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Aflatoxin control strategies in the groundnut value chain in Ghana

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WORKING PAPER 33 | June 2013

INTRODUCTION

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

National per capita groundnut consumption was is estimated at 0.61 kg/week (Awuah 2000), while Jolly et al. (2008) estimate that 80 percent of Ghanaians consume groundnuts or groundnut products at least once a week and 32 percent at least three times a week. Groundnut is an important source of protein in Ghana. Informal small-scale processing of groundnut is widespread, particularly among women, who supply groundnut paste, the intermediate product used in groundnut soup, a common dish in West Africa (Osseo-Asare 2002; Shanahan et al. 2003).

Groundnuts are frequently contaminated by aflatoxin, the secondary metabolite of Aspergillus species of fungus[1]. Aflatoxin suppresses the immune system of humans and animals. It makes the vulnerable—especially growing children, sick and elderly people—susceptible to other diseases. It stunts growth in children and has been recognized as a cause of liver cancer. Aflatoxin contamination of food crops is a global problem and occurs in various food products (Ibeh et al. 1991), but most commonly through groundnuts and cereals (Bandyopadhyay et al. 2007). Williams et al. (2004) report that, according to WHO, aflatoxin has been confirmed or suspected in having influence on six of the ten most important health risks in developing countries.

OBJECTIVE

The objective of this paper is to identify strategies to reduce aflatoxin contamination of groundnuts in Ghana in order to enable the development of competitive and safe groundnut-based value-adding enterprises. We examine the quality assurance institutions with oversight on the groundnut value chain and the perceptions and practices of farmers and other agents along that value chain. We also test for aflatoxin contamination in groundnuts and groundnut products that have received varying degrees of processing.

METHODOLOGY

The study is based on information collected through questionnaires administered to 249 farmers, 22 wholesalers, 29 market vendors, and 30 cottage industry processors, mostly in Ghana's Northern Region, the primary commercial groundnut production area in the country, in July and August 2010. The villages for the farmer survey were randomly selected from a list of villages in the districts surrounding Tamale. In each selected village, the survey team randomly picked the sampled farmers from a list of all village farmers.

Wholesalers and vendors were randomly selected for interview. Vendors include petty traders, mostly women who sell groundnut by bowls rather than by sacks often in spaces belonging to their spouse or other trader who are engaged in wholesale trade. The main customers for the vendors are women who purchase groundnuts to make paste. The selection of small-scale processors for the survey posed a challenge because only a small portion of them are engaged in the processing of groundnut full time. They were identified with the help of residents in selected neighborhoods and from randomly selected buyers of groundnuts.

[1] Four commonly identified forms of aflatoxin are B_1, B_2, G_1, and G_2. Two other forms, M_1 and M_2, are found in milk and result from eating aflatoxin-contaminated feed or food. However, in this paper, the term aflatoxin refers to the total aflatoxin found in food products.

Aflatoxin

Aspergillus species are indigenous to soils in Ghana. Soil is the primary source of 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 is between 18°C and 33°C and relative humidity is above 50 percent. Conditions suitable for fungal growth prevail during most of the year in Ghana. Although contamination is difficult to prevent, specific cultural and postharvest handling techniques can reduce the degree of contamination. Harvested groundnuts have high moisture content. Consequently, if drying is delayed or incomplete, fungal growth is encouraged on the pods. The pods act as barriers and protect kernels from becoming contaminated, but will not prevent contamination in the case of a prolonged storage under inappropriate conditions. A single contaminated pod can lead to contamination of the entire batch. Cross-contamination is common and groundnuts have to be guarded against contamination during handling, storage, and processing to remain aflatoxin-free.

Oil pressed from contaminated groundnut kernels is aflatoxin-free because aflatoxin remains in the cake. Groundnut cake is used as food or feed. In either case, consumption leads to ingestion of potentially harmful amounts of aflatoxin. Adding small amounts of aflatoxin binding agents makes the cake acceptable as food or feed, but such substances are not available in Ghana or other countries of the region.

PRODUCTION AND POST-HARVEST

Production practices in Ghana make the crop susceptible to infection. Groundnuts are often intercropped with maize, but also with cassava, millet and sorghum, all highly susceptible to aflatoxin contamination. Irrigation is virtually non-existent in northern regions of Ghana and farmers cannot alleviate drought stress. Drought, especially in the latter stage of growth, makes groundnuts susceptible to aflatoxin contamination (Mehan et al. 1988).

An integrated management strategy for pre-harvest control of aflatoxin in groundnuts was proposed by Waliyar et al. (2008). However, it requires the application of soil amendments such as gypsum and compost. The treatment may not be economically feasible for farmers who lack the resources needed to even purchase seed (none of which is certified), fertilizer, or herbicides. Therefore, until higher prices or increased yields can help them recover the additional production costs, the focus on managing aflatoxin must remain on postharvest handling.

