Aflatoxin Contamination and Potential Solutions for Its Control in Nigeria
A summary of the country and economic assessment conducted in 2012 and the aflatoxin stakeholder workshop held on November 5 and 6, 2012 in Abuja

What are aflatoxins and how do they occur?
Aflatoxins are naturally occurring toxins produced by certain fungi: mainly Aspergillus flavus and Aspergillus parasiticus. Several types of aflatoxins (B1, B2, G1, and G2) are produced by these fungi. The B1 form is recognized by the International Agency for Research on Cancer as one of the most naturally occurring toxic and carcinogenic substances found in nature.1 These aflatoxin-producing fungi can contaminate several dozen food commodities, including many of Africa’s important staple crops: maize, sorghum, millet, rice, oilseeds, spices, groundnuts, tree nuts, and cassava.2 Countries such as Nigeria that are located between 40°N and 40°S latitude offer suitable growing conditions for the fungi. Since Aspergillus spp. originates in the soil, the biochemical risk of aflatoxin contamination begins with planting, and can be worsened later through inappropriate harvesting, handling, storage, processing, and transport practices. Contamination during crop development and after harvest depends on environmental conditions that are optimal for the growth of fungi. Damage by pests (birds, mammals, and insects) or the stress of hot, dry conditions can contribute to significant Aspergillus infection. Drought stressors (elevated temperature and low relative humidity) increase the number of Aspergillus spores in the air, increasing the chance of contamination. Heavy rain can cause spores to splash onto fruit and grain. After harvest, high crop moisture coupled with warm temperatures, inadequate drying and poor storage can further increase the risk of contamination.

What are the adverse impacts of aflatoxin contamination?
Aflatoxin contamination can affect the entire supply chain for susceptible crops. Control measures (or their absence) taken along the supply chain can directly affect the availability of aflatoxin-free crops to households for both their own consumption and for sale to the consuming public. The sum total of action and inaction can impact all four pillars of food security: availability of food, access to food (by affecting incomes), utilization of food (by affecting what households consume), and stability (in terms of continuity of safe food supply as well as associated price determination).

Aflatoxin contamination impacts three sectors: agriculture, trade, and health. If crops with very high levels of aflatoxin contamination are consumed by humans, poisoning (i.e., aflatoxicosis) and even death can occur. Chronic exposure to low levels of contamination in crops consumed regularly increases liver cancer risk and can suppress the immune system, particularly for populations that test positive for the hepatitis B virus (HBV). Aflatoxins can also enter the human diet through livestock products if the

livestock are given contaminated feed. Children can be affected through breast milk or direct consumption of weaning foods.  

Aflatoxin contamination can also lead to rejection of specific export shipments and increased inspection and sampling rates. If plant quarantine authorities perceive the contamination as chronic, they can curtail the right of countries to export susceptible products. These effects on trade result in lost revenues. Economic losses to producers and traders can also occur in the domestic market if either consumer awareness about the problem rises, leaders in marketing channels begin to pay more attention, or regulations are tightened or more strictly enforced. Thus, aflatoxin contamination can adversely affect both individual livelihoods and agricultural sector output. 

**Aflatoxins disproportionately impact women and the poor.** Food-insecure households are more likely to consume contaminated food rather than sell it at lower prices or discard it. The poor may also not be able to adopt costly control strategies. Even a well-intentioned awareness campaign can reduce prices for aflatoxin-contaminated food, resulting in direct market losses for the poor and more severe health impacts because of farmers’ own consumption of low-price-yielding, contaminated grain. Women are also less likely to have access to information and resources for aflatoxin control and mitigation. Lack of decision making power with women may inhibit adoption of mitigation strategies even if information and resources are not a constraint.

**How prevalent is aflatoxin contamination in Nigeria?**

The Standards Organization of Nigeria (SON) sets standards on many food commodities, taking into account global standards as well as national production and target export markets. While it is generally recognized globally that there is no “safe” level of aflatoxin exposure, SON has set the maximum acceptable limit for maize grain at 4 ppb for total aflatoxins and 2 ppb for B1.  

The groundnut seed standard is 20 ppb, while the standard for the commonly eaten groundnut cake snack known as *kulikuli* has a total aflatoxin standard of 4 ppb and an aflatoxin B1 standard of <2 ppb.

Due to the financial resources, equipment, and skilled diagnostic capacity necessary for appropriate aflatoxin detection, testing is limited within Nigeria. Additionally, because testing is typically performed only in areas of suspected contamination, there is a reporting bias in available studies. Among staple cereals in the Nigerian diet, maize has the highest levels of aflatoxin contamination. There is also evidence of high levels of contamination in Nigerian groundnuts. Over the past 5 years, there were 12 published studies assessing aflatoxin prevalence in Nigeria (7 assessing aflatoxin prevalence in maize and 5 assessing prevalence in groundnuts). The evidence does suggest that aflatoxin contamination in Nigeria warrants attention.

**Aflatoxin contamination of key staples—maize, groundnuts—is above regulated levels for both total aflatoxins and B1 in many parts of Nigeria.** A summary of the published studies reveals:

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3 There is also some evidence to suggest that aflatoxin exposure can affect child stunting and lead to greater susceptibