AFLATOXIN: QUALITY INSTITUTIONS IN THE GROUNDNUT VALUE CHAIN IN GHANA

Wojciech J. Florkowski[1], Shashi Kollavali[2]

[1] University of Georgia, USA, [2] International Food Policy Research Institute

Abstract

The paper examines opportunities for afaltoxin reduction in peanuts. Aflatoxin contamination of peanuts is common in Sub-Saharan Africa including Ghana. Because of its detrimental health effects and economic losses, reduction of aflatoxin contamination in peanuts and peanut products is highly desirable. The paper uses data collected from farmers in the primary peanut growing area, the Northern Region, to illustrate the disparities between the current practices and the desired practices known to reduce aflatoxin presence in peanuts. The outlined containment strategy involves combining the pre- and postharvest methods to aflatoxin reduction proposing the time sequence of implementing individual elements of the strategy.

Keywords: resource-constrained farmer, Aspergillus spp., Ghana

1. Introduction

Aflatoxin is the secondary metabolite of *Aspergillus* species. Aflatoxin contamination occurs in various food products (Ibeh et al., 1991). Commonly, peanuts and grains are contaminated (Bandyopadhyay et al., 2007), but the frequency and severity varies across climate zones. Recently, the European Food Safety Agency (EFSA) found that the aflatoxin levels in grains and grain products are within limits across Europe (EFSA, 2013). Imported foods are tested. In developing countries, many face aflatoxin contamination and are seldom aware of the extent of the contamination (Florkowski and Sarpong, 2012). Aflatoxin affects groundnuts, an important source of plant proteins and often a limiting nutrient in the diet.

The importance of aflatoxin contamination is measured by its effects on people through ingestion of foods containing contaminated plant matter or indirectly through consumption of milk or other products from animals fed contaminated feed. Aflatoxin suppresses the immune system of humans and animals. Williams et al. (2004) report on a possible link between aflatoxin and six of the World Health Organization's most important health risks. Aflatoxin makes the vulnerable- especially growing children, sick and elderly people - susceptible to other diseases. Ingested aflatoxin stunts growth in children, suppresses the immune system, leads to carcinoma, and in very large doses results in acute aflatoxicosis causing death (Cotty and Jaime-Garcia, 2007).

In Ghana, groundnut is an important cash crop and an essential component of the Ghanaian diet. In 2009, Ghanaian farmers produced 495,000 metric tonnes (MT) of groundnuts on 346,900 ha (Ghana Statistical Service 2011). The production may have tripled between 1995 and 2005 (Yaw et al. 2008). Groundnut is grown throughout the country, but is most important in the two regions, Northern and Upper East, where about a fifth of farmers name groundnut as one of the two most important crops (Ghana Statistical Service 2011).

2. Objective

Awareness of aflatoxin is low among producers and traders (Florkowski and Kollavali, 2013), and even well educated consumers (Florkowski and Sarpong, 2012). Farmers are basically ignorant of the aflatoxin presence and its impact on health. Awuah et al. (2009) showed that up to 90 percent of surveyed farmers, processors, and consumers are unaware of aflatoxin, while 92 percent of farmers in the Ejura Sekyeredumase district of Ashanti Region in Ghana had never heard of aflatoxin (Jolly et al., 2006).

In this paper, we examine the reported practices of farmers from the primary peanut growing area in Ghana, the Northern Region. The data were obtained through a survey implemented in 2010. The discussion of the summary of farmer responses takes place in the context of their implications for reducing Aspergillus inoculation and the subsequent aflatoxin contamination. The comprehensive approach to aflatoxin reduction begins with on-farm decisions. Variety selection, input application, cultural practices, and harvesting methods have the potential of reducing aflatoxin contamination. Key management decisions of resource-constrained farms are not solely influenced by economic factors (e.g., farmer gender). The relative importance of each factor is confounded by the functioning of markets and surrounding institutions (e.g., the existence and application of grading standards) including the accessibility to selected inputs. The outlined strategy requires a combination of pre- and postharvest methods of afaltoxin reduction implemented in proper sequence.

The next section describes aflatoxin, its effects, and efforts to limit it in the food chain. The survey and its implementation described in the subsequent section detail collection of data presented in the Discussion section. Containment strategies are included in the second to the last section. The paper ends with Concluding Remarks.

3. Aflatoxin

Aflaoxin is a metabolite of the fungi from *Aspergillus flavus* and *Aspergillus parasiticus*. *Aspergillus* species are indigenous to soils in Ghana and soil is the primary source of the inoculum (Horn, 2003). Spores of the fungi are present virtually everywhere because they are airborne, but specific environmental conditions are necessary for the fungus to contaminate crops. Specifically, *Aspergillus* grows when temperature fluctuates between 18°C and 33°C and the relative humidity is above 50 percent. Conditions suitable for fungi growth prevail during most of the year in Ghana.

Aspergillus grows on the outer surface of the peanut pod in the soil and spreads inward eventually reaching the inside of the kernel. Aflatoxin contamination leads to kernel discoloration, but it becomes visible only after the testa has been removed. Immature or shriveled kernels are susceptible to contamination and efforts to remove them often bring the level of contamination below the allowable limit. Damaged kernels are exposed and more likely to become contaminated. Therefore, the mechanical damage during harvest or poor postharvest handling (e.g., insect infestation during storage) can contribute to contamination. Once the kernel becomes infected by *Aspergillus*, it will continue to grow under a favorable combination of temperature and humidity. Consequently, undetectable levels of aflatoxin at harvest do not guarantee aflatoxin-free peanuts later.

The Ghana Bureau of Standards follows internationally recognized regulations. Codex Alimentarius allows 15 ppb of total aflatoxin in raw shelled peanuts intended for further processing, basing the test on a 20 kg sample. In Ghana, international standards apply to commercially processed and packaged peanut products, but the vast majority of consumers purchase fairly small quantities of peanut products from cottage industry processors or vendors at open air markets, street stalls, and hawkers. The cottage industry is not subject to the existing regulations. Therefore, the prevention and reduction of peanut contamination in the field is particularly important.

4. Data

The study is based on information collected through questionnaires from 249 farmers in Ghana's Northern Region, the primary commercial groundnut production area in the country. The villages were from the districts surrounding Tamale. The survey instrument was drafted in July 2010, reviewed, and used in the survey of farmers conducted between July 18 and July 24, 2010. Also, a limited number of agricultural input suppliers represented by farm supply shop operators were interviewed. All questionnaires were completed through face-to-face interviews.

Selection of villages and towns included in the farmer survey

First, the villages and towns within each district were randomly selected from a drafted list [unclear] using of the Microsoft Excel's random number generator. Smaller village clusters were separated from town clusters. Arrangements for the survey were made with assemblymen and leaders in each location. The selection of farm households in the surveyed villages and towns was based on a list of peanut farmer names in the village or town and names were picked at random. None of the farms is a large commercial farm.

5. Discussion

Because of the indigenous nature of Aspergillus, the contamination is difficult to prevent. From the selection of a planted variety, purchase of seed, cropping pattern, application of inputs, growing conditions, decision to harvest, digging plants, to plucking and handling pods after harvest, all decisions and their implementation have the potential for discouraging growth of fungi and reduce aflatoxin presence.

The mode of entry of Aspergillus is soil and seed. It is more prevalent on stems and roots and eventually penetrates the pod (Cole et al., 1986). Assuming optimal plant health from planting is a way to limit Aspergillus growth on roots reducing chances of the subsequent pod penetration. A combination of cultural practices is recommended to reduce contamination by aflatoxin (Strosnider et al., 2006; Waliyar et al., 2006a; Klich, 2007). However, little attention has been paid to the existing farmer practices, reasons behind the observed choices, input accessibility and farmer abilities to apply and follow crop management recommendations because there is a general absence of systematically collected data to identify specific choices and behavior that is confounded by economic, environmental, and cultural factors. These general sets of recommendations have been narrowed for sub-Saharan African low-input farmers recently (Hell and Mutengi, 2011).

Farm characteristics

The average farm planted peanuts on 3.86 acres. This is a sizable area if it is to be tended or harvested by hand. The range of area dedicated to peanuts ranged from one acre to 20 acres with 26 percent reporting two acres, 16 percent reporting 3 acres, and 14 percent reporting four acres. Less than ten percent reported planting peanuts on an area larger than seven acres. Nearly 90 percent of interviewed farmers planted peanuts at a single location. Those planting peanuts on large areas reported planting them at more than one location. The size of an area planted with peanuts has indirect implications for aflatoxin reduction because it implies the potential ability to purchase inputs, including certified seeds of aflatoxin resistant varieties. Consequently, small farms may have to be targeted for certified seed distribution if broad efforts to reduce aflatoxin risk in peanuts are undertaken.

Labor and farmer gender

Field work was mostly done by hand. Among the interviewed farmers only about 4% reported owning a tractor. A larger number of farmers hired a tractor to do the ploughing or ridging on peanut fields. However, there are also differences between genders in choosing a variety. Men tend to plant Mani Pinta (also called Abain or Agric) or Bugla, while women prefer Simkarzie. Women choose Simkarzie because it is easier to pull plants from the ground once harvest begins. Pulling plants from the ground is the first stage of harvesting peanuts, and if a female farmer can do it alone she does not need to pay a man (or men) for help. Plants are left to dry in the field for several days and then pods are plucked from the vines. The gender of the farmer determines who receives the money from peanut sales. Therefore, reaching female farmers with aflatoxin resistant varieties that are easy to harvest is important in reducing contamination risk. In addition, instructing male and female farmers in cultural practices that contribute to aflatoxin reduction is needed and implies that farm advisers must interact directly with persons performing specific tasks. Survey results showed minimal contact with advisory service personnel for 12 months preceding the survey.

Variety selection and variety-relevant attributes

Farmers plant several varieties of peanuts in Ghana. Among the interviewed farmers some planted more than one variety. Variety selection reflects production risk aversion. First, various varieties mature at different times preventing the accumulation of field work. Second, in case of unfavorable growing conditions, different varieties help distribute the production risk and improve chances that some peanuts will be produced. Third, husbands and wives plant different varieties which allow for varying strength during harvest.

Groundnut varieties fall into three categories in the Northern Region. The varieties are unlikely to represent the pure genetics of the original varieties introduced into the region because farmers use either a portion of their own peanut crop as seed or purchase seed in the market from peanut vendors or wholesale traders (details about seed sources and purchase follow in the subsequent sections). The three main varieties are:

- *Simkarzie* or Chinese; most often planted; small kernel size; preferred by women because the plants are easily pulled out of the soil at harvest;
- *Simbaligu*; originates from Mani Pinta (also called Agric or Abain); introduced through government agencies several decades ago; high oil content; second to *Simkarzie* in trade volume;
- *Bugla*; traditional local variety; large kernels; low oil content; highly valued for its taste; sells at a premium over the other varieties, but is not grown by many farmers.

The surveyed farmers were asked to name varieties according to the area allocated to it starting with the variety with the largest share of land allocated to peanuts. About 52% of respondents named Simkarzie as being planted on the largest area followed by Simbaligu (Mani Pinta) (38%). The two varieties were named as the best selling varieties by the interviewed wholesale traders. Bugla was named by about 10% of farmers selecting it as the primary variety. Farmers growing more than one peanut variety still selected Simkarzie (55%) followed by Simbaligu (33%), and Bugla (13%). None of the interviewed farmers grew more than two varieties.

The susceptibility of different varieties to allow Aspergillus to colonize plants varies directly and indirectly in response to the genetic makeup. Already at the crucial stage of variety selection, the lack of established and applied standards for grades that could account for resistance to aflatoxin contamination leads to disincentives to adopt and plant potentially resistant varieties. The existing pricing mechanism does not inform and reward choosing a potentially resistant variety. Peanuts are separated primarily according to size. Buyers use quality assessment criteria on an inconsistent basis (Florkowski and Kollavali, 2013) and although farmers shell peanuts before sale in an attempt to remove molded kernels (likely to by contaminated by aflatoxin), the sorting allows a sizable portion of poor quality kernels to enter the marketing channels. Among common damage to kernels is insect damage, which facilitates aflatoxin contamination.

Planting decision

Planting decisions are made individually by each farmer although the observation of other farmer behavior plays a role. During the interview, each respondent was presented four indicators when to plant. The most frequently selected indicator was “after few rains” (71 percent) followed by “after first rain” (24 percent). “After maize” and “other” were each named by slightly more than two percent of respondents. The option “other” allowed the respondent to describe the indicator but few did.

The importance of rain prior to planting is underscored by the lack of irrigation in the area. Inability to manage the drought stress raises the risk of aflatoxin contamination when pods are still growing in the soil. The timing of planting has been named as an important decision in the comprehensive approach to limit pre-harvest aflatoxin contamination under rain fed conditions (Waliyar et al., 2006a). Soil temperature and moisture affect pre-harvest infection with Aspergillus flavus leading to aflatoxin contamination (Craufurd et al., 2006) and early planting resulted in higher yields and lowered aflatoxin concentration. Other research indicates that soils warmer locations with low precipitation levels had particularly high concentration of Aspergillus (Monyo et al., 2012). Farmers require training to make that decision at their location and services providing such training are much needed. The training has to recognize that women may plant different varieties than men and planting times may differ among varieties. Means of communication about optimal planting time could involve radio, but among the surveyed farmers few reported having a radio. Text messages send by cell phone assume that the recipient is functionally literate. It is possible to send a single message to an individual in a village, who then informs others if such approach is locally acceptable. Later, the same communication channel can be used to inform farmers about possible insect infestation or conditions favoring diseases. Prevention of such events reduces aflatoxin contamination risk.

Yield

High yield was ranked as very important by 90% of 248 farmers who responded to this question, while about 2% named it as not important (Tab. 1). The importance of yield must be considered in the context of the dependence of many families on peanuts for their diet. Although peanuts are a cash crop, a portion of the harvest is consumed by the farm household.