Traders do not buy from farmers groundnuts with high moisture content because they are aware that the groundnuts could become moldy and discolored. They also buy only the shelled nuts so that the quality can be easily judged. They, however, judge the moisture content just by handling the nuts. Newly harvested groundnuts are difficult to sell and nearly 85 percent of the surveyed farmers did not sell immediately after harvest.

Poor storage practices contribute to infestation because farmers do not control key factors that stimulate Aspergillus growth. Farmers traditionally stored in-shell groundnuts in traditional pupuris, traditional storage structures. However, because of the increased incidence of theft of stored produce, most farmers now store groundnuts in jute or polyethylene bags. Pupuris allowed ambient air to circulate throughout the stored groundnuts, potentially slowing the growth of Aspergillus. If groundnuts are not dried properly (to the level of less than 12 percent moisture content), placing them in bags encourages contamination because of the heat and moisture generated. Also, because all the bags used by groundnut farmers are re-used after handling other crops such as maize, rice, sorghum, beans, or cocoa, the probability is high that the insides of the reused bags contain Aspergillus spores (Awuah and Kpodo 1996; Hell et al. 2000).

On average, a farmer stores about 18 bags, about half a tonne of groundnuts. Farmers indicated they sold about 10 bags in a season. Groundnuts were sold at village markets (75 percent), on farm, or in town. Farmers sell groundnuts as and when they need cash, because the food is in high demand throughout the year.

Wholesalers also typically keep their inventory in jute or polyethylene sacks, which are stored in wooden sheds to protect the groundnuts from rain, but do little to control temperature or relative humidity. The storage conditions are conducive to the continued growth of the fungi and to cross-contamination, as large lots of groundnuts consist of many smaller volumes purchased from multiple suppliers.

PROCESSING

Women process groundnuts on a small scale, typically on a part-time basis. Fewer than 10 percent of the interviewed women processed groundnuts daily. Nearly half the women process groundnuts once or twice a week. Typically, a woman processes ten bowls of groundnuts, which yield almost the same amount of paste. Processors purchase groundnuts by the basin from women vendors, lightly roast the kernels without removing the testa, and have them ground at a neighborhood

mill. They will wait to process another batch until after they have sold their supply of paste. Processing kernels without removing the testa (a process known as blanching) does not reveal the kernel discoloration. Patterns of discoloration are a reliable indicator of possible aflatoxin contamination and a batch of paste can become heavily contaminated by including just a few aflatoxin-containing kernels.

In the Northern Region, pressing of groundnuts to obtain oil takes place at home. It is done by women, who sell most of the pressed oil for cash. The remaining oil is used at home, often to fry snacks made from the pressed groundnut cake. Cake is used to make a traditional and widely eaten snack, kulikuli. Aflatoxin is not transferred to oil and concentrates in the cake. Crushed kulikuli, called kulikuli sim, is a popular condiment used to flavor grilled meats, roasted plantain and added to soups, potentially increasing the ingestion of aflatoxin. Grilled meats are eaten by well-off Ghanaians, while roasted plantain and soups are consumed by people of all income levels. The use of damaged kernels or splits, which are more likely to be contaminated by aflatoxin than fully developed whole kernels, to make paste or crush oil, increases the risk of aflatoxin presence in groundnut products.

SORTING FOR QUALITY

Groundnut varieties fall into three categories in Northern Region.

- *Simkarzie* or China. Most often planted; small kernels; preferred by women because the plants are easily pulled out of the soil at harvest.
- *Simbaligu.* Originated from the Mani Pinta variety; 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 choice of a variety is determined by many factors, including yield and price. Price differs somewhat across the three varieties, but not to the extent of providing clear incentives for a farmer to choose one over the other (Table 1).

Table 1— Average wholesale prices per bowl or per sack for groundnut varieties, August 2010

Variety	Price per bowl (GHC)		Price per sack (GHC)	
	New crop	Old crop	New crop	Old crop
Abain/Mani Pinta	3.00	-	102.50	-
Simkarzie/China	2.88	3.00	121.70	136.25
Bugla	-	-	120.00	-
No crop season distinction				
Abain/Mani Pinta	3.00		100.00	
China	-		110.00	
Bugla	2.94		-	

Source: Summary of own survey results.

Price differences per bowl are very small, regardless of when the groundnuts are harvested or their relative importance to the wholesaler or trader. The relatively high price for the old crop may result from low moisture content and can be expected to drop as newly harvested groundnuts enter the market.

Buyers expressed preferences for three groundnut attributes: color, kernel size, and oil content (Table 2). All three groups of buyers verified the color very often and paid most attention to this attribute. The color of the skin is an indication of the variety and any damage from mold. Although they seldom know about aflatoxin, the use of color as a quality measure plays an important role in aflatoxin control in the groundnut value chain because it eliminates at least a portion of potentially contaminated groundnuts from traded batches. But, seldom are the sorted out kernels removed from the food chain.

