escape end-of-season drought, and the emphasis has been on the identification of short-duration farmer-preferred genotypes with resistance to or tolerance of *Aspergillus* spp. However, access to seed of improved varieties is still a challenge across communities in Ghana and most parts of SSA.

Soil amendments

The applications of lime (or any calcium source) and farmyard manure (FYM) when combined with good agronomic practices can minimize pre-harvest infection by *A. flavus* (Table 8) [27]. Studies have shown that application of lime alone can reduce aflatoxin contamination by 72%, while application of FYM reduces aflatoxins by 42% under field conditions. When combined, the two treatments result in aflatoxin contamination being reduced up to 84%.

Agronomic Practices	Potential to reduce aflatoxin contamination (%)
Use of plant residue	28
Farm Yard manure	42
Plant residue + Farm yard manure	53
Lime	72
Plant residue + lime	82
Plant residue + farm yard manure +Lime	83
Farm yard manure + Lime	84

Table 8: Potential reduction in aflatoxin contamination by single or multiple agronomic practices.

Sources: Waliyar., *et al*. [27].

Harvest practices

Harvest practices such as harvesting at right maturity and windrow drying have been shown to be effective in reducing aflatoxin contamination in groundnuts [21,25,27]. Some of the best harvest practices are: reducing damage to pods during harvest, stripping the pod immediately after harvest (harvest to thrashing interval), removing immature pods, removing damaged, shrivelled and immature pods, and not mixing clean harvested pods with gleaned pods. Mechanical damage caused during harvesting and shelling of groundnuts also makes them susceptible to *Aspergillus* species invasion both on the field and during storage [21].

Drying

In addition, management practices such as using appropriate drying techniques (including drying on raised surfaces or on mats), reducing kernel moisture content to 8-10%, proper threshing methods, and sorting the kernels before sale or consumption can significantly influence the level of aflatoxin contamination. Aflatoxin reduction under these practices can vary from 63 to 88% depending on location. Quick and proper drying to moisture level of about 10% may help limit *Aspergillus flavus* proliferation and toxin production [7,11,27,28]. Another study conducted in the Northern Region of Ghana showed that drying groundnuts on clean tarpaulins could reduce aflatoxin levels to about 50% compared to drying on bare ground [14].

Storage and shelling practices

Very paramount among postharvest operations are method and length of storage [7,11,27]. The quality of stored foods markedly depends on the storage conditions they have been subjected to. However, methods and duration of storage of food commodities seem to differ from one agro-ecological area or ethnic group to another. Cost and availability of storage vessels largely dictate the method of storage patronized in a particular production hub. Most of the storage structures commonly used by farmers in Africa are traditional vessels which provide poor protection from water, insects and rodents. The length of storage predisposes food commodities to aflatoxin contamination as all long stored samples of groundnuts registered aflatoxin levels above 88.0 ppb [29,30]. Hell and co-workers [30] explained that mechanical injury caused by pests during storage destroys the seed coat of grains and accelerates fungal inoculum penetration to interior parts of the grains. Besides, storage conditions such as temperature and relative humidity should be well controlled to minimize fungal activity and aflatoxin development. This however, calls for investment for building appropriate storage structures to control temperature and relative humidity.

Shelling practices

Traditional practices of wetting groundnut shells to facilitate shelling can increase the risk of aflatoxin contamination. Whereas the use mechanical shelling is becoming popular, the high mechanical damage to nuts remains the most important challenge.

Biocontrol agents

This involves employing microbial antagonist to keep the disease-causing agents in check by reducing their populations to economically insignificant levels around the susceptible host organ/tissue, resulting in no disease incidence. Several bacterial and fungal biocontrol agents have already been screened all over the world to identify potential antagonists to *A. flavus.* Although promising biocontrol agents have been identified for groundnut aflatoxin management, research is more advanced in maize. Several biocontrol commercialized products (eg. Afla-guard®, AflasafeTM) are available. However, its efficacy in multi-environment and multi-state conditions and under longer time horizons has yet to be understood. ICRISAT has identified a host of potential biocontrol agents that work against aflatoxin-producing molds in groundnuts, including antagonistic bacteria (*Pseudomonas* spp), fungi (*Trichoderma* spp), and actinomycetes (*Streptomyces* spp) strains.

Conclusion

Across sub-Saharan Africa and many developing countries, challenges to the adoption and use of good practices for aflatoxin management include lack of farmer knowledge, little market reward for quality, and slow action of regulatory institutions and policymakers. This study highlights the risk of aflatoxin contamination in groundnut and identified integrated management approaches that can be employed to minimize the negative effects on human health. The study recommends the need to regularly track aflatoxins levels in food products, especially the most susceptible commodities (such as groundnut and maize) to allow for early warning and commensurate interventions to minimize short-and long-term health risk. Intensifying awareness creation, good agronomic practices, drying, sorting and storage can reduces prevalence of aflatoxins at least to safe limits. Food diversification to crops less susceptible to mycotoxin contamination, such as vegetables, roots and tubers, has been suggested as one future option. However, this option appears to be more costly since grains are generally consumed by the poor, due to their low cost and ready availability. Regulatory agencies such as Food and Drugs Authority, Standards Authority and Department of Agriculture of Ghana must conduct routine monitoring to ensure that food commodities which are on the market with aflatoxin contamination above permissible limits are withdrawn.

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