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Strategies to Control Aflatoxin in Groundnut Value Chains

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ABSTRACT

Groundnuts, which are widely consumed in West Africa, are prone to contamination by aflatoxin during production and storage. Although aflatoxin plays a role in many of the important health risks in developing countries, individuals and governments ignore the risks because their health effects are not immediate. In the developed world strong regulations remove contaminated kernels and their products from the food systems. The objective of this paper is to examine production and marketing practices, particularly grading methods, in Ghana's groundnut value chain to obtain a clear understanding of the sources and levels of aflatoxin contamination in the crop and how such contamination can be sharply reduced. The study finds that seemingly inferior kernels, which are likely to be contaminated, are indeed sorted out but that the rejects are not taken out of the food system; instead, they are offered to consumers in a crushed form as an ingredient in cooking and flavoring. Testing for aflatoxin confirmed high levels of contamination particularly in products that contained crushed groundnuts. The paper suggests a multipronged strategy suitable for a developing country in which stringent enforcement of regulation may be infeasible.

Keywords: aflatoxin, Ghana, quality, groundnut, grading, sorting, regulation

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1. INTRODUCTION

Aflatoxins are carcinogenic metabolites produced by a specific fungus in the genus *Aspergillus flavus.* The fungus contaminates with aflatoxin a wide range of cereals and legumes and is commonly observed in maize and groundnuts in particular (Bandyopadhyay et al. 2007). Aflatoxin has been confirmed as, or suspected of, playing a role in 6 of the 10 most important health risks in developing countries, has been shown to cause acute hepatitis and liver cancer, and is associated with impaired growth in children (Turner et al. 2002). However, aflatoxic-related illnesses often go unnoticed. This is because symptoms are not immediately apparent but manifest themselves only after long-term exposure to moderate to low aflatoxin concentrations. Moreover, chronic exposure to aflatoxin has been responsible for lowering the body's immune system and interferes with protein metabolism. Some estimate that exposure and its toxic effects on immunity and nutrition are responsible for more than 40 percent of the disease burden in developing countries (Williams et al. 2004). The economic costs of the direct and indirect effects of aflatoxin ingestion are huge although—because of the mode of inflicting damage—difficult to isolate and quantify.

Among developing countries, those in Africa suffer disproportionally from aflatoxin contamination. The high temperature and humidity typical in most African countries south of the Sahara favor the growth of the fungus and aflatoxin production (Wagacha and Muthomi 2008). Consequently, crops in the region are more susceptible to contamination than those in temperate regions. Apart from its impact on health, aflatoxin contamination denies these countries access to export markets for their crops that are most susceptible to aflatoxin contamination. African countries are estimated to lose approximately $670 million annually due to the inability of African farmers to meet the aflatoxin standards of the European Union for the crops that they produce (Otsuki, Wilson, and Sewadeh 2001).

Developed countries remove aflatoxin from food and feed by means of extensive enforcement of regulations using advanced testing technologies. In the United States, for example, the US Department of Agriculture (USDA) regulates the quality of groundnuts through a marketing agreement program. The agreement requires all raw groundnuts marketed in the United States to be officially inspected for aflatoxin and graded by federal or federal and state inspectors. The Federal State Inspection Service maintains more than 400 inspection offices throughout the 10 peanut-growing states in which nearly a million acres were planted with peanuts in 2013 (USDA 2014).

Raw groundnuts in shell are inspected and graded at buying points (where peanuts are transferred from a grower to a sheller) or shelling plants. Federal State Inspection Service agents draw samples of raw groundnuts at buying points to analyze amounts of foreign material, size of pods, size of kernels, amount of damaged kernels, and kernel moisture content. The kernels in the samples are then tested for aflatoxin using the visual A. flavus method. Only groundnuts determined to have no aflatoxin using the visual A. flavus method can be shelled (Fletcher 2008). Lots that exceed the threshold for acceptable aflatoxin contamination—15 micrograms per kilogram (μg/kg) set by the USDA for human consumption—are rejected.

Shelled groundnuts are tested again for aflatoxin using chemical methods at USDA-approved labs, and the lots that exceed the threshold level are rejected. The contaminated nuts are usually pressed to obtain aflatoxin-free oil. The byproduct cake, however, would be contaminated. The cake is required to be detoxified through fermentation, ammoniation, or use of chemical solvents before being used in products such as animal feed or soil fertilizers. Regulations thus keep the contaminated material out of food systems.

The reason aflatoxin contamination does not attract significant public attention in Africa is that there is only limited awareness of its presence in food and of its consequences. There have been changes recently, however. In March 2011, African leaders asked the African Union to mainstream sanitary and phytosanitary issues in the Comprehensive African Agriculture Development Plan framework. The leaders also asked the African Union to establish an Africa-led Partnership for Aflatoxin Control in Africa (PACA). Launched in October 2012, PACA aims to provide leadership and coordination for Africa's aflatoxin-control efforts. However, PACA's activities of this partnership are in only the early stages of implementation.

Minimizing aflatoxin contamination in food and feed systems in developing countries is a challenge. An average Western consumer is unlikely to be aware of aflatoxin in foods or of its health effects, since regulations and their enforcement ensure that contaminated foods, including groundnuts and groundnut products, do not reach consumers. Stringent regulatory enforcement in developed countries drives the adoption of innovations to minimize contamination in both the production and the processing of crops susceptible to aflatoxin contamination. But in poorer countries, the necessary resources may not be available to put in place a sufficiently robust regulatory system for effective aflatoxin control. The Ghana Standards Board, for example, allows only up to 20 µg/kg of total aflatoxin contamination in in-shell or shelled groundnut kernels regardless of grade (Ghana Standards Board 2001). Specific grade requirements have not been established (Ghana Standards Board 2001, 2), likely because of the varietal differences. For example, kernel size varies in the three types of groundnut grown in Ghana (Bugla, Abain, and China), and the distinction is not clear because the certified (genetically uniform) groundnut seeds are unavailable to farmers. The processed groundnut products are to meet the EU maximum allowable limit of 4 µg/kg. But the enforcement of the existing standards is weak.

The transaction costs of enforcement of standards would be amplified in many African countries, relative to more developed countries, because most crop production in Africa is undertaken by numerous smallholders who would be beyond the reach of many regulatory bodies. Even if regulation would be feasible, there remains the question of whether producers can adopt available innovations to minimize contamination in crop production. In addition, removing aflatoxin-contaminated food from the system is an activity that would present its own unique set of challenges.

Objective and Methodology

The objective of this paper is to examine production and marketing practices, particularly grading methods, in Ghana's groundnut value chain to obtain a clear understanding of the sources and levels of aflatoxin contamination in the crop and how such contamination can be sharply reduced. The evidence generated through this study will then be used to contribute to the development of a strategy to minimize aflatoxin contamination in Ghana—one that might be appropriate for other developing countries in which vigorous regulation and control of aflatoxin is infeasible. As part of this study, we tested samples of groundnuts and groundnut products for their levels of contamination. Our tests covered groundnuts at varying degrees of processing. These ranged from raw, in-shell groundnuts from the previous year's crop to commercially processed and packaged groundnut products sold in local supermarkets. We also examined farmers' practices to achieve marketable quality, as well as the practices of other agents along the groundnut value change. Moreover, we examined the perceptions of these farmers and agents.

Our study is based on information we collected from questionnaires administered to 249 groundnut farmers, 22 wholesalers, 29 market vendors, and 30 cottage industry processors. Most of these people were in Ghana's northern region, the primary commercial groundnut production area in the country. The questionnaires were administered 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 farmers to be interviewed for the study from a list of all village farmers.

We selected wholesalers and vendors randomly for the interviews. Vendors included petty traders, mostly women who sell groundnut by bowls rather than by sacks, often in spaces belonging to their spouses or other traders who are engaged in wholesale trade. The main customers for the vendors are women who buy groundnuts to make paste. The selection of small-scale processors for the survey posed a challenge because only a small portion of them process groundnuts full-time. These processors were identified with the help of residents in selected neighborhoods and from randomly selected buyers of groundnuts.

The rest of the paper is presented in three sections. Section 2 offers a brief overview of aflatoxin and technologies available to control contamination at various stages. The findings from the Ghana survey are presented in Section 3. The last section offers a strategy that might be appropriate to Ghana and other similar developing countries.

2. AFLATOXIN AND ITS CONTROL

Aflatoxin is a secondary metabolite of the Aspergillus species of fungus, which is indigenous to soils in Ghana. Soil is the primary source of inoculum (Accinelli et al. 2008). 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 best when the temperature is between 18°C and 33°C and the relative humidity is greater than 50 percent. Ghana offers conditions suitable for fungal growth during most of the year. Although contamination is difficult to prevent, specific cultural and postharvest handling techniques can reduce the contamination. Delayed and incomplete drying of harvested groundnuts, which usually contain high levels of moisture, encourages fungal growth on the pods. The pods usually act as barriers to protect kernels from becoming contaminated, but not if they are stored for prolonged periods under conditions conducive for growth. A single contaminated pod can infect the entire batch, and as cross-contamination is rapid, groundnuts have to be handled carefully during storage and processing. When contaminated groundnuts are milled, the oil produced is aflatoxin free, leaving the metabolite in the cake. If this cake is used for food or animal feed, potentially harmful amounts of aflatoxin may be ingested.

Technologies are available to reduce Aspergillus infestation in the field and during storage. The international agribusiness firm Syngenta, for example, offers a biocontrol product known as Afla-guard® to manage aflatoxin in US groundnut fields. Afla-guard employs nontoxigenic strains of the fungus that can competitively exclude toxigenic strains from colonizing crops, reducing aflatoxin contamination by 70 to 90 percent (Dorner 2009). The product uses Aspergillus lines that are indigenous to the soil of a given country. In Africa, the International Institute of Tropical Agriculture, the Agricultural Research Service of USDA, and their partners have successfully adapted this competitive displacement technology to produce Aflasafe™. Aflasafe is a mixture of four native nontoxigenic strains of Aspergillus fungus for use on maize and groundnut fields in Burkina Faso, Kenya, Nigeria, and Senegal. With approval from national regulatory agencies, farmers have applied Aflasafe products to more than 3,000 hectares in those four countries. Product development is now under way in Ghana, Mozambique, Tanzania, and Zambia (Bandyopadhyay and Cotty 2013).

Introducing aflatoxin-resistant crop varieties is another technology that can reduce Aspergillus infestation. Breeding of aflatoxin-resistant lines is most advanced in maize. Several resistant maize genotypes have been identified through field screening, but these maize lines as yet do not generally possess commercially acceptable agronomic traits. Efforts continue in the breeding of aflatoxin-resistant varieties that would be more acceptable to consumers (Brown et al. 2013).

Good agricultural practices also can reduce the risk of contamination. Practices such as timely planting, maintaining optimal plant densities, and proper plant nutrition have been shown to reduce aflatoxin contamination. So has avoiding drought stress and controlling other plant pathogens, weeds, and insect pests (Dietzgen 1999). In the United States, aflatoxin contamination levels were shown to be reduced by 99 percent in irrigated and pesticide-treated maize compared to nonirrigated, nontreated maize (Wu and Khlangwiset 2010a).

Postharvest contamination can be reduced by sorting out physically damaged and infected kernels and grains. These can be identified by discoloration, small size, and odd shape. Removing these abnormal-looking kernels and grains can result in a 40 to 80 percent reduction in aflatoxin levels (Hell et al. 2011). In developed countries, mechanical blanching of groundnuts that removes the testa, or skin, followed by electronic sorting, can remove nearly all contaminated kernels.

Another technology is mechanical shelling of groundnuts. In some developing countries, the practice of watering the nuts to soften the shell for easier hand shelling is common. Unfortunately, it introduces moisture that promotes fungal growth on the kernels, exacerbating the problem of aflatoxin contamination. A number of organizations are developing cost-effective models to encourage mechanization of shelling (Emmott 2013).

Fumigation in storage using compounds such as ethylene oxide and methyl bromide has also been shown to significantly reduce the incidence of fungi. Another factor, smoking, has been shown to reduce infestation of harvested grain by fungi. In Nigeria, lower levels of aflatoxin contamination were observed in the stores of those farmers in Nigeria who use smoke to preserve their grain (Hell et al. 2011).

Finally, technologies are available to reduce the damage from consumption of contaminated foodstuffs. Additives such as NovaSil clay and chlorophyllin in food and feed reduce the uptake of aflatoxin by humans. In addition, administering hepatitis B virus (HBV) vaccine reduces aflatoxin-induced hepatocellular carcinoma by lowering HBV risk, thereby preventing the synergistic way that HBV and aflatoxin induce liver cancer (Wu and Khlangwiset 2010b).