Table 2—Quality preferences for groundnut at time of purchase, Northern Region (%)

Surveyed group/ attribute	Almost never	Seldom	Neither seldom nor often	Often	Very often
Wholesalers *(n=22)*					
Color	32	0	0	0	68
Kernel size	32	0	0	0	68
Oil content	87	0	0	0	13
Cottage processors *(n=30)*					
Color	0	0	0	20	80
Kernel size	0	7	7	10	76
Oil content	10	3	3	3	80
Traders/vendors *(n=29)*					
Color	11	0	5	21	63
Kernel size	21	0	0	32	47
Oil content	0	0	0	0	0

Source: Summary of own survey results.
Note: Sums may not add to 100 due to rounding.

Kernel size was also highlighted as an important attribute to verify, but not all of the traders or processors pay attention to it. In consequence, immature and undersized kernels remain in the sold batches. Shrunken or immature kernels are more likely to be contaminated by aflatoxin than are mature, fully developed, whole kernels. Market vendors sell raw shelled groundnuts that include various size kernels. It is up to the buyer to further sort for size. However, even if some undersized kernels are removed, they may still be used as feed for household livestock and end up as food. Knowledge among the public on aflatoxin in groundnuts and its effects on health is absent.

Once purchased, wholesalers will have their groundnuts sorted, but only when time permits. Table 3 shows the frequency of sorting for specific purposes. The majority often or very often remove split (64 percent), broken (58 percent), discolored (59 percent) or damaged kernels (76 percent) – all possibly contaminated. However, 20 to 33 percent of wholesalers seldom or almost never sorted for such kernels. Convenience dictates the degree to which groundnuts are sorted and only buyer demands lead wholesalers to undertake additional sorting. Yet, the intensity of sorting is left to the judgment of the wholesaler and the hired sorting crew. The lack of well-defined standards and sampling protocols to confirm that a batch complies with standards allows contaminated groundnuts to remain in a batch. Consequently, contaminated kernels enter the food chain as they are shipped across the country.

Table 3—Sorting and pre-marketing functions performed by wholesalers (%)

Function	Almost never	Seldom	Neither seldom nor often	Often	Almost always
Shell groundnuts	57	24	5	10	5
Clean groundnuts by removing foreign matter	-	14	5	23	59
Sort groundnuts by size	23	9	5	18	46
Remove split kernels	9	23	5	18	46
Remove broken kernels	19	14	10	10	48
Remove skin from kernels	29	10	-	24	38
Remove discolored kernels	14	18	9	23	36
Remove damaged kernels	10	10	5	24	52

Source: Summary of own survey results.
Note: Sums may not add to 100 due to rounding.

Cottage industry processors often consider the presence of split or broken kernels when assessing quality, but one fifth of them almost never paid attention to these two attributes (Table 4). However, kernel size was frequently considered. Skin color was the most considered attribute, and removal of discolored kernels reduces the chances of aflatoxin contamination. However, removal of such discolored kernels was not done consistently.

Table 4—Groundnut attributes considered by surveyed cottage industry processors (%)

Attribute	Almost never	Seldom	Neither seldom nor often	Often	Very often
Color of skin	-	-	-	20	80
Taste	7	7	-	13	73
High oil content	10	3	3	3	80
Kernel size	-	7	7	10	76
Presence of split kernels	20	-	-	-	80
Presence of broken kernels	20	-	-	-	80
Presence of groundnut straw	20	-	3	-	77

Source: Summary of own survey results.
Note: The sum may exceed 100 percent due to rounding.

Table 5 shows the sorting procedures actually applied to assure that attributes listed in Table 4 are achieved in a batch destined for processing. From the standpoint of reducing aflatoxin contamination, the sorting targets the potential sources: discolored, damaged by insects or rodents, or "bad" kernels. Heavy aflatoxin contamination can be detected visually. However, to identify the contaminated pods they have to be shelled and the skin from kernels must be removed. The motive for keeping skins is to save additional time required to remove skins and sort damaged kernels after lightly roasting groundnuts (requiring additional time and fuel).

Table 5—Sorting procedures used by the surveyed cottage industry processors (%)

Sorting function	Almost never	Seldom	Neither seldom nor often	Often	Very often
Shell groundnuts myself	13	67	3	13	3
Sort kernels by size	21	14	4	7	55
Remove skin from kernels	-	-	-	-	100
Remove discolored kernels	-	-	3	17	80
Remove kernels damaged by insects	-	-	-	17	83
Remove kernels damaged by rodents	3	3	-	17	77
Remove kernels think are bad	-	-	-	17	83
Roast groundnuts	10	-	-	7	84

Source Summary of own survey results.
Note: The sum may exceed 100 percent due to rounding.

