Integrated peanut aflatoxin management for increase income and nutrition in Northern Ghana

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Abstract: Aflatoxins contamination in peanut seeds remains a major challenge in Ghana. This study evaluated aflatoxin levels in peanut samples from farmer storage units, and participatory on-farm research trials. In all, 240 respondents were covered from six main producing districts in northern Ghana through a multi-stage sampling approach. Samples were analysed for total aflatoxins using the indirect Enzyme Linked Immunosorbent Assay technique. Overall, total aflatoxins in the farmer stored nuts showed wide variations across communities and districts. At 20 ppm permissible level, 92.9% of samples (n = 240) from farmer stored peanuts and 98.7% of samples (n = 150) from the on-farm demonstrations were classified as safe at 4–8 weeks after harvest. Therefore, sustainable reduction of aflatoxins to safe limits is possible through greater collaboration among the value chain actors. Low-cost good agricultural practices within the remit of the growers should be prioritized alongside public awareness programmes.

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Keywords: on-farm storage; aflatoxin management; food safety; awareness; public health
1. Introduction
In Ghana, peanut (*Arachis hypogaea* L, Fabaceae) production plays an important role in the livelihoods of particularly women farmers in the rural communities (Carlberg, Kostandini, & Dankyi, 2014). Peanut is an important cash crop and component of diet, particularly protein source for many rural households. Although the crop is grown throughout the country, the most important production areas are the three regions of northern Ghana. In these regions, about 20% of farmers consider peanut among their two most important crops. National per capita peanut consumption is estimated at 0.61 kg/week (Awuah, 2000). Informal small-scale processing into paste, oil and cake is widespread particularly among rural women; providing vital source of livelihoods (Shanahan, Carlsson-Kanyama, Offei-Ansah, Ekstrom, & Potapova, 2003). Farmers cultivate peanut on small scales, both in pure stands and in crop mixtures with other cereals (Naab et al., 2005).

However, several abiotic stresses (drought, high temperatures, poor fertility, low pH, Ca deficiency and chlorosis), biotic stresses (diseases - rust, leaf spot and aflatoxin contamination) as well as insect pests (pod borers, aphids, thrips, millipedes and mites) are still limiting factors in peanut production (Carlberg et al., 2014). Other production constraints include access to land, farmer recycled seed, poor agronomic practices and non-supportive small scale agricultural policies (Konlan, Sarkodie-Addo, Asare, Adu-Dapaah, & Kombiok, 2013). In addition, the peanut seed system is not well developed compared to maize, rice, soybean or cowpea (Masters, James, Daniels, & Sarpong, 2013).

Aflatoxins contamination in peanut seeds remains a major challenge in most parts of Africa (Florkowski & Kolavalli, 2013). The fungi responsible for the production of toxins are mainly *Aspergillus flavus* and *A. parasiticus* and *A. nomius* (Waliyar et al., 2008). Ingestion of higher doses of aflatoxin can result in acute aflatoxicosis, which manifests as hepatotoxicity and fulminant liver failure and death in severe cases (Richard & Abbas, 2008). Close to 60–85% of smallholder farmers in developing countries are not protected by commercial food safety regulations (Wild, 2007). They often lack the capacity to protect crops against aflatoxin contamination, and awareness about risk of aflatoxin is poor. A report by International Institute of Tropical Agriculture (IITA Report, 2013) suggests that aflatoxins contamination in maize and peanut remains a major non-tariff barrier to international trade since agricultural products that exceed the permissible levels (4–15 ppb) are banned. About $1.2 billion in commerce is lost annually due to aflatoxins contamination; with African economies losing $450 million each year (IITA Report, 2013).

In Ghana, some studies have been conducted on perception, prevalence and health risk related to aflatoxins in maize and peanut (Florkowski & Kolavalli, 2013; Jolly et al., 2006; Shuaib et al., 2012; Sugri et al., 2015). Albeit, most of such have concentrated on prevalence, consumer risk and perception surveys; such studies are often fragmented and covering only a few zones. Jolly et al. (2006) found high levels of aflatoxin B1 (AF–B1) albumin adducts in blood and aflatoxin M1 (AF–M1) metabolite in urine of consumers in major peanut and maize consuming regions. Another study on aflatoxin B1-Lysine (AF–ALB) adduct levels among pregnant women showed high levels as well (Shuaib et al., 2012). Higher socioeconomic status, namely, higher education and income, small household size, being employed or having a flush toilet were inversely associated with aflatoxin levels (Jolly et al., 2006; Shuaib et al., 2012). Aflatoxin analysis in peanut products showed higher level (288.9 ppb) in rejected kernels which consist of discoloured, mouldy or split peanuts sorted out of a batch of raw peanuts. Among the processed products, high contamination was recorded in peanut paste (42.5 ppb) and kulikuli (76.91 ppb) (Florkowski and Kolavalli (2013).