Adoption of aflatoxin-resistant varieties, which may be no worse than current varieties in other attributes, appears to be the most practical control strategy for Africa, given that integrated control strategies may impose additional costs that smallholders may be reluctant to bear. However, development of aflatoxin-resistant varieties is a long and complex process that includes direct selection for resistance to fungus and aflatoxin accumulation and indirect selection for resistance or tolerance to biotic and abiotic stresses. Another part of the process is selection for morphological traits such as ear, kernel, and husk characteristics that impede or delay fungal introduction or growth. In addition, stress tolerance must be combined in new maize varieties with improved agronomic performance as low-yielding varieties will not be adopted. So far, aflatoxin-resistant breeds are in only various stages of testing (Bandyopadhyay and Cotty 2013).

Another strategy is the use of moisture-controlled drying and storage facilities that help reduce aflatoxin contamination in the postharvest period. Such a capital-intensive agricultural practice, however, often is too costly for African smallholder farmers and governments to adopt. Therefore, the challenge with controlling aflatoxins in African countries is to develop feasible control strategies that take into account the limited resources, limited institutional capacity, and reality of insufficient food in such countries.

3. GROUNDNUT VALUE CHAIN IN GHANA

Groundnut is an important cash crop in Ghana and an essential component of many Ghanaians' diets. Its production is estimated to have tripled between 1995 and 2005 (Yaw et al. 2008). In 2009, Ghanaian farmers produced nearly 500,000 metric tons of groundnuts (Ghana Statistical Service 2011). Groundnut is grown throughout the country but is most important in the two regions of the north, the northern and upper east regions, where about a fifth of farmers name groundnut as one of their two most important crops (Ghana Statistical Service 2011).

In 2000, national per capita groundnut consumption was estimated at 0.61 kg per week (Awuah et al. 2000). Nearly 80 percent of Ghanaians consume groundnuts or groundnut products at least once a week and 32 percent at least three times a week (Jolly et al. 2008) because groundnuts are an important source of protein. It is women, mostly, who informally process groundnuts on a small scale to supply groundnut paste. This paste is the intermediate product used in groundnut soup, which is a common dish in West Africa (Osseo-Asare 2002; Shanahan et al. 2003). Boiled and roasted groundnuts are also widely consumed.

Production and Postharvest

Production practices in Ghana make the crop vulnerable to infection with aflatoxin. Groundnuts are often intercropped with maize and also with cassava, millet, and sorghum. All of these crops are highly susceptible to aflatoxin contamination. Crops often go through drought stress since irrigation is virtually nonexistent in the northern regions of Ghana. Drought, especially in the latter stage of growth, makes groundnuts susceptible to aflatoxin contamination (Mehan et al. 1988). Disease and insect infestations occur when conditions are right and increase chances of aflatoxin contamination (Hell et al. 2000). One-third of 251 surveyed farmers reported using herbicides, but few of them take up measures to control pests and diseases. None of the farmers applied fertilizers, because they said groundnut-specific fertilizers were locally unavailable. Some indicated that fertilizers in general are expensive and that groundnuts can be produced without their application.

Some of the trading practices associated with groundnuts do reduce the spread of contamination. Traders do not buy groundnuts with high moisture content from farmers because they are aware of the risk of mold and discoloration. They also buy only shelled kernels so they can see their quality. Traders usually judge moisture content just by handling the kernels. Newly harvested groundnuts are difficult to sell; nearly 85 percent of the surveyed farmers did not sell immediately after harvest.

Producers store groundnuts at home, often under conditions that stimulate Aspergillus growth. They sell groundnuts as and when they need cash. An average farmer stores about 18 bags or nearly half a ton of groundnuts. They traditionally stored groundnuts in the shell in traditional storage structures known as pupuris, which allowed ambient air to circulate, potentially slowing the growth of Aspergillus. However, because of the increased incidence of produce theft from stores, most farmers now store groundnuts inside their homes in jute or polyethylene bags. If groundnuts are not dried properly to bring the moisture content to less than 12 percent, the heat and moisture generated in the bags encourages contamination. Ghana's specification for groundnuts establishes the in-shell groundnut moisture at 9 percent and 7 percent moisture level for kernels (Ghana Standards Board, 2001, 2). In addition, farmers often store groundnuts in bags that previously stored maize, rice, sorghum, beans, or cocoa. There is a high probability that these reused bags will be sources of contamination by Aspergillus spores (Awuah and Kpodo 1996; Hell et al. 2000). Wholesalers too typically keep their inventory in jute or polyethylene sacks. The sacks are kept in storage sheds that protect them from rain but do little to control temperature or relative humidity. Moreover, the groundnut stocks of wholesalers are particularly susceptible to contamination through the general practice of wholesalers' mixing smaller lots purchased from numerous suppliers, any one of which may be contaminated with aflatoxin.

Processing

Women process groundnuts on a small scale to sell as paste, typically as a part-time occupation. Nearly one-half of the women we interviewed processed groundnuts once or twice a week. Fewer than 10 percent of the interviewed women processed groundnuts daily. Typically, a woman processes 10 bowls of groundnuts at a time, which yields almost the same quantity of paste. She purchases groundnuts from women vendors, roasts the kernels lightly without removing the testa, and then has them ground at a neighborhood mill. Unfortunately, kernel discoloration, a reliable indicator of possible aflatoxin contamination, is not revealed when kernels are processed without removing the testa. Just a few aflatoxin-containing kernels can contaminate an entire batch of paste.

In the northern region, women press groundnuts at home to obtain oil. Retaining whatever they may need for home consumption, they sell the rest. The oil is often used to fry snacks made from the pressed groundnut cake. *Kulikuli*, the traditional snack made from the cake, is widely consumed. Crushed kulikuli, called *kulikuli sim*, is a popular condiment used to flavor grilled meats, roasted plantains, and soups. Better-off Ghanaians eat grilled meats, and people of all income levels eat roasted plantains and soups. To make paste or crush oil, the women often use damaged kernels or split ones. These are more likely to be contaminated by aflatoxin than are fully developed whole kernels, increasing the probability of aflatoxin presence in groundnut products.

Sorting for Quality

The quality attributes important to traders have the potential to eliminate contaminated kernels along the chain. Traders told us that they pay attention to three attributes: color, kernel size, and oil content (Table 3.1). All three groups of buyers pay the most attention to kernel color, which indicates the variety and any damage from mold. The traders generally do not know about the problem of aflatoxin. Nevertheless, their use of color as a quality measure helps control the amount of aflatoxin in the groundnut value chain as it eliminates at least a portion of potentially contaminated groundnuts from traded batches.