However, groundnuts rejected in the sorting process do not leave the food chain. Farmers use the removed groundnuts for food or feed. Table 6 shows that more than half of wholesalers sell the rejects, while traders or vendors sell them or grind them into paste. In developed economies, a combination of regulations, alternative uses such as clay-treated feed, and the higher price paid by consumers for aflatoxin-free groundnut products prevent aflatoxin contamination.

Table 6—Disposal of rejected kernels by wholesalers and cottage industry processors (%)

Action	Wholesalers	Traders/vendors
Ground into paste	-	30
Sell them as they are	55	25
Other	45	55

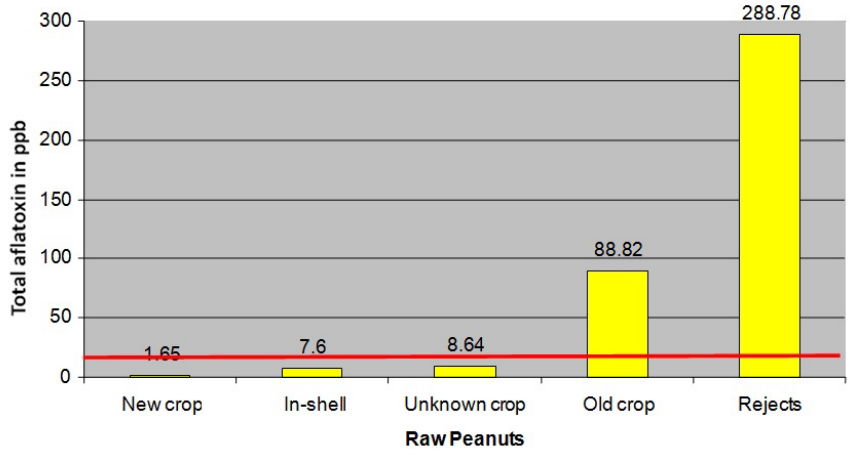
Source: Summary of own survey results.

In Ghana, despite all of the sorting of groundnuts that takes place before marketing and processing, the groundnuts that reach the market still contain aflatoxin in amounts exceeding allowable limits. Each party along the value chain under the current pricing system has an incentive to under-sort because the standards for grades are nonexistent, the sampling to verify quality follows ad hoc procedures dependent on the buyer's requirements, and monetary incentives to sort are absent. The aflatoxin contamination of food has been a persistent problem in Ghana. Bearwood (1964) surveyed the groundnut market in Accra and reported that 69 percent of tested samples were highly contaminated.

For the current study, groundnut and groundnut product samples were obtained from farmers, wholesalers, vendors, cottage processors, hawkers, and supermarkets during the survey. All samples (70 total) were tested for total aflatoxin content by a commercial laboratory in Texas, USA. The sample size was a standard volume consisting of about two handfuls

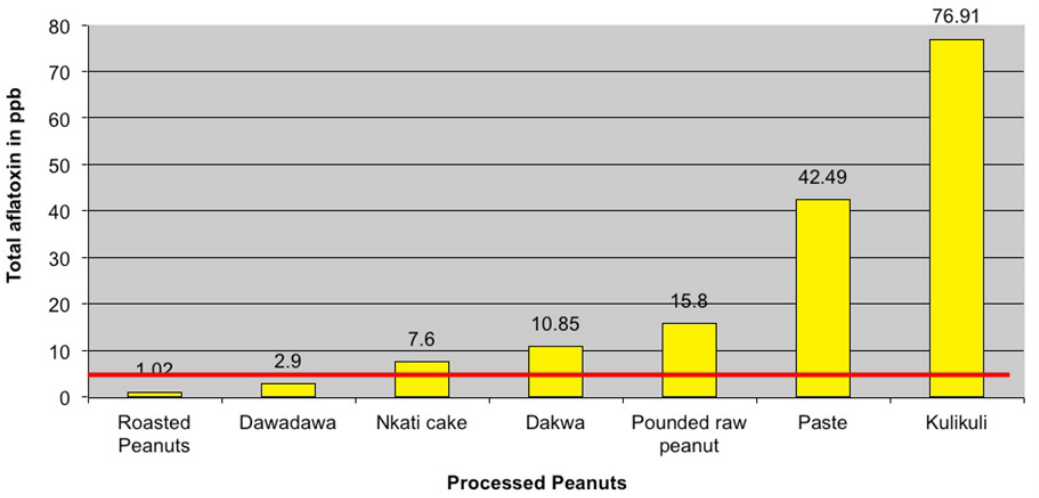
of groundnuts. As expected, the groundnuts that were stored longest or had gone through processing had the highest levels of contamination (Figures 1 through 3).