This study evaluated aflatoxin levels in peanut samples from farmer storage units, and participatory on-farm research trials.
2. Materials and methods

2.1. Scope of study
The survey was conducted in six districts, comprising of three districts each in Upper East and Upper West Regions of Ghana, from November to December 2013. The research tools employed included field surveys, focus group discussions and key informant interviews. A multistage sampling approach targeting main producing districts, communities and households was adopted in selecting the respondents. In all, 240 respondents from 24 communities were covered using structured questionnaire. Information captured included demographic and socio-economic factors; cropping systems and scale of production; postharvest operations; integrated pest management strategies; farmers’ knowledge of aflatoxins; and challenges in peanut storage. Focus group discussions were carried out with different gender groups using a checklist designed to capture all relevant information.

2.2. Sampling and sample analysis
Peanut samples (240 each weighing ~ 0.5–1 kg) were obtained from farmer storage units: granaries, barns, bags and silos of the respondents. Sampling was conducted in November to December, 2013; approximately 4–8 weeks after harvest. To ensure that samples are representative of the entire batch, triplicate samples were obtained from the proximal, mid and distal points of storage bags, whereas the same procedure was followed at the upper, middle and bottom points of nuts stored in granaries and barns. The samples were then reduced to working samples through the coning and quartering method. The samples were analysed for total aflatoxins at the Plant Pathology Laboratory of ICRISAT, Mali, using the indirect Enzyme Linked Immunosorbent Assay (ELISA) technique.

2.3. Participatory on-farm evaluation
The participatory on-farm evaluation assessed the performance of 10 peanut genotypes consisting of 8 aflatoxin resistant lines from ICRISAT-Mali, and 2 local checks from Ghana. Field trials were established at Tingoli, Sambligoo and Nyagli in the Northern, Upper East and Upper West Regions, respectively in year 2014 and 2015. All experiments were established between 2nd and 3rd weeks of July and harvesting was done in the 3rd and 4th week of October in both years. At each location, the genotypes were evaluated using researcher-managed “mother trials” and farmer-managed “baby trials”. Two farmer field schools were organized at the maximum vegetative growth and harvesting stages for selected farmers from communities. The participants were schooled on good agricultural practices (GAP) in peanut production and aflatoxin management. At harvesting, GAP massages focused on prompt harvesting, quick drying, sorting, storage and processing methods. Also, participatory variety selection was done to enable farmers identify genotypes they preferred as well as traits that are critical to end-users.

2.4. Data analysis
The socio-demographic data was analyzed using Statistical Package for Social Sciences (SPSS 16). Data sets on aflatoxin levels were subjected to Analysis of Variance (ANOVA) to determine significant differences among samples by using GenStat (9th Edition) statistical package. The agronomic data sets were analyzed as a randomized complete block design with genotypes over years and locations. Differences between treatment means were separated by Fischer Least Significant Difference at 5% level of probability. Descriptive statistics involving frequencies, minimum, maximum, mean and range were employed in reporting.

3. Results

3.1. Socio-economic importance
The results in Table 1 showed that 33.2% of growers produced up to 3 bags, 42% harvested up to 10 bags and less than 11% harvested more than 25 bags per season. The harvested unshelled peanut was sun-dried for 4–6 sunshine days and stored during the drier months of the year. The dried unshelled peanut was stored in polypropylene (70.4%) and jute bags (20.8%). From the study, only few respondents applied chemicals in anticipation of prolong storage or when insect infestation was noticed during storage.
Table 1. Characteristics of major production and postharvest operations in the study communities