Table 3.1 Quality preferences for groundnuts at time of purchase, northern region (%)

Surveyed Group/ Attribute	Almost never	Seldom	Neither seldom not 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 authors' own survey results.
Note: Sums may not add to 100 percent due to rounding.

The cottage processors are the most discerning traders, but even these traders rarely remove sorted-out kernels from the food chain. Cottage processors said kernel size is also an important attribute they consider, but it appears to attract less attention than color because they do not regularly remove immature and undersized kernels. These are more likely to be contaminated by aflatoxin than mature, fully developed, and whole kernels. Market vendors sell raw shelled groundnuts that include various sized kernels.

Wholesalers sort their groundnuts only when time permits. Table 3.2 shows the frequency with which they undertake different sorting operations. The majority of them often or very often remove split (64 percent), broken (58 percent), discolored (59 percent), or damaged kernels (76 percent)—all possibly contaminated with aflatoxin. However, 20 to 33 percent of wholesalers seldom or almost never sort for such kernels. They appear to undertake sorting only when demanded by buyers. The absence of trading in well-defined grades of groundnuts permits contaminated kernels to remain in the food chain.

Table 3.2 Sorting and premarketing 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 authors' own survey results.
Note: Totals may not add up to 100 percent due to rounding. Dashes indicate that none of the respondents selected given option.

Cottage industry processors often consider the presence of split or broken kernels when assessing quality, but one-fifth of them almost never pay attention to these two attributes (Table 3.3). However, such processors frequently take account of kernel size. Skin color is the most considered attribute, and removal of discolored kernels certainly reduces the chances of aflatoxin contamination. However, removal of such discolored kernels was not done consistently.

Table 3.3 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 authors' own survey results.
Note: The sum may exceed 100 percent due to rounding. Dashes indicate that none of the respondents selected given option.

Table 3.4 shows the sorting procedures of processors. From the standpoint of reducing aflatoxin contamination, their sorting removes potential sources: discolored or *bad* kernels and ones damaged by insects or rodents. Heavy aflatoxin contamination can be detected visually in a batch of groundnuts, but to identify which of the pods are contaminated, each one has to be shelled, and the skin from each kernel must be removed. Current practice among cottage processors is to keep the skin with the kernels and grind them with the skin. The skin is retained if the roasting is light. Only some pieces of skin separate from the kernels and may be separated from the ground batch. Light roasting is a result of the desire to limit fuel use because fuel is expensive.

Table 3.4 Sorting procedures used by the surveyed cottage industry processors (%)

Sorting function	Almost never	Seldom	Neitherseldom 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	—	—	—	17	83
Remove kernels damaged by	3	3	—	17	77
Remove kernels I think are bad	—	—	—	17	83
Roast groundnuts	10	—	—	7	84

Source: Summary of authors' own survey results.
Note: The totals may exceed 100 percent due to rounding. Dashes indicate that none of the respondents selected given option.

To make things worse, even when contaminated groundnuts are removed from a batch, they remain in the food chain. This is because farmers use the removed groundnuts for food or feed. Table 3.5 shows that more than half of wholesalers sell the rejects, while traders or vendors sell them or grind them into paste.

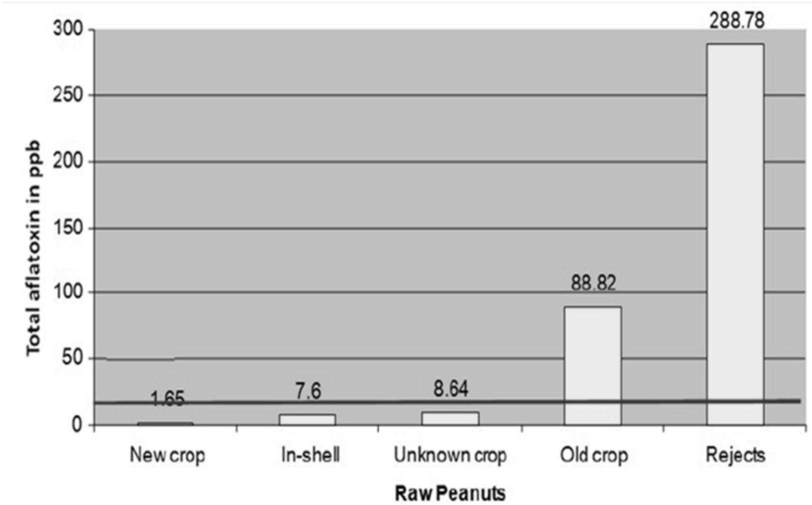
Table 3.5 Disposal of rejected kernels by wholesalers and cottage industry processors (%)

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

Source: Summary of authors' own survey results.
Note: Dash indicates that none of the respondents selected given option.

Moreover, and unsurprisingly, despite the various degrees of sorting, the groundnuts that reach the market still contain aflatoxin in amounts exceeding allowable limits. Aflatoxin contamination of food has been a persistent problem in Ghana. A survey in the early 1960s showed high contamination in 69 percent of tested samples (Bearwood 1964). For the current study, we obtained groundnut and groundnut product samples from farmers, wholesalers, vendors, cottage processors, hawkers, and supermarkets. All samples (70 total) were tested for total aflatoxin content by a commercial laboratory in the United States. The sample size was a standard volume consisting of about two handfuls of groundnuts. As expected, the groundnuts that were stored longer or had gone through processing had higher levels of contamination (Figures 3.1 through 3.3).