Figure 1—Average total aflatoxin content in raw groundnuts



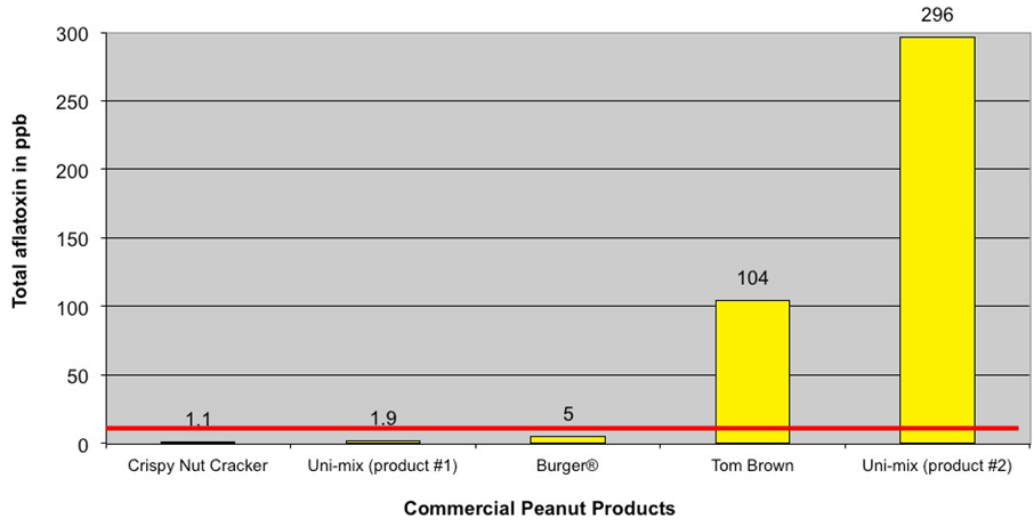
Note: The EU limit in process food products, shown in red, is 4 ppb.

Figure 2—Average total aflatoxin content in cottage industry process groundnut products



Note: The EU limit in process food products, shown in red, is 4 ppb.

Figure 3—Average total aflatoxin content in manufactured groundnut products



Note: The EU limit in process food products, shown in red, is 4 ppb.

The tests confirm the earlier reported observations that new crop groundnuts (groundnuts harvested at the beginning of August 2010), even if contaminated, contain low, allowable levels of aflatoxin. However, because groundnuts are kept in storage between harvests, the level of contamination rises with time and significantly exceeds the allowable level. The highest level of contamination was found in rejected kernels (288.78 parts per billion (ppb)) purchased at one of the Accra markets. The rejects included discolored, molded, or split groundnuts sorted out of a batch of raw groundnuts marketed by one of the vendors. The sample of 'rejects' was a small bag filled with scooped groundnuts by a vendor at the time of purchase.

Among the processed products sold by the cottage industry, the level of contamination varied. It was not surprising to observe unacceptably high contamination of groundnut paste (on average, 42.49 ppb, about 10 times higher than the threshold for entry to the EU). Moreover, the very high average contamination of kulikuli, 76.91 ppb, was anticipated because of inadequate processing. However, although rejected kernels are likely eaten by the poor, while the paste is consumed by almost all households, *kulikuli* or *kulikuli sim* is eaten by wealthier consumers able to purchase prepared meat dishes. Moreover, the test results of commercially produced products reveal no particular pattern of contamination. For example, two weaning mixes that contained groundnut flour showed markedly different contaminant levels, one of which was unacceptably high. Commercially manufactured salted, roasted groundnuts contained 25 times more total aflatoxin than the allowable limit.

GRADES AND TESTING FACILITIES

The domestic standard for aflatoxin content is mandated with regard to manufactured packaged products in Ghana. The cottage processing industry, which operates outside the existing regulations because it does not package their product, sells paste by volume measure. Other products, like *dakwa*, *dawadawa* or *nkati* cake, are sold by piece and placed commonly in small polyethylene bags by vendors. Domestic regulations are similar to those applied in the EU, which allow up to 5 ppb of total aflatoxin contamination in processed groundnut products. Although these regulations apply only to commercially packaged groundnut products, even in manufactured products, packaged in moisture-barrier materials, aflatoxin contamination significantly exceeded the allowable threshold.

Testing for aflatoxin is expensive. Even commercial manufacturers may encounter serious difficulties in testing for aflatoxin levels because commercial laboratories capable of conducting the tests in Ghana are lacking. The government research institutions or the leading universities have the expertise and equipment, but the cost of a single test of about US$100 is unaffordable for small processors and can be prohibitively expensive even for some commercial manufacturers who would have to test each batch.[3]

Knowledge of these standards is also weak. None of the interviewed responding traders or processors mentioned using standards for grading groundnuts in their trade or marketing practices. In fact, none of them was aware of the existence of such standards. In the absence of knowledge and application of standards for grading, the risk of contamination increases. Commonly, standards for shelled groundnuts specify the percentage of damaged, split, or undersized kernels (all more likely to be aflatoxin-contaminated than mature kernels) and limit contamination. In the case of groundnut processing in the United States, for example, procedures applied to the handling of raw groundnuts are in place to reduce contamination (Adams and Whitaker 2004). Stringently enforced testing of sorted groundnuts for aflatoxin content is required on the premises of every groundnut shelling plant.