| Production and postharvest operations                                                                 | Description            | %  |
|------------------------------------------------------------------------------------------------------|------------------------|----|
| Average quantity harvested per farmer (1 bag ~85 kg)                                                 | 1–3                    | 33.2 |
|                                                                                                      | 4–10                   | 42.0 |
|                                                                                                      | 11–25                  | 12.8 |
|                                                                                                      | >25                    | 11.9 |
| Contribution of peanut to household agricultural income                                              | 0–20%                  | 13.7 |
|                                                                                                      | 21–40%                 | 22.1 |
|                                                                                                      | 41–60%                 | 21.7 |
|                                                                                                      | 61–80%                 | 30.1 |
|                                                                                                      | 81–100                 | 12.4 |
| Mode of storage after harvest                                                                       | Bare floor             | 0.9 |
|                                                                                                      | Jute bags               | 20.8 |
|                                                                                                      | Poly-bags               | 70.4 |
|                                                                                                      | Poly/jute bags          | 7.5 |
|                                                                                                      | Plastic bags            | 0.4 |
| Duration of storage (months)                                                                         | 1–4                    | 28.8 |
|                                                                                                      | 5–8                    | 59.3 |
|                                                                                                      | 9–12                   | 9.7 |
|                                                                                                      | 12–24                  | 2.2 |
| Period of pest infestation during storage (months)                                                   | 1–4                    | 46.0 |
|                                                                                                      | 5–8                    | 34.5 |
|                                                                                                      | After 9                | 4.0 |
|                                                                                                      | No pest incidence      | 15.5 |
| Integrated pest management strategies adopted                                                        | Only drying            | 37.6 |
|                                                                                                      | Plant botanicals       | 1.3 |
|                                                                                                      | Phostoxin fumigation    | 10.6 |
|                                                                                                      | Insecticide dust (Actellic) | 14.1 |
|                                                                                                      | No protection          | 36.3 |
| Peanut market channels                                                                               | Local market           | 37.0 |
|                                                                                                      | Nearby market          | 49.2 |
|                                                                                                      | Distant market         | 4.2 |
|                                                                                                      | Other middlemen        | 9.5 |
| Critical challenges in peanut production                                                            | Drought stress         | 48.4 |
|                                                                                                      | Access to improved varieties | 23.7 |
|                                                                                                      | Poor yield             | 11.6 |
|                                                                                                      | Diseases               | 6.8 |
|                                                                                                      | Insect pests           | 4.7 |
|                                                                                                      | Market access          | 2.6 |
|                                                                                                      | Tractor service        | 2.1 |
The focus group discussions revealed that peanut production contributed immensely to household income and food security. The crop performs well on poor soils even without fertilizer as well as minimal susceptibility to biological pests. Currently, peanut is produced under rain fed conditions by using cultivars which have been recycled for over three decades now. Early planting from May to June is preferred by farmers in Northern and Upper West Regions. Although, this period usually coincides with terminal and prolong drought which are reportedly associated with occurrence of aflatoxins. Late planting was done from mid-June to late July across all three northern regions. At the harvesting period, pod piercing and sucking bugs invade peanut fields particularly where harvesting to thrashing interval is delayed. Lack of adequate sunshine days and intermittent rainfalls were listed as challenges during drying. Access to market was not a major challenge, however occasional glut, low price at harvest and exploitation by middlemen were recurrent problems to farmers.

3.2. Total aflatoxins in stored peanut
Total aflatoxins in stored peanut samples is summarized in Figure 1. Aflatoxin levels ranged from 0.0 to 1,546 ppb with wide variations occurring within and across communities and districts (Table 2). Total aflatoxins was below 20 ppm in 20 communities but some excessive levels of 25.7, 75, 171.5 and 252 ppm were recorded at Baazu, Nimbare, Denegu and Bantanfargigu, respectively. Total aflatoxins in samples from Garu-Tempane and Jirapa districts was significantly higher ($p < 0.05$) compared to counterpart districts. The overall analysis showed that up to 92.9% of the samples could be classified as safe at permissible level of 20 ppb.

3.3. Performance of the genotypes
Table 3 provides a summary of the field performances of the 10 genotypes across 3 locations. Overall, good seedling establishment was noticed for all genotypes except Nkatie-SARI with extreme low germination rate. Using the number of days to 50% flowering (DFF) stage as a criteria for earliness, all the genotypes can be grouped as early maturing, attaining DFF by 28–32 days after planting (DAP) except Nkatie-SARI, which attained DFF by 37–42 DAP. Yield was generally low (0.266–0.437 t/ha) across the genotypes compared to yield potential of peanut (1.8–2.2 t/ha) in Ghana. However, this could be attributed to late planting of the trial in mid-July since the trials could not be established if the farmers had not planted their farmlands. Significant genotype and environment interaction ($p < 0.05$) was recorded for pod yield and yield component traits which will be considered in future agronomic evaluations.
Table 2. Prevalence and levels of total aflatoxins (ppb) in peanut samples