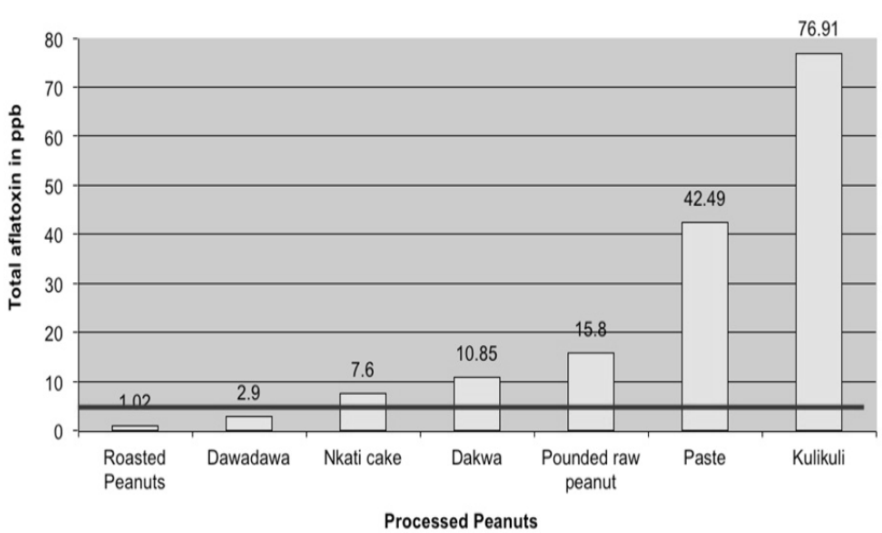
Figure 3.1 Average total aflatoxin content in raw groundnuts



Source: Results based on self-collected samples

Note: The EU limit in processed food products, shown in red, is 4 micrograms per kilogram. The line shows the 15 micrograms per kilogram limit, the maximum allowable content of aflatoxin in groundnuts exported to the EU.

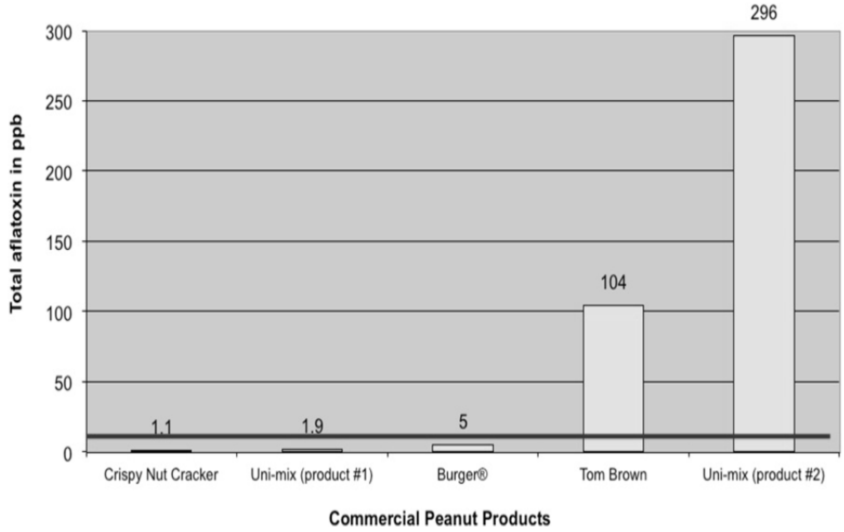
Figure 3.2 Average total aflatoxin content in cottage industry processed groundnut products



Source: Results based on self-collected samples

Note: The EU limit in processed food products, shown in red, is 4 micrograms per kilogram.

Figure 3.3 Average total aflatoxin content in manufactured groundnut products



Source: Results based on samples collected by authors.
Note: The EU limit in process food products, shown in red, is 4 micrograms per kilogram.

The test results reflect the natural process of Aspergillus contamination of groundnut shells, which may begin in the soil prior to harvest. For the fungus to grow and produce aflatoxin in detectable amounts, Aspergillus requires the proper combination of moisture and temperature. The new crop of groundnuts (groundnuts harvested at the beginning of August 2010), contained low, allowable levels of aflatoxin, that is, less than the 15 µg/kg limit for EU-destined groundnuts, according to tests of samples collected in this study (Figure 3.1). However, between harvests, the contamination level of stored groundnuts rose with time and significantly exceeded the allowable level. The highest levels of contamination were found in rejected kernels (288.78 µg/kg) purchased at one of the Accra markets. The rejects included discolored, molded, or split kernels sorted out of a batch of raw groundnuts marketed by one of the vendors.

Levels of contamination varied among the processed products sold by cottage industries (Figure 3.2). It was not surprising to observe unacceptably high contamination of groundnut paste (on average, 42.49 µg/kg, about 10 times higher than the threshold for entry to the EU). Moreover, very high average contamination was found in kulikuli, 76.91 µg/kg. Compromised kulikuli is why the poor are not the only Ghanaians who consume high levels of aflatoxin-contaminated groundnut. Better-off Ghanaians also consume high levels because of the kulikuli or kulikuli sim in the prepared meat dishes they favor. The test results of commercially produced products revealed no particular pattern of contamination (Figure 3.3). 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

Although Ghana has standards that are as stringent as those of the EU, informal processing of groundnuts makes their enforcement infeasible. The cottage processing industry, which does not package its products, escapes these regulations. Although these regulations apply to commercially packaged groundnut products, our testing showed that aflatoxin contamination in such products significantly exceeded the allowable threshold of 4 µg/kg permitted in the EU. This was true even in manufactured products packaged in moisture-barrier materials. Large international food corporations active in Ghana apply the EU standards for allowable aflatoxin content (S. Affrifah, personal communication 2011) although the published standards permit higher levels. Such an approach is precautionary, but it signals safety expectations to public and private entities.

Testing for aflatoxin is expensive, and Ghana does not have commercial laboratories capable of conducting the tests. While government research institutions or the leading universities have the expertise and equipment, small groundnut processors cannot afford the $100 cost of a single test. Even commercial manufacturers might find this cost prohibitively expensive if they were required to test each batch they produce.

None of the traders or processors whom we interviewed mentioned using official standards for grading groundnuts in their trade or marketing practices. In fact, none of them were aware of the existence of such standards. US standards for shelled groundnuts, for example, specify the percentage of allowable damaged, split, or undersized kernels. As such substandard groundnuts are all the more likely to be aflatoxin contaminated than are whole, mature kernels, such standards serve to limit aflatoxin contamination in the US groundnut value chain. Ghana's published standards (Ghana Standards Board 2001) did not provide specifics for grades, indicating that they were under development. Absence of foreign matter is specified, and aflatoxin level is indicated at 20 µg/kg. The latter is the most important because most groundnuts in Ghana are processed into paste or meal and safety is more important than a specific grade given their utilization.

Awareness of Aflatoxin

Awareness of the health effects of aflatoxin-contaminated food is low among the public in Ghana. However, there are occasional panics about aflatoxin. In 1998, a front-page newspaper article led to public panic by reporting that *kenke*, a common maize-based food, contained aflatoxin and caused cancer (Plange 1999). However, after emotions subsided, the issue of aflatoxin in food was sidelined and received little public attention.

Moreover, 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 allocating resources to reduce contamination, but they are unaware of the extent of aflatoxin's economic and health risks (Hendrickse 1999). Moreover, even if the knowledge exists, these professionals may assign aflatoxin a low priority, as might policymakers and government officials, given the range of other more pressing issues they need to address.