AWARENESS OF AFLATOXIN

Awareness of the health effects of aflatoxin contaminated food is low among the public in Ghana. In spite of the omnipresence of aflatoxin and its deleterious health effects and economic impact on agriculture, few agriculturists or health professionals in Ghana are aware of the health risks associated with aflatoxin (Jolly et al. 2009). Some of those professionals are charged with the allocation of resources to reduce contamination, but they are unaware of its economic and health risks (Hendrickse 1999).

However, there are occasional panics about aflatoxin. In 1998, a sensational front-page newspaper report led to public panic by reporting that *kenke*, a common maize-based food, contained aflatoxin and caused cancer (The Ghanaian Chronicle, 1998). However, after emotions subsided, the issue of aflatoxin in food was sidelined and received little public attention.

Awareness itself may not suffice. For example, Wu and Khlangwiset (2010) view awareness and education on aflatoxin among farmers, governmental functionaries, and the general public as crucial to providing economic incentives to adopt interventions. Contrary to suggestions that, for example, the more that professionals in decision-making positions are aware of contamination, the more they will be willing to implement measures to reduce the presence of contaminated groundnuts

from the food supply, their actual behavior does not bear this out (Jolly et al. 2009). Reports on aflatoxin contamination in foods in Ghana and West Africa have been available for decades (Awuah et al. 2008).

Awareness of aflatoxin is low among producers and traders. Few are aware that improper groundnut storage can aggravate contamination. 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 had never heard of aflatoxin (Jolly et al. 2006). None of the interviewed persons indicated any knowledge of aflatoxin, while farmers were explicitly asked if there were any detrimental health effects of consuming "too much groundnut paste." The aflatoxin concept itself is not simple, because of the abstract nature of the toxin and because the timing of the affliction eventually caused by prolonged ingestion being significantly detached from the time of consumption.

Containments Strategies

The current internationally applied quality requirements and quality control mechanisms reduce aflatoxin contamination through the application of advanced sorting processes and repeated testing. However, the cost of advanced sorting equipment is prohibitive for wide application in Ghana. Production practices are inadequate to prevent the inoculation of groundnut pods by toxic strains of *Aspergillus* in the soil. In postharvest handling, drying in-shell groundnuts to the acceptable moisture level is crucial to control *Aspergillus* growth and subsequent aflatoxin contamination. However, even properly dried pods are eventually stored in conditions of high relative humidity and temperature because the construction and operation of modern storage facilities is beyond the reach of typical Ghanaian farmers and wholesalers.

All value chain participants sort groundnuts, but not to the degree necessary to bring aflatoxin contamination to low levels. This under sorting increases the volume of groundnuts offered for sale, and given the lack of any mandatory standard or grades, none of the value chain participants willingly gives up potentially larger earnings by removing more poor quality kernels than what is necessary to complete a sale. Indeed, the rejects re-enter the food chain because they are sold at a discount and purchased by price-sensitive buyers or are used in products where the customer is unable to assess the conditions of kernels visually.

The existing regulations are consistent with international standards, but mandatory enforcement is limited only to commercial processors, leaving the vast women-owned cottage processing sector unregulated. Existing aflatoxin testing facilities and equipment are very expensive, time-consuming to use, and, for the vast majority, difficult to access due to the testing facility location.

Aflatoxin contamination reduction poses a considerable challenge because of low consumer awareness. To regulate the sales at numerous open air markets, street stalls, or by mobile hawkers is virtually impossible. Even if consumers were made aware, many would have difficulty comprehending the magnitude of risk because of the particular, slow manner in which the toxin affects health. The long-term health consequences are less likely to attract resources given the many other, more apparent and perceived as urgent, health issues.

Although they are not currently available in Ghana, existing technologies can reduce *Aspergillus* infestation in the field and control aflatoxin contamination.[2] In addition, storage technologies could control the spread of aflatoxin contamination by directly affecting the growth of toxic *Aspergillus* strains and indirectly by control of insects feeding on groundnuts. With or without the introduction of both pre- and postharvest technologies, two different approaches that are not mutually exclusive are feasible.

- The first is market-based and relies on consumer demand. This entails educating consumers to goad them into changing their demand and enforcing regulations that ensure that the products are accurately and adequately labeled to facilitate consumer action. Importantly, it also entails willingness on the part of consumers to accept higher prices for quality. This approach may be appropriate for some products among a portion of consumers.
- The second approach relies on regulation where consumer awareness is not necessary, although helpful. If adequate resources are devoted, even informal processing units can be regulated to some extent, particularly when regulation is combined with awareness-increasing campaigns. However, to the extent that some consumers are willing to risk buying and eating the rejects, this approach becomes infeasible.