Table 1. Importance of peanut variety characteristics assessed using a five-step scale where 1=not important and 5-very important

Attribute	Response distribution across the five-step scale [%]				
	1	2	3	4	5
Variety-relevant attributes					
High yield	2	0	5	3	90
Insect resistance	25	9	36	2	28
Disease resistance	27	9	37	2	26
Drought tolerance	22	8	25	2	42
Price and price-relevant attributes					
Taste	41	4	21	6	29
Taste when paste made	47	6	22	4	22
Growing time	67	2	26	1	4
Kernel size	16	4	31	9	40
Time to marketing	15	0[a]	14	10	61
High price	0[a]	0	16	1	83

[a] Less than 0.5 percent of respondents provided an answer falling into this category.

The yields reported by farmers are higher than the average in Africa, but African yields tend to be among the lowest across continent and countries (Dwivedi et al., 2007). A total of 25 farmers reported Bugla as the variety planted on the largest area. The average yield was 13.68 bags per acre. Simkarzie was much more popular and the reported yield by 118 farmers was, on average, 10.68 bags per acre. A much higher average yield of 15.82 bags per acre was reported by 101 farmers in case of Simbaligu/Mani Pinta (Abain or Agric). Despite the lower average yield, Simkarzie was the most popular variety. Its popularity was likely associated with it being popular with wholesale traders, but also with ease of harvesting.

Some farmers planted more than a single variety. Bugla was not very popular as the second variety and its yield of 15 bags per acre was reported only by one farmer. Chinese or Simkarzie was the second choice of 13 farmers, who harvested, on average, 18 bags per acre, while Mani Pinta (Abain or Agric) was the second variety reported by four farmers averaging 17.25 bags per acre. When a second variety was planted, only yields of the small kernel Simkarzie variety were considerably higher than yields of the other two varieties.

Assuming a bag weighing about 50 kg (the upper range of a bag's weight), the average yields were below one ton per acre. The reported yield ranges suggest harvesting between 684 kg and 750 kg per acre in case of Bugla. China or Simkarzie could yield on average between 534 kg and 900 kg. Finally, Simbaligu produced an average yield between 791 kg and 863 kg per acre.

Price and price-relevant attributes

The high price was very important to nearly 83% of farmers and unimportant to less than 1% of farmers. The importance of price suggests that with proper incentives farmers are likely to be responsive to production and postharvest practices consistent with the supply of safe aflatoxin-free peanuts. However, during the interviews with farmers and along the peanut value chain, none of the interviewed participants mentioned standards for grades of peanuts. Therefore, farmers lack guidance regarding market quality expectations. The observation explains the widespread ignorance of aflatoxin contamination and conscious efforts to prevent it.

The selection of a variety is influenced by other factors than price because price differences across varieties were very small. Prices recorded at the markets in Tamale shortly after the farmer survey showed a four percent difference in per bowl prices between Simbaligu and Simkarzie with the latter sold at a discount. There was no difference between old and new crop peanuts for the same variety although old crop was scarce. Per sack prices showed a reverse relationship between Simbaligu and Simkarzie: Simkarzie was sold at an 18 % premium. Bugla was sold at nearly the same per sack price as Simkarzie. It appears that a high overall peanut price matters rather than price for a variety, and it is determined by growing conditions directly influencing the production volume. This confirmed differences in variety preferences among buyers, yet the lack of clear price differences lead to resource allocation in response to overall household cash needs and own peanut use. Farmers do not see benefits from choosing a variety based on buyer preferences and make their decisions using personal criteria stemming from their experience, beliefs, gender, or resource base.

The lack of price difference absence creates an opening for the introduction of a pricing scheme that would offer higher prices for growing an aflatoxin-resistant variety. The introduction of such a variety involves a number of other changes including the availability of certified seed, training of farmers beyond the use of certified seeds, and the ability of the market to separate varieties in the value channel, among others. The variety itself has to have attributes that are important to farmers and peanut buyers including the ease of harvesting.

Importance of variety attributes

The size of kernels was important to one half of farmers. Nearly 20% of farmers thought it was an unimportant variety attribute, while about 30% were indifferent. Yet, the expressed importance of kernel size did not reflect the planting of varieties that had large kernels (Bugla) because the most commonly planted were the small kernel Simkarzie. The latter are most preferred by female farmers making them a key player in the introduction of aflatoxin-resistance peanut varieties in Ghana. The market does not discriminate according to kernel size likely because a small portion of the crop is sold as roasted peanuts (where the size may matter), while the remaining peanuts are chopped or ground into paste.