Moreover, awareness itself may not suffice. For example, Wu and Khlangwiset (2010b) view awareness and education among farmers, government functionaries, and the public as crucial to allocating finances to fight aflatoxin. Knowledge itself is not adequate to make policymakers take measures to control aflatoxin (Jolly et al. 2009). Reports on aflatoxin contamination in Ghanaian and West African foods have been available for decades (Awuah et al. 2008).

4. CONTROL STRATEGIES

In developed countries, stringent enforcement of regulations backed by advanced sorting and testing processes and repeated testing drive innovations to control aflatoxin contamination during crop production and storage. This control takes place without consumer awareness of the risks from aflatoxin. The cost of such regulation would be prohibitive for a developing country such as Ghana. This is particularly so because groundnuts are produced by numerous smallholders, traded at hundreds of places, processed informally in all communities, and served up for consumption in all eating establishments. Technologies that have been developed in wealthier countries also would have limited adoption in Ghana. This would be the case even if these technologies were to become available, unless there is a way to ensure that producers and traders emerge no worse off in terms of gross revenues. If such controls were to add to costs, producers and traders would have incentives to adopt them only in the presence of regulatory enforcement or a premium on quality.

Producers, traders, and processors sort for defective groundnuts to eliminate kernels that might be infected, but not to the degree necessary to bring aflatoxin contamination down to acceptable levels. Even if sorting were to take place to fully remove the infected kernels, the rejects re-enter the food chain because they are sold at a discount to be ground and then used in various products. These are all critical differences from the situation in developed countries, where contamination is eliminated by strict enforcement of regulations.

While Ghana has regulations on aflatoxin contamination that are consistent with international standards, enforcement is limited only to commercial processors, if at all. This leaves the vast informal sector unregulated. To regulate the sales at numerous open-air markets, street stalls, or mobile hawkers is virtually impossible. Existing aflatoxin testing facilities are few, and testing charges are high.

A strategy appropriate for minimizing aflatoxin contamination in Ghana needs to take several factors into consideration. These are the costs of enforcing regulations, the burden those regulations may place on various agents in the value chain, and consumer willingness to pay for products free from contamination. There are options available in two broad categories:

- ***Consumer driven:*** The first would be a market-based approach in which contamination is minimized because of consumer demand. This would necessarily entail consumers' willingness to pay for products with acceptable levels of contamination. Consumers in the North Rift and the Eastern Provinces of Kenya, for example, were willing to pay a premium for clean and aflatoxin-tested maize. Their willingness was positively influenced by consumer income and negatively influenced by consumer age (Walker and Davies 2013). However, this strategy entails consumer education and appropriate testing and labeling of products, as consumers cannot visually assess the quality. To the extent that some consumers are willing to risk buying and eating contaminated kernels and even rejects, this approach would not reach all consumers.

- ***Regulation driven:*** The second option would be to use regulations to drive innovations among various actors in the groundnut value chain to minimize contamination or bring it down to publicly acceptable levels. Consumer awareness is not necessary, but regulations would be accepted if they did not place undue burden on any actors in the value chain, including consumers.

Approaches based on willingness to pay would benefit only a small portion of the consumers, but they could offer a price premium for producers and processors of aflatoxin-free material. The assumption is that it would be difficult to create awareness among the entire population and that most people would not change their groundnut consumption behavior because the bad health effects of aflatoxin contamination are not immediately apparent. The willingness to pay on the part of a small portion of consumers, however, needs to be channeled into the development of products and the emergence of processors to supply those aflatoxin-free products. Ideally these processors can offer incentives upstream to reduce contamination. This is essential to sustain grading practices and to influence the behavior of traders and producers. At the other end of the consumer spectrum, the challenge is to persuade retailers and informal processors to remove contaminated products from the food chain (Table 4.1).

Table 4.1 Groundnut value chain participants and factors that might offer them incentives to supply aflatoxin-free groundnut products

Actors	Desired behavior	Some of the disincentives	Intervention
Consumers	• Reject products that are contaminated with aflatoxin	• A small section that could be persuaded to pay for aflatoxin-free products does not have the opportunity • The remaining will continue to consume because they are not convinced of the health effects, their economic considerations, or both	• Introduce aflatoxin-free products and market development-oriented awareness
Formal processors	• Not to process aflatoxin- contaminated raw material • Take advantage of willingness to pay for aflatoxin-free products	• They will continue to process as before unless regulated • They will likely cease production if it is not viable for them to meet the regulatory requirements	• Provide formal processors with assistance (market development and establishment of aflatoxin-free supply chains) to develop aflatoxin-free products
Informal processors	• Take groundnut rejects out of the food system	• They will not do so unless regulated or consumers begin to question the quality of groundnuts that go into products such as paste	• Develop schemes to purchase rejects and turn them into products safe for the livestock sector, for example, establishing enterprises that buy sorted-out groundnuts to produce safe products for the animal and poultry industries
Traders	• Grade, offer premium for higher quality kernels, and dispose of sorted-out groundnuts	• They will do so only if a premium is offered downstream for aflatoxin-free groundnuts	• Introduce a market for graded groundnuts through formal processors • Train traders in sorting and the use of moisture meters
Producers	• Adopt production and storage practices that reduce contamination	• They will do so only if offered higher prices or if their outputs are rejected; in the case of the latter, if there are no feasible technical options they will withdraw from groundnut production	• Create a market for graded groundnuts • Provide access to and information about technologies to meet the demands downstream for contamination-free raw material • Introduce technologies that make producers no worse off economically, while minimizing contamination

Source: Authors.

One point of entry would be to begin where regulation enforcement is feasible, which is among formal processors. Depending on whether they already adhere to existing regulations, they could be encouraged to develop products the price for which may require a premium from consumers to be viable for manufacturers. However, they may need to be subsidized by the government initially, as the costs of fully complying with the regulations might be more than what the consumers may be able to bear, putting at risk the businesses of these producers of aflatoxin-free groundnut products. In Ghana, for example, processors may have to discard 25 percent of the kernels from groundnuts purchased in wholesale markets, thus increasing costs significantly. 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.

Formal processing and marketing units may have the opportunity to pass on the costs of meeting the quality requirements to consumers of their products. They might be able to create a niche for their products in the domestic market or to enter global markets, taking advantage of the willingness of discerning consumers to pay for aflatoxin-safe products. These products might also meet the import requirements within West Africa as well as the lucrative markets of the EU and the United States. Both are home to a large diaspora of Ghanaians and West Africans, a natural market niche.