[2] Currently, commercial products are available in selected countries. When applied directly onto growing groundnut plants, the colonization of the plant and pods by toxic strains of *Aspergillus* is prevented. However, the effectiveness of the application depends on the environmental conditions. In addition, the products are unavailable in Ghana and prices would likely prevent the majority of groundnut farmers from using them.

Both of these solutions recognize interactions between the scale and the solution to be effective. Although with the current technology and price-cost relationships, the complete removal of aflatoxin (or any mycotoxin) is not feasible, a reduction to or below allowable limits is a realistic goal.

Given the infeasibility of any one approach being effective, multiple interventions need to be considered. Some interventions may trigger other changes, so one needs to consider the pathways of change that can be expected from different interventions, their costs, and the feasibility of intervention. Moreover, the interventions may need to be sequenced so as to reduce the cost of implementation and to enhance the benefits by building on secondary changes that some interventions are capable of generating.

A convenient point of entry is with formal processing plants that are marketing groundnut or groundnut products, whose regulation is feasible. However, regulation alone will not be adequate. It needs to be combined with incentives. By meeting regulatory requirements, formal processing units have an opportunity either to create a niche for themselves in the domestic market or to enter global markets. They are in the best position to meet the costs of increased quality. Consumers typically pay a premium for such products, which will offset the additional processing costs (i.e. the removal of contaminated kernels).

Producing aflatoxin-safe products that meet the import requirements within West Africa as well as for the lucrative markets of the EU and the US—both of which have a large diaspora of Ghanaians and West Africans, a natural market niche—is clearly a goal worth pursuing. Export demand creates additional economies of scale and further lowers manufacturing costs.

Contaminated groundnuts can be effectively removed from the food chain through the application of a simple, inexpensive sorting technique (Lustre et al. 2007). The initial implementation involves presorting and process sorting of groundnuts on plant premises. Presorting involves the removal of visibly damaged kernels with skin still attached such as kernels with insect or rodent damage. Once these kernels are removed and the remaining kernels are blanched, the process focuses on the removal of other visibly damaged kernels. Even then, the incremental costs can be considerable. In Ghana, for example, to produce aflatoxin-free products, it might prove necessary to discard 25 percent of the kernels from a bag purchased at a market. Commercial processors need to be assisted in assuring quality in the markets where they buy their groundnuts through teaching sorting techniques and training suppliers.

The implementation of sorting techniques can be effectively achieved within a few weeks if performed by food processors who pay the prevailing price for groundnuts in the market. As a result, the processor assures a safe product while withholding rejected groundnuts. A potentially large volume of rejected groundnuts can repay the processors in kind because pressing rejects into oil, which remains aflatoxin-free because aflatoxin does not transfer to oil, can pay rich dividends. The disposal of the cake left after the oil pressing may require initial monetary incentives. The contaminated cake would have to be destroyed or treated before re-entering the food or feed chain. In developed economies, an addition of mycotoxin binders (e.g. bentonite), which absorbs the toxin in the guts of animals, is permitted, rendering the cake valuable. In Ghana, government approval and initial assistance is needed to manage this part of the solution.

Once commercial processors are trained to sort for aflatoxin-contaminated kernels, they can pass signals upstream and demand higher quality, perhaps offering higher prices or a premium for the supply of aflatoxin-free groundnut. This is a far better option than throwing away a significant portion of a valuable product. All this hinges on formal processors being willing to make the effort to source local groundnuts or offer a premium for quality in local markets.

Technological developments in a number of areas will help either to control or to improve the quality of supplies. Encouraging the cultivation and increasing adoption of varieties that resist colonization by toxic *Aspergillus* strains is an agronomic solution. Such varieties must be tested for their resistance to contamination, their marketable yield, and their sensory attributes to assure consumer acceptability. Survey results reveal differences in taste of varieties. Processing requirements may reflect additional preference attributes, including oil content, ease of shelling, susceptibility to splits, and kernel size. These attributes influence the availability and cost of various groundnut varieties and groundnut products, such as groundnut oil, paste, and roasted groundnuts. Current pricing does not differentiate groundnut quality.

Technologies are currently available to control *Aspergillus* spp. in the fields, but these are at present unavailable in Ghana and may be too expensive for local use. The international agribusiness firm, Syngenta, for example, offers a product known as Afla-guard to control aflatoxin in US groundnut fields, but the product uses an *Aspergillus* line that is indigenous to the soil of a given country. Local adaptation and approval of the producer entails expending considerable resources.