| District    | Number of samples showing up to | Total Aflatoxins (ppb) |
|-------------|---------------------------------|------------------------|
|             | 0–4 ppm | 4.1–15 ppm | 15.1–20 ppm | 20.1–100 ppm | >100 ppb | Min. | Ave. (±SD) | Max. |
| Bongo       | 26      | 12         | –           | 2           | –        | 0.4  | 6.1 ± 12.7 | 71.3 |
| Garu-Tempate| 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        | P0.05 = 0.0027, LSD0.05 = 4.03, CV (%) = 548 |
| Overall (%) | 72.1    | 17.9       | 2.9         | 4.6         | 2.5      | 72.1 | 90.0       | 92.9 |
| Cumulative (%) | 72.1   | 90.0       | 92.9        | 97.5        | 100      | 72.1 | 90.0       | 92.9 |

Note: 240 peanut samples were collected from 24 communities in November to December 2013; about 4–8 weeks after harvest.
The total aflatoxins across locations showed that all 10 genotypes recorded levels of <15 ppb (range of 0.00–38.6 ppb) at 4–8 weeks after harvest (Figure 2). Genotypes: ICGV-94379 (0.6–38.7 ppb), farmer variety (0.92–22.6 ppb) and ICGV-91284 (0.4–19.9 ppb) were quite susceptible compared to their counterparts. Significant \( (p < 0.05) \) regional variation was recorded where samples from the Upper East Region recorded higher levels compared to Northern and Upper West Regions. The overall analysis showed that up to 98.7% of the samples could be classified as safe at permissible level of 20 ppb (Table 4).

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Table 3. Some yield component performance of 10 peanut genotypes

|                     | Plant population/ha (000) | Day to 50% flowering | Plant height at 90 DAP (cm) | Canopy spread at 90 DAP (cm²) | Rosette score (%) | Haulm yield (t/ha) | Pod yield (t/ha) |
|---------------------|--------------------------|----------------------|-----------------------------|-------------------------------|-------------------|---------------------|------------------|
| **Location (A)**    |                          |                      |                             |                               |                   |                     |                  |
| Northern            | 61.4                     | 29.4                 | 13.0                        | 29.6                          | 8.4               | 0.424               | 0.436            |
| Upper-East          | 31.3                     | 29.4                 | 10.1                        | 26.0                          | 8.7               | 0.668               | 0.419            |
| Upper-West          | 21.8                     | 30.9                 | 14.5                        | 23.2                          | 12.4              | 0.269               | 0.163            |
| S.E.                | 12.8                     | 0.26                 | 0.37                        | 0.63                          | 1.25              | 0.260               | 0.03             |
| **Genotype (B)**    |                          |                      |                             |                               |                   |                     |                  |
| ACC-IC-GV-91278     | 45.0                     | 28.3                 | 12.5                        | 26.2                          | 8.2               | 0.465               | 0.358            |
| ACC-IC-GV-91279     | 36.8                     | 28.8                 | 13.1                        | 28.2                          | 7.4               | 0.463               | 0.288            |
| ACC-IC-GV-91284     | 38.7                     | 29.2                 | 12.9                        | 26.0                          | 7.2               | 0.522               | 0.368            |
| ACC-IC-GV-91315     | 42.6                     | 29.1                 | 12.4                        | 24.3                          | 6.2               | 0.450               | 0.437            |
| ACC-IC-GV-91317     | 39.8                     | 28.3                 | 12.1                        | 27.5                          | 10.5              | 0.384               | 0.336            |
| ACC-IC-GV-91324     | 38.5                     | 29.1                 | 12.1                        | 28.3                          | 8.5               | 0.415               | 0.310            |
| ACC-IC-GV-93305     | 40.6                     | 29.1                 | 12.2                        | 25.8                          | 11.5              | 0.425               | 0.266            |
| ACC-IC-GV-94379     | 37.8                     | 29.6                 | 12.8                        | 25.4                          | 12.1              | 0.440               | 0.341            |
| Nkatie-SARI         | 26.8                     | 37.3                 | 11.7                        | 24.2                          | 15.7              | 0.567               | 0.335            |
| Farmer variety      | 35.1                     | 29.6                 | 13.4                        | 26.5                          | 11.1              | 0.407               | 0.357            |
| S.E.                | 76.0                     | 0.48                 | 0.67                        | 1.15                          | 2.27              | 0.026               | 0.047            |
| **A**               | **                        | **                    | **                          | **                            | **                | **                  | **               |
| **B**               | **                        | **                    | NS                          | *                             | **                | NS                  | *                |
| **AxB**             | **                        | **                    | NS                          | *                             | **                | NS                  | *                |
| **CV (%)**          | 15.1                     | 3.9                  | 13.2                        | 10.7                          | 56.6              | 25.0                | 34.2             |

Note: NS-Not significant.

*Significant at \( p < 0.05 \).

**Significant at \( p < 0.0001 \).
3.4. Gender roles in the value chain

The focus discussions showed that peanut plays enormous role in livelihoods across gender in northern Ghana. All gender (men, women and youth) were involved at all stages of crop production, processing and food preparation (Table 5); although the degree of involvement varied according to task. Women were more involved in seed selection, shelling as well as primary and secondary processing operations. At the utilization stage, women were primarily responsible for processing and value addition activities up to consumption.

![Graph](image)

Figure 3 presents a model which put emphasis on smallholder actors (growers, traders, processors and consumers) at centre of the chain with associated technical support and market linkage services to support the actors. The model emphasizes on strong linkages among research, extension service, policy, smallholder actors and allied services. To reduce drudgery, the development of small scale equipment such as simple planters, thrashing, shelling and oil pressing machines require some attention. In addition, community level trainings and awareness on the emerging food safety threat of aflatoxins in peanut and peanut products should be put at the fore.

4. Discussion

Aflatoxin contamination can be minimized during “on-farm” operations by using a combination of agronomic and genetic strategies including control of soil arthropods, nutrient amendments, crop rotation, appropriate plant density and host plant resistance. Postharvest operations such as monitoring of thermal time and kernel moisture content, reducing the cutting to thrashing intervals, quick drying, good crop storage are additional management options (Wright & Cruickshank, 1999). Adjustments of sowing dates and application of gypsum can reduce pre-harvest contamination (Waliyar, Osiru, Sudini, & Njoroge, 2013). The applications of lime or any calcium source fertilizer alone is reported to reduce aflatoxins contamination by 72% compared to farm yard manure (42%) under field conditions, but combined application of both sources reduced aflatoxin contamination up to 84% (Waliyar et al., 2008). Intercropping of zimmu (*Allium sativum* L., *Allium cepa* L.) and an antagonistic bacterium *Burkholderia* sp. strain TNAU-1 for the control of *Aspergillus flavus* infection and aflatoxin B1 contamination in peanut exhibited some potential (Vijayasamundeeswari, Vijayanandraj, Paranidharan, Samiyappan, & Velazhahan, 2010). Seed treatment at 10 g/kg or soil application at 2.5 kg/ha on 30, 45, 60 days after sowing with the formulation of *Burkholderia* sp. significantly reduced infection by *A. flavus* and aflatoxin B1 contamination in kernels. Recently, the

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**Table 4. Prevalence and levels of total aflatoxins (ppb) in peanut samples from on-farm research trials**

| 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           | –   | –   | 0.92 | 5.27 ± 6.31 | 22.60 |
| Frequency      | 122       | 22          | 4   | 2   |     |            |     |
| Overall (%)    | 81.3      | 14.7        | 2.7%| 1.3|     |            |     |
| Cumulative (%) | 81.3      | 96.0        | 98.7| 100|     |            |     |

Note: A total of 150 samples (15 samples of each genotype) were collected in November to December 2014; about 4–8 weeks after harvest for the analysis.
effectiveness of biological control involving Aflasafe™, which uses native strains of A. flavus that do not produce aflatoxins, in the field has been reported (IITA Report, 2013). Aflatoxin contamination in maize and peanut was consistently reduced by 80–90% using aflasafe™ (IITA Report, 2013).

Information dissemination and public awareness including training, fact sheet and radio broadcast in local languages have been suggested (Sugri et al., 2015). Wu and Khlangwiset (2010) suggested awareness and education of farmers, governmental functionaries, and the general public as well as economic incentives to adopt interventions. Ilesanmi and Ilesanmi (2011), recommended the possibility of incorporating awareness into routine health talks to increase level of awareness among

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**Table 5. Assessment of gender roles in peanut production operations chain in Northern Ghana**

| Production operations | Description of tasks | Relative involvement |
|-----------------------|----------------------|----------------------|
|                       |                      | Women | Men | Youth |
| Production            | Land selection and preparation | xx   | xxx | xx   |
|                       | Planting             | xxx  | xx  | xx   |
|                       | Seed acquisition     | xx   | xx  | x    |
|                       | Seed selection       | xx   | xxx | x    |
|                       | Fertilizer/manure application | xx | xxx | xx |
|                       | Weeding              | xxx  | xx  | xx   |
|                       | Pest control: chemical application | x | xxx | xx |
|                       | Equipment maintenance| x    | xx  | xx   |
|                       | Cultivation by gender| xxx  | xx  | xx   |
| Harvesting            | Harvesting: manual   | xx   | xx  | xx   |
|                       | Harvesting: mechanical| x   | xxx | xx   |
|                       | Hauling the produce/transportation | xx | xxx | xx |
| Postharvest           | Separation at farm (threshing) | xx | xx | xxx |
|                       | Drying               | xxx  | xx  | xx   |
|                       | Grading/clearing/sorting | xx | xx | x |
|                       | Storage              | xx   | xx  | x    |
|                       | Manual shelling      | xx   | xx  | x    |
|                       | Mechanical shelling  | x    | xx  | x    |
|                       | Small scale processing at home/family | xxx | x | x |
|                       | Commercial processing| xxx  | xx  | x    |
|                       | By-product utilization| xx  | xx  | x    |
| Marketing             | Selling peanut products at family | xx | xx | x |
|                       | Transporting produce to market | xxx | xx | x |
|                       | Selling peanut products commercially | xxx | xx | x |
|                       | Selling peanuts as food or snacks | xxx | xx | x |
|                       | Family enterprise/vending | xxx | xx | x |
|                       | Large scale commercial enterprise | xx | xx | x |
| Consumption/utilization | Consumption at household | xxx | xxx | xxx |
|                       | Most versatile at household | xxx | xx | x |
|                       | Most preferred at household | xxx | xx | xxx |
|                       | Relative nutritional benefits | xx | xx | xxx |

Notes: x shows the relative involvement in the task by gender where x: not often involved; xx: often involved and, xxx: most often involved.
patients and their families. However, awareness of aflatoxins contamination in food is low in most parts of sub-Saharan Africa. Some reports from Nigeria and Ghana suggest that in spite of several campaigns on the health effects and economic impact of aflatoxins, few agriculturists or health professionals were cognizant of the associated health risk (Ilesanmi & Ilesanmi, 2011; Jolly, Bayard, Awuah, Fialor, & Williams, 2009; Sugri et al., 2015). In some instance the professionals in charge of the allocation of resources to reduce contamination are unaware of its economic and health risks (Hendrickse, 1999). A study in northern Ghana for instance revealed that although 78% of respondent were aware of aflatoxins in maize and peanut a large majority (68.1%) did not perceive it as a major food safety issue (Sugri et al., 2015). Among health workers in Nigeria, it was found that 95% of respondents had previous awareness of aflatoxins, however class room lectures was the common source of information to 56% of respondents (Ilesanmi & Ilesanmi, 2011). They noticed that none of the health workers had ever discussed with their patients about the risk of Aflatoxins in food.

This study suggests that at 20 ppm permissible level, 92.9% of samples from farmer stored peanuts and 98.7% of samples from the participatory on-farm experiments were safe for human use at 4–8 weeks after harvest. This trend is similar to earlier study by Florkowski and Kolavalli (2013). They reported that freshly harvested peanuts, even if contaminated, may contain low levels of aflatoxins. However, because peanut is stored after harvest, the level of contamination rises with time and significantly exceeds the permissible limits. Integrated strategies such as resistant genotypes, soil amendments and quite recently Aflasafe™ should be demonstrated to the small-holder growers. Low-cost strategies such as improved seed, clean farm operations, quick drying, sorting and used of improved storage methods, which are within the remit of the smallholder growers should be prioritized during farmer field schools and public awareness programmes. The eight genotypes evaluated showed yields comparable to the two standard checks (Table 3). Given that these are early maturing and possess resistance to aflatoxin, they have been advanced to on-farm evaluations to validate their yield potentials.

5. Conclusion
From this study, sustainable reduction of aflatoxins to safe limits is possible through greater collaboration among the peanut value chain actors in Ghana. In addition to the good agricultural practices, others actors such as the Food and Drugs Board, the main food regulatory agency in Ghana, should be strengthened to provide periodic testing for aflatoxins in grain markets. Traders and consumers could be trained to use simple testing kits to determine safety levels of grains being traded or consumed. In this regard, the Department of Agriculture and private sector involvement in aspects of providing testing kits, training or initially operating such system would be required. In the interim, intensifying training of frontline actors such as public and private agricultural extension agents and community health workers, to assist in creating awareness of aflatoxins in routine community outreach programmes, should be pursued.

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References

Awuah, R. T. (2000). Aflatoxicogenic fungi and aflatoxin contamination of peanut and peanut-based products in Ghana: Implications and concerns. In R. T. Awuah & W. O. Ellis (Eds.), Proceedings of a national workshop on peanut and peanut aflatoxins, 19–21 September 1999 (pp. 17–26). Kumasi: Kwame Nkrumah University of Science and Technology.

Carlberg, E., Kostandini, G., & Dankyi, A. (2014). The effects of integrated peanut aflatoxin management for increase income and nutrition in Northern Ghana. Issah Sugri, Moses Osiru, Mumuni Abudulai, Mutari Abubakari, Yahaya Aiseku, Salim Lamini & Muhttaru Zakaria, Cogent Food & Agriculture (2017), 3: 1312046.

Shanahan, H., Carlson-Kanyama, A., Ofie–Ansah, C., Ekstrom, M. P., & Patapova, M. (2003). Family meals and disparities in global ecosystem dependency. Three examples: Ghana, Russia and Sweden. International Journal of Consumer Studies, 27, 283–293.

Shuaib, F. M. B., Jolly, P. E., Ehiri, J. E., Ellis, W. O., Yotch, N. J., Funkhouser, E., ... Wang, J.-S. (2012). Socio-demographic determinants of aflatoxin b1-lysin adduct levels among pregnant women in Kumasi, Ghana. Ghana Medical Journal, 46, 179–188.

Sugri, I., Osiru, M., Larbi, A., Buah, S. S. J., Nutsugah, S. K., Aiseku, V., & Lamini, S. (2013). Aflatoxin management in Northern Ghana: Current prevalence and priority strategies in maize (Zea mays L). Journal of Stored Products and Postharvest Research, 6, 48–55.

Vijayasundar, A., Vijayamardhan, S., Paranidharan, V., & Viscontti, A. (2003). Family meals and disparities in global ecosystem dependency. Three examples: Ghana, Russia and Sweden. International Journal of Consumer Studies, 27, 283–293.

Samiyappan, R., & Velazhahan, R. (2010). Integrated management of aflatoxin B 1 contamination of groundnut (Arachis hypogaea L) with Burkholderia sp. and zimmu (Allium sativum L× Allium cepa L) intercropping. Journal of Plant Interactions, 5, 59–68.

Walyar, F., Kumar, P. L., Traore, A., Ntare, B. R., Diarra, B., & Kodio, O. (2008). Pre and post-harvest management of aflatoxin contamination in peanuts. In J. F. Leslie, R. Bandyopadhyay, & A. Visconti (Eds.), Mycotoxins: Detection methods, management, public health and agricultural trade, CAB international (pp. 209–218). Wallingford. doi:10.1079/9781845930820.0209

Walyar, F., Osiru, M., Sudini, H. K., & Njorage, S. (2013). Reducing aflatoxins in groundnuts through integrated management and biocontrol. In Aflatoxins: Finding solutions for improved food safety. CGIAR, IFP Focus 20: Brief 18, November 2013 Afl.Atoxins. Finding Solution. Retrieved from www.ifpri.org

Wild, C. P. (2007). Aflatoxin exposure in developing countries: The critical interface of agriculture and health. Food and Nutrition Bulletin, 28, S372–S380. http://dx.doi.org/10.1177/0198430506285217

Wright, G. C., & Cruickshank, A. L. (1999). Agronomic, genetic and crop modelling strategies to minimize aflatoxin contamination in peanuts. In R.G. Dietzgen (Ed.), Elimination of Aflatoxin Contamination in Peanut (p. 98). Canberra: ACIAR Proceedings No. 89.

Wu, F., & Kliangwiset, P. (2010). Evaluating the technical feasibility of aflatoxin risk reduction strategies in Africa. Food Additives & Contaminants: Part A, 27, 658–676. http://dx.doi.org/10.1080/19440041003639582