These commercial units may be assisted by an aflatoxin-control initiative in a number of ways to encourage the development of products. One of them could be to help develop an aflatoxin-free value chain; another way could be to help product and market development, which would serve the public purpose of generating awareness. The units could be trained by the initiative to remove contaminated groundnuts from the food chain through the application of simple and inexpensive techniques that involve presorting and in-process sorting on premises (Lustre et al. 2007). Presorting involves the removal of visibly damaged kernels with skin still attached, such as kernels with insect or rodent damage. Once these kernels were removed and the remaining kernels were blanched, the process would focus on the removal of other visibly damaged kernels.

What the processing plants would do with kernels that have been sorted out remains a question. They could extract oil from them but would still have the incentives to release the cake into the food chain. For example, the United States, which produces about 100,000 tons of groundnut oil cake per year (Gray 2012), still limits the use of groundnut cake to feed and fertilizer markets, as the material contains high aflatoxin concentrations. Additional incentives are needed to persuade processors to push oil cakes out of the food system.

The feasibility of establishing enterprises that buy sorted-out groundnuts to produce safe products for the animal and poultry industries needs to be considered. This is especially true given the need to take sorted-out groundnuts not only from formal processors but also from informal processors, who have even less incentive to take them out of the food chain. This could be done eventually by formal processing units. The viability of such an enterprise would depend on the extent to which grading would take place and the price of groundnuts. Viability would also depend on access to and cost of technologies to turn cake into safe product and the market for such products.

The introduction of low-cost testing facilities is an obvious and necessary complementary step. Current testing using high-performance liquid chromatography equipment to measure contamination is not necessary for regulatory purposes, because all that is required to meet the regulations is to be within the threshold limits for total aflatoxin. There is an opportunity for the private sector to answer the need for rapid testing methods that can robustly assess whether the aflatoxin level in a batch of groundnuts or a groundnut product is too high. The rapid testing procedure could more than halve the current costs of about $100 per test.[1] The technology for this procedure should also include moisture meters. The fact that

[1] Personal information obtained from the Food Research Institute, Council of Scientific and Industrial Research, Accra, Ghana, in January 2012.

commercial processors will accept only groundnuts that meet a specific moisture content could encourage good drying practices by smallholders (Emmott 2013). The National Smallholder Farmers' Association of Malawi and Twin, the alternative trading company based in the United Kingdom, are piloting a buying system in which smallholders receive a bonus for selling groundnuts with low moisture content.

Having met the quality requirements, the commercial units involved would signal stakeholders upstream to supply aflatoxin-free material. The units might possibly offer a premium, depending on the competitiveness of locally produced nuts. The focus on aflatoxin reduction is of foremost importance, and the absence of specified grades in terms of kernel number per standard unit of weight, a variety-specific trait, is of secondary importance. Training programs in grading and sorting for traders who supply commercial processors would serve as a subsidy for the processing firms and traders. The training would, 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 would eat safer products, thus improving their health. Through the agricultural extension service, information could be made available to producers about safer methods of production and storage.

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. Then, over time, consumers will become more selective about purchasing groundnut products.

Interventions therefore would include support to formal processors to develop aflatoxin-free products for niche markets. This support would entail market development, stringent regulation, and certification of products from formal processing. It would also entail development of testing facilities, training of traders engaged in formal processing supply chains, and piloting of processing centers in smaller towns. These processing centers would purchase rejects for producing feed for animals or poultry. This means that multiple approaches are required to begin to introduce products that are free from contamination. These various approaches complement each other. Some interventions may trigger changes that make other interventions more effective. Therefore, one needs to consider pathways of change that can be expected from different interventions, along with their costs and feasibility. Moreover, the interventions may need to be sequenced. This would reduce implementation costs and enhance the benefits of the interventions by building on the secondary changes that some interventions are capable of generating.

REFERENCES

Accinelli, C., H. K. Abbas, R. M. Zablotowicz, and J. R. Wilkinson. 2008. "Aspergillus Flavus Aflatoxin Occurrence and Expression of Aflatoxin Biosynthesis Genes in Soil." *Canadian Journal of Microbiology* 54: 3379.

Awuah, R. T., and K. A. Kpodo. 1996. "High Incidence of Aspergillus flavus and Aflatoxins in Stored Groundnut in Ghana and the Use of Microbial Assay to Assess the Inhibitory Effects of Plant Extracts on Aflatoxin Synthesis." *Mycopathologia* 134: 109–114.

Awuah, R. T., O. Kwaku, S. Agyemang, C. Fialor, and C. M. Jolly. 2000. "Aflatoxigenic Fungi and Aflatoxin Contamination of Groundnut and Groundnut-based Products in Ghana: Implications and Concerns." In Proceedings of a National Workshop on Groundnut and Groundnut Aflatoxins, 19—21 September 1999, edited by R. T. Awuah and W. O. Ellis, 17–26. Kumasi, Ghana: Kwame Nkrumah University of Science and Technology.

———. 2008. "Are Ghanaians Aware of Aflatoxin Menace?" In Mycotoxins: Detection Methods, Management, Public Health and Agricultural Trade, edited by J. F. Leslie and A. Visconti, 327–334. Cambridge, MA, US: CAB International.

Bandyopadhyay, R., and P. J. Cotty. 2013. *Biological Controls for Aflatoxin Reduction.* 2020 Focus Brief 20(16). Washington, DC: International Food Policy Research Institute.

Bandyopadhyay, R., P. J. Cotty, M. Kumar, and J. F. Leslie. 2007. "Relative Severity of Aflatoxin Contamination of Cereal Crops in West Africa." *Food Additives and Contaminants* 24 (10): 1109–1114.

Bearwood, C. J. 1964. "Detection of Aflatoxin in Groundnut in Accra." *Ghana Medical Journal* 3: 87–88.

Brown, R. L., D. Bhatnagar, T. E. Cleveland, Z. Chen, and A. Menkir. 2013. "Development of Maize Host Resistance to Aflatoxigenic Fungi." In Aflatoxins: Recent Advances and Future Prospects, edited by M. R. Mehdi. Rijeka, Croatia: InTech.

Dietzgen, R. G., Queensland Department of Primary Industries, and Institut Pertanian Bogor. 1999. "Elimination of Aflatoxin Contamination in Peanut: A Collaborative Workshop Project between the Queensland Department of Primary Industries and Australia and Bogor Agriculture University, Indonesia." ACIAR Proceedings 89. Canberra: Australian Centre for International Agricultural Research.

Dorner, J. W. 2009. "Development of Biocontrol Technology to Manage Aflatoxin Contamination in Peanuts." *Peanut Science* 36(1): 60-67.

Emmott, A. 2013. *Market-led Aflatoxin Interventions: Smallholder Groundnut Value Chains in Malawi*. 2020 Focus Brief 20(8). Washington, DC: International Food Policy Research Institute.

Fletcher, M. S. 2008. A Feasibility Analysis of the Peanut Grading System and Potential Impact of Alternative Systems on the US Peanut Industry. Washington, DC: USDA Federal-State Marketing Improvement Program.

Ghana Standards Board. 2001. Nuts—Specification for Groundnut. GS 313: 2001. Accra, Ghana.

Gray, N. 2012. Enzyme Technology May Provide Value-added Extracts from Peanut Waste. Food Navigator. Accessed July 30, 2014. www.foodnavigator.com/Science-Nutrition/Enzyme-technology-may-provide-value-added-extracts-from-peanut-waste.

Hell, K., K. F. Cardwell, M. Setamou, and H. M. Poehling. 2000. "The Influence of Storage Practices on Aflatoxin Contamination in Maize in Four Agroecological Zones of Benin, West Africa*." Journal of Stored Products Research* 36: 365–382.

Hell, K., K. F. Cardwell, M. Setamou, H. M. Poehling, and C. Mutegi. 2011. "Review: Aflatoxin Control and Prevention Strategies in Kenya Crops of Sub-Sahara Africa." *African Journal of Microbiology Research* 5 (5): 459–466.

Hendrickse, R. G. 1999. "Of Sick Turkeys, Kwashiorkor, Malaria, Perinatal Mortality, Heroin Addicts and Food Poisoning: Research on the Influence of Aflatoxins on Child Health in the Tropics." *Annals of Tropical Paediatrics* 19 :229–235.

Jolly, C. M., B. Bayard, R. T. Awuah, S. C. Fialor, and J. T. Williams. 2009. "Examining the Structure of Awareness and Perceptions of Groundnut Aflatoxin among Ghanaian Health and Agricultural Professionals and Its Influence on Their Actions." *Journal of Socio-economics* 38: 280–287.

Jolly, C. M., B. Bayard, R. T. Awuah, S. C. Fialor, J. T. Williams, R. T. Awuah, S. C. Fialor, K. O. Agyemang, J. M. Kagochi, and A. D. Binns. 2008. "Groundnut Consumption Frequency in Ghana." *International Journal of Consumer Studies* 32:675–686.

Lustre, A. O., L. S. Palomar, M. L. Francisco, and A. V. A. Resurreccion. 2007. Impact Assessment of the Peanut CRSP Project in the Philippines, Part 2. USA-Philippines Monograph Series No. 9. Griffin, GA, US: University of Georgia, US Agency for International Development—Peanut Collaborative Research Support Program.

Mehan, V. K., R. C. Nageswara Rao, D. McDonald, and J. H. Williams. 1988. "Management of Drought Stress to Improve Field Screening of Peanuts for Resistance to Aspergillus flavus." *American Phytopathological Society* 78 (6): 659–663.

Osseo-Asare, F. 2002. "We Eat First with Our Eyes." *Gastronomica* 2 (1): 49–57.

Otsuki, T., J. S. Wilson, and M. Sewadeh. 2001. "Saving Two in a Billion: Quantifying the Trade Effect of European Food Safety Standards on African Exports." *Food Policy* 26 (2001): 495–514.

Plange, P. K. 1999. Fufu, Gari Can Also Cause Cancer—Food Research Inst. Ghana Chronicles. Access July 30, 2014. www.modernghana.com/news2/7772/4/mr-ibu-is-champion-sportsman.html.

Shanahan, H., A. Carisson-Kanyama, C. Offei-Ansah, M. P. Ekström, and M. Potapova. 2003. "Family Meals and Disparities in Global Ecosystem Dependency—Three Examples: Ghana, Russia and Sweden." *International Journal of Consumer Studies* 27 (4): 283–293.

Turner, P. C., A. Sylla, M. S. Diallo, J. J. Castegnaro, A. J. Hall, and C. P. Wild. 2002. "The Role of Aflatoxins and Hepatitis Viruses in the Etiopathogenesis of Hepatocellular Carcinoma: A Basis for Primary Prevention in Guinea–Conakry, West Africa." *Journal of Gastroenterol Hepatology* 17 (suppl.): S441–448.

USDA (United States Department of Agriculture), National Agricultural Statistics Service. 2014. Crop Production 2013 Summary. Accessed July 28, 2014. http://usda01.library.cornell.edu/usda/current/CropProdSu/CropProdSu-01-10-2014.pdf.

Wagacha, J. M., and J. W. Muthomi. 2008. "Mycotoxin Problem in Africa: Current Status, Implications to Food Safety and Health and Possible Management Strategies." *International Journal of Food Microbiology* 124:1–12.

Walker, S., and B. Davies. 2013. *Farmer Perceptions of Aflatoxins: Implications for Interventions in Kenya*. 2020 Focus Brief 20(7). Washington, DC: International Food Policy Research Institute.

Williams, J. T., T. D. Phillips, P. E. Jolly, J. K. Stiles, C. M. Jolly, and D. Aggarwal. 2004. "Human Aflatoxicosis in Developing Countries: A Review of Toxicology, Exposure, Potential Health Consequences and Interventions 1'2'3." *American Journal of Clinical Nutrition* 80 (5): 1106–1122.

Wu, F., and P. Khlangwiset. 2010a. "Costs and Efficacy of Public Health Interventions to Reduce Aflatoxin-induced Human Disease." *Food Additives and Contaminants* 27 (7): 998–1014.

———. 2010b. "Evaluating the Technical Feasibility of Aflatoxin Risk Reduction Strategies in Africa." *Chemistry, Analysis, Control, Exposure and Risk Assessment* 27 (5): 658–676.

Yaw, A. J., R. Akromah, O. Safo-Kantanka, H. K. Adu-Dapaah, S. Ohemeng-Dapahh, and A. Agyeman. 2008. "Chemical Composition of Groundnut, Arachis hypogaea (L) Landraces." *African Journal of Biotechnology* 7 (13): 2203–2208.

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