Low-cost testing would obviously encourage more testing. Current testing using HPLC equipment is not appropriate for regulatory purposes, because all that is required to meet the regulations is to be within the threshold limits for total aflatoxin. It is unnecessary to establish the actual amounts of various types of aflatoxin. Such detailed information may be helpful in

monitoring the problem, but unnecessary for a commercial processor. Rapid testing methods that robustly assess whether or not the aflatoxin content in a batch of groundnuts or a groundnut product exceeds the maximum allowable level offers an opportunity for the emergence of a private sector company in the new business venture. The rapid testing procedure could bring the price per test from about US$100 to less than half that amount.[3] This has been the experience of other countries, like Uganda. Such a company would need to be certified to assure that its test results are internationally recognized. The process for certification exists, but may have to be facilitated by the appropriate government agencies, such as the Ghana Bureau of Standards.

The availability of mycotoxin binders that have been used to prevent intake of aflatoxin from animal feed in many developed countries offers a possible solution to the problem in Ghana (Kolosova and Stroka 2011). Adding binders to groundnut products eaten by people, including children, has also been effective in preventing the absorption of aflatoxin into the bloodstream. The sorting procedure is an alternative solution and applicable in the numerous small and medium enterprises that dominate the Ghana's groundnut processing industry. As long as the market, rather than regulators, decides about the suitability, acceptability, and economic viability of each method, the goal of supplying safe groundnuts and groundnut products to consumers will effectively be achieved at no cost to the government.

Sequencing of Interventions

To assure an aflatoxin-safe supply of groundnuts, a strong regulation of commercially produced products must be established through monitoring and enforcement. If a safe domestic groundnut supply cannot be established, the domestic commercial processing sector either will wither because of unprofitability or will turn to imports to meet the domestic (and possibly subregional) demand for aflatoxin-safe products, especially paste. Indeed, the high groundnut prices in Accra markets in early 2012 suggest that imported groundnuts could be price-competitive. The use of domestic groundnuts will impose the cost of testing on domestic processors, who will complain that the enforcement of aflatoxin-content regulations imposes an undue burden on them.[4]

The enforcement of regulations must involve the allocation of additional resources to properly monitor the processing industry, possibly extending to other value chain participants. However, first, inexpensive rapid aflatoxin testing facilities must be established. Such facilities are needed at several locations throughout the country to assure accessible, credible, and prompt service. For example, testing laboratories could be established in Tamale and Accra, and also in major agricultural markets or processing centers such as Techimen or Kumasi.

The need for rapid testing creates an opportunity for government involvement in furnishing equipment, selecting and training personnel, and initially operating the testing facilities. Alternatively, the laboratories could function as public-private partnership entities. For example, a laboratory operating at major groundnut markets could attract sufficient volume that, even with low-cost testing, it could operate as a commercial rather than a government institution.

A complementary, but independent effort is the implementation of a broad training program for traders and processors to learn about aflatoxin contamination. The training could be initiated by a government agency and involve public research institutions. The direct outcome of such a program would be the assurance of a reliable domestic supply of safe groundnuts and would spur the expansion of the domestic food processing industry. The program could engage experts already involved in ongoing groundnut commercialization programs in Ghana.

Support of training programs on grading and sorting for traders that supply commercial processor will serve as a subsidy for the processing firms and traders. The training will, in turn, raise expectations and the traders would perceive their self-interest in working with their customers. As a result, consumers of the commercial processing groundnut industry will eat safer products, thus improving health conditions. Through extension, information could be made available to producers on safer methods of production and storage (Table 7).

[3] Personal information obtained from the FRI-CSRI, Accra, Ghana, in January 2012.

[4] The number of mycotoxin (including aflatoxin) regulations per country differs widely. It is estimated at 19.6 regulations per country in Europe vs. 1.5 per country in Africa (Logrieco 2012).

Table 7—Groundnut value chain participants and factors that might offer them incentives to supply aflatoxin-safe groundnut products

Agents in value chain	Influencing factors
Formal processors	Enforcement Training of their dealers on how to best supply aflatoxin-free groundnuts
Traders	Derived demand from formal processors
Producers	Demand from traders Information from agricultural extension on sorting and appropriate storage practices
Informal processors	Provide knowledge through traders Consumer demand for aflatoxin-free groundnut products leading to changes in behavior
Consumers	Public education campaigns. Could be done cheaply by making information available to radio stations. Agricultural extension system used to pass information to farmers.

The introduction of aflatoxin-resistant varieties is a long-term goal. It will require continuing government support of breeding programs supplemented by the establishment of certified groundnut seed distribution. The lack of access to certified groundnut seed negatively influences groundnut production and supply.

For informally processed groundnut and groundnut products, the essential issue is consumer education. Massive consumer education is unrealistic. However, through traders and vendors, some information will flow to the rest of the population about the factors that are detrimental to their health and livelihoods, and over time, consumers will become more selective about purchasing groundnut products.

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This Working Paper has been prepared as an output for the Ghana Strategy Support Program, funded by USAID, and has not been peer reviewed. Any opinions stated herein are those of the author(s) and do not necessarily reflect the policies or opinions of IFPRI.