The maturity time, however, was very important or important to 71% of farmers and unimportant only to 15% of them. Immature peanuts are more susceptible to aflatoxin contamination because pods have high sugar content and are hygroscopic. As noted, what represents an immature kernel requires knowledge and experience because kernel size is not a perfect indicator of immaturity (Sanders et al., 1995). Training could be provided in recognizing signs of plant maturity for various varieties by NGOs or the existing farm advisory services sponsored by the government if farmers come into contact with the trainees.

Insect resistance was neither important nor unimportant to 36% of respondents and not important to 35% of the interviewed farmers. The minority, 29%, viewed insect resistance as important. Insect feeding sites facilitate the penetration of fungal spores and eventually leads to aflatoxin contamination. Insects can infect pods or kernels with fungi-producing aflatoxin as peanut plants have been pulled out of the ground and dry before plucking pods. However, insect control is difficult because their presence varies in response to dynamic environmental conditions. Moreover, insecticides are expensive and the majority of the interviewed farmers reported relatively low income, an issue recognized as a constraint in aflatoxin reduction (Waliyar et al., 2006a). The timing of a needed insecticide application that typically precedes the availability of cash (from the sale of harvested crops) to purchase an insecticide is another constraint. Only households with adequate accumulated cash could consider insecticide application if the farmer recognizes the need for application or is informed about conditions favoring infestation. The potential reduction of aflatoxin contamination requires that information from a weather monitoring system is promptly transmitted to makers of crop management decisions.

The importance of disease resistance was ranked similarly to insect resistance. Diseases weaken a plant and contribute to Aspergillus colonization leading to aflatoxin contamination. To assure plant health and the production of fully matured (therefore less susceptible to aflatoxin) kernels, breeding for disease resistance has been a major goal. Progress has been achieved, but farmers need to have access to seeds of resistant varieties before they can benefit from the reduced risk of aflatoxin contamination. But, among the surveyed farmers none bought certified seeds and the search throughout the region did not identify a single supplier of certified peanut seeds. Therefore at the regional level, improved disease resistance does not contribute to aflatoxin reduction.

Drought stressed peanut plants are more susceptible to aflatoxin contamination. Underground kernels remain immature for longer periods as plant growth slows, allowing additional time for Aspergillus to colonize them. Drought tolerance was very important or important to 44% of responding farmers and ranked as unimportant by 31% of farmers. Periodic droughts happen in northern Ghana (dry savannah zone), but their unpredictable occurrence and farmer's lack of resources prevent investing in irrigation. The share of farmers not concerned about drought appears large. It is a potentially important issue because the end-of-season drought may not be perceived as having much effect on the crop, but favors peanut fungal infection and aflatoxin contamination (Waliyar et al., 2006b).

Seed source

Some peanut varieties grown in Ghana have been introduced by government institutions. Mani Pinta or Abain (meaning "government" in local language), also known as Agric, was introduced in the 1960s. It is characterized by high oil content and the intent was to use it for oil production. Attempts to maintain the steady supply of peanuts as seeds to farmers failed. Farmers lacked money to regularly purchase seeds causing the demand for seeds to fluctuate from year to year, while some seeds bypassed the intended distribution channels and found their way to farmers. Demand for peanut seeds also fluctuates in response to peanut prices and the risk of the payoff from planting certified seeds discourages farmers from sustained purchases. Given the overall situation, seeds of varieties that may have improved resistance to aflatoxin do not reach farmers. The potential for reducing aflatoxin contamination through planting resistant varieties is not exploited.

When asked how much seed was used in the 2010 planting season by the source of seeds, 156 farmers named using own seed. Among them, 106 saved on average 18.73 bowls of seeds. The average was quite close to the median. Another 50 farmers reported using, on average, 3.23 sacks of own seeds, but the majority (54%) used only one sack. Farmers (81) who used peanut seeds bought by the bowl at a local market, purchased, on average, an amount almost identical to the amount of own saved seed, namely 18.38 bowls. Also, the average volume of seeds purchased by sack was close to the volume saved from own production, and amounted to 3.44 sacks. However only 25 farmers purchased by sack and 48% of them bought only one sack of seeds.

None of the interviewed farmers purchased seeds from a seed company or an NGO. It is possible that some seeds are bartered between neighbors. Given the source of seeds, there appears to be a great potential for improvement of yields if selected seeds are used in production under reasonable growing conditions. Under the current conditions, it is quite plausible that a substantial portion of seeds is inoculated by Aspergillus. Aspergillus flavus is known to stunt the growth of peanut plants causing yellow mould of seedlings (Pettit, 1984). An immediate approach to reduce aflatoxin in peanuts is establishment of a healthy peanut seed supply system because aflatoxin is also suspected in lowering seed viability (Klich and Lee, 1982) leading to lower yields. Given that, on average, a farmer bought 18 bowls of seeds, a sizable amount of peanut seeds is needed every year.

Seed prices. Farmers who had to purchase peanuts for seed paid higher amounts than they received for peanuts when selling after harvest. On average, the reported price for a bowl of peanuts for seeds was 3.15 cedis. Among surveyed farmers, those who bought peanut seeds at the market paid about 66 cedis for 18 bowls. The price level and the spent amount provide a benchmark for evaluating the economic viability of a seed supply business. It could be that premium prices could be charged for better seed viability and inoculation with competitive strains of fungi limiting the presence and growth of Aspergillus.

Intercropping. Among production practices that make peanuts susceptible to Aspergillus infection in Ghana is intercropping. Corn, cassava, millet, and sorghum, all susceptible to Aspergillus colonization, are intercropped with peanuts and risk peanut contamination. About 75 percent of the interviewed farmers intercropped peanuts with other crops. To reduce the threat of aflatoxin contamination of peanuts, farmers would have to limit intercropping, possibly lowering the presence of Aspergillus in the soil of a particular field. Also, intercropping increases competition among plants for nutrients, especially nitrogen, and water, potentially weakening peanut plants and making it easier for Aspergillus to colonize. However, resigning from intercropping is unlikely among resource-constrained farmers because of the principal need to secure an adequate food supply for the household.

Irrigation. Irrigation is virtually non-existent in northern regions of Ghana and farmers cannot alleviate drought stress. Drought, especially in the latter stage of growth (pod-filling stage), makes groundnuts susceptible to aflatoxin contamination (Mehan et al. 1988; Craufurd et al., 2006; Waliyar et al., 2006b).

Fertilizer application. Out of 246 farmers who responded to whether they applied fertilizer to peanuts, only one responded in the affirmative. Some commented that they did not know one could fertilize peanuts, others indicated that the fertilizer specifically for peanuts was not available, the application of general fertilizer made the peanut plants grow large, and many indicated that the price of fertilizer was, in general, too high for them to afford.

Soil amendments have the potential to reduce the pre-harvest Aspergillus flavus infection and aflatoxin contamination (Waliyar et al., 2006c). A combination of gypsum, sorghum crop residues, and biocontrol agents seemed most effective among the tested approaches, but the application of such treatments requires both knowledge and resources to purchase some of the amendments. The approach is impractical for resource-constrained farmers, and fertilizers designed for peanut plants are a more realistic option.

Herbicide spraying. About one third of the interviewed farmers sprayed peanuts with herbicides during the growing season. Those spraying applied 1.98 gallons of the spray per acre, on average. The majority, however, sprayed one gallon (59%) and 14% sprayed two gallons per acre. Only about 17% of 81 farmers providing a response to this question sprayed more than two gallons per acre. Farmers were asked about the price of the agro-chemical per gallon. The respondents provided a wide range of prices, from two new cedis to 84 new cedis, and one respondent listed the price at 130 new cedis. It is plausible that farmers purchase diluted substances, which may be ready to use in many cases, while others purchase the original concentrated formula. About 60% of farmers did not pay more than 13 new cedis per gallon and the average price was 20.39 new cedis. Weed control indirectly reduces the aflatoxin contamination threat by eliminating competition for nutrients. It also allows better use of farm labor. Moreover, the application of herbicides teaches application of chemicals, and may help in encouraging the application of insecticides to control the role of insects preventing Aspergillus infection.

Plant maturity evaluation. Maturity varies across varieties. For example, Mani Pinta or Abain is a late-maturing variety. The majority of farmers, 78 %, selected "when half of leaves turn yellow" as an indication that plants have matured and peanuts could be harvested. Two other options were "when almost all leaves turn yellow" selected by 20 percent of farmers, and "other ways to determine the harvest," which was chosen by two percent of respondents. When asked for details on how they decided to harvest, those responding most often indicated the number of days or months it took for a particular variety to mature. One farmer stated that he uprooted a plant to check the maturity before making the decision whether to harvest, while another indicated changes in leaves of a plant as a sign it was time to harvest.

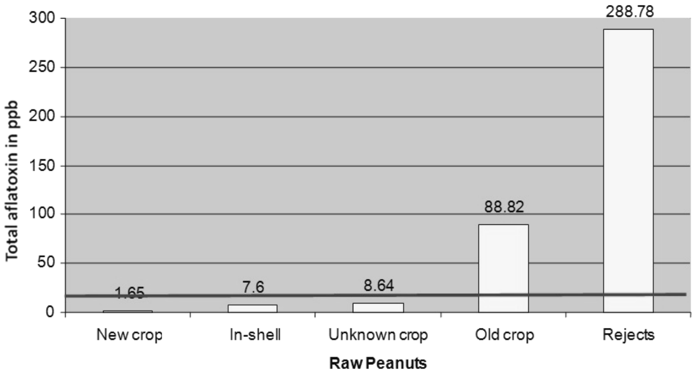
Poor timing of harvest, either too early or too late, has implications for the risk of aflatoxin contamination. Immature pods are more susceptible to aflatoxin contamination prior to and after harvest. Aspergillus flavus can cause mature pods to rot in the soil if harvest is delayed (Pettie, 1984). Rot lowers yields of marketable peanuts, while such pods may still be used on the farm. Advisory services, whether public or private, need to visit farms at the time peanuts mature and provide training if aflatoxin contamination is to be reduced. Such training is an integral part of the comprehensive approach to aflatoxin contamination reduction.

Containment strategies

None of the surveyed persons described in this paper indicated any knowledge of aflatoxin. While farmers were explicitly asked if there were any detrimental health effects of consuming peanut paste, a majority responded that "eating too much groundnut paste" is harmful. The most commonly mentioned affliction associated with eating too much peanut paste was gastric upset, although a variety of diseases was mentioned, including cataracts. The association between peanut paste consumption and health problems presents an opportunity to introduce farmers to changes in the selection of seeds, cultural practices, and harvesting methods that have the potential to reduce afflictions. An understanding of aflatoxin and how it affects health requires some cognitive skills on the part of the recipient of the message because of the abstract nature of the toxin. Awareness without knowledge how to prevent contamination or remove the contaminated kernels is ineffectual in changing behavior. The focus is therefore on actions that a farmer can undertake or apply if buyers communicate quality parameters for which they are ready to compensate.

The samples of peanuts collected during the implementation of the survey from markets in Tamale and occasionally from farmers in nearby villages were tested for aflatoxin content (Fig. 1). Tests confirmed that the new crop groundnuts (groundnuts harvested at the beginning of August 2010), even if contaminated, contained allowable levels of aflatoxin. However, because groundnuts enter storage already infected with Aspergillus or even contaminated with aflatoxin, common storage methods allow the level of contamination to increase and exceed the allowable level multiple times.

Figure 1. Average total aflatoxin content in raw peanuts from samples collected in Ghana in July and August 2010.
Note: The European Union (EU) limit in raw groundnuts, shown in red, is 15 ppt.
Source: Florkowski and Kollavali, 2013



The highest level of contamination was found in rejected kernels (288.78 ppb) purchased at one of the Accra markets. The rejects included discolored, molded, or split groundnuts.

For farmers to recognize a need to apply practices leading to the reduction of pre-harvest aflatoxin contamination they require training about the practices, while simultaneously having the opportunity to obtain inputs that control Aspergillus infections and gain from price differences based on quality.

Access to a certified seed supply has been a major problem for small farmers. Past attempts by public sector institutions were economically unsustainable. There appear opportunities for public-private partnership in production and supply of certified seeds given that among the surveyed farmers about one half spent nearly 60 cedis on not-certified seed. Peanut production is common in the area and there is a schedule of rotating market days in and around Tamale, where certified seeds can be sold.

Production of seeds can involve farmers, but peanuts for seeds need to be collected, sorted, and evaluated by a qualified lab prior to entry in the distribution channels. Demonstration plots for training purposes are also necessary. Such plots require the collaboration of farmers, village leaders, and advisory service personnel. Selection of the site and farmer are essential and must account for local traditions. Also, it may be useful to have separate demonstration plots managed by male and female farmers given the evidenced differences in planted varieties.

Demonstration plots can serve as a way to introduce farmers to the use of crop residue and soil amendments such as gypsum. Crop residue is available to farmers in the Northern Region, but if demonstrations are to be successful, farmers need access to gypsum. Given the small size of peanut fields reported by survey participants, the volume of gypsum would be relatively small. An obstacle that may require outside assistance is transportation of gypsum from a supplier to the field.

Another issue that can be addressed with or without the use of demonstration plots is the effect of intercropping and the use of fertilizers suitable for peanut plants. The dual peanut production system reflected in demonstration plots recognizes that some farmers produce peanuts only on relatively large fields, while, women farmers (because women grow also food crops for the household), may intercrop. A separate advice may have to be provided to men and women, even from the same household to assure access to knowledge.

The survey results indicated that peanut-specific herbicides were rare. Training in the selection and use of herbicides appropriate for peanuts will contribute to lessening weed competition. Because some farmers are functionally illiterate, the herbicide purchase is risky because they depend on the vendor for information. Also, as observed, the sale of herbicides in non-original packaging could be risky because the buyer cannot easily verify the name and concentration of the product. Buying an original large container by more than one farmer could eliminate such risks, but requires an agreement among two or more farmers, which, as observed in many other societies, requires a degree of mutual trust. But it can be a way for several female farmers to gain access to a labor saving practice (less weeding). A spillover effect is learning how to apply herbicide, which, once resources permit, can facilitate the application of insecticide.

Farmers need information about the conditions favoring development of diseases or insect infestation. A regional weather monitoring system is needed to predict environmental conditions and disseminate that information. The system of stations has to be fairly dense to account for specific locations for which general forecast models are adopted. Survey results indicated that few farmers had a radio and even fewer owned a television, therefore, dissemination of information needs to involve a resident in each village, who can serve as a contact person to receive and distribute it. The weather monitoring system is a major undertaking, but its benefits extend beyond the peanut farmers and agriculture to general economy and public.

The introduction of aflatoxin-resistant varieties is a long-term goal. It will require continuing government support of breeding programs supplemented by a certified groundnut seed distribution system. Progress in developing aflatoxin-resistant varieties has been made. Varieties may need to be tested in each region because of the possible variation in soils or Aspergillus strains. Resistant varieties supported by cultural practices that can be instilled prior to their development have the potential of substantially reduce pre-harvest aflatoxin contamination of peanuts.

Pre-harvest control of aflatoxin complements the postharvest efforts to reduce aflatoxin contamination and both require training. The economic feasibility of the control will be substantially accelerated if peanut market prices cover additional production costs. At present the lack of standards for peanut grades and the absence of buyers insisting on managing aflatoxin shift the focus to post-harvest handling. The current procedures can remove contaminated peanuts from sold batches, but do not remove them from the food chain (Florkowski and Kollavali, 2013). The sorted out unsalable peanuts remain on the farm or find their way to other users. Pre-harvest practices that contribute to aflatoxin reduction are undertaken in response to a distinct market signal, the price. To encourage the adoption of pre-harvest practices, farmers may have to be first encouraged to adopt postharvest practices. The absence of grading standards rewards under sorting of peanuts offered for sale because more peanuts imply additional weight, while the quality is assessed visually by buyers who use their own criteria. The criteria are not identical or consistently and uniformly applied (Florkowski and Kollavali, 2013).

Two different, not mutual exclusive, approaches to create aflatoxin-free peanut supply have been recommended in Ghana (Florkowski and Kollavali, 2013). One approach is market-based and implies creating demand for well sorted peanuts by domestic commercial processors selling their product to high income segment of domestic consumers or to export markets. Such consumers are in the position to meet the costs of increased quality because of additional sorting and removal of a portion of unacceptable kernels.

In the proposed approach, food manufacturers learn the effective technique of removal of contaminated or highly likely contaminated kernels by the trainers (Lustre et al., 2007). Once the technique is adopted, food manufacturers transfer the sorting function to farmers in exchange of price premium or the portion of labor savings from not sorting on the processors premises. The sorted peanuts supplied by farmers, if they choose to adopt the practice, need to be tested for aflatoxin content. Currently, there is a lack of rapid testing facilities in the country, but this establishment of such facilities is feasible (Florkowski and Kollavali, 2013). Sorted peanuts sold to processors fetch a farmer higher price (implying higher revenues for peanut sale) and create preconditions for adoption of pre-harvest approaches to aflatoxin reduction associated with purchase of selected inputs.

The implementation of the combined efforts of pre- and postharvest methods to control aflatoxin, one must recognize different time horizons of implementing individual elements. As stated, postharvest methods are adopted in response to the effective demand by processors. Among pre-harvest elements, some require support system, such as the advisory services or weather monitoring stations, that must be organized and function. The offered sequencing of aflatoxin-reduction efforts provides a time period when support services can become fully operational, but require government assistance and leadership. Because the support services do not limit its participation to peanut production, investing in them provides broad gains to farmers growing also other crops.

6. Concluding comments

The direct and indirect economic costs of aflatoxin contamination in peanuts are difficult to estimate in Ghana. The indirect costs result from health problems causing loss of human and animal productivity. The direct effect is lower yields of marketable peanuts reducing income of farmers in primary peanut growing areas, where the average incomes are already substantially less than in other regions of the country and lack of access to export markets. The reduction of aflatoxin has potentially direct effect on incomes, especially, given the survey results, on incomes of female farmers.

Securing a plentiful supply of safe peanuts has the potential of fundamentally changing food manufacturing, food exports, and the domestic food market in Ghana. Consequently, new jobs can be created in processing industries, while farmers' gains can result from a sustained market demand. The societal benefits occur from eating aflatoxin-free peanuts and peanut products, and healthy society generating long-term welfare gains.

7. References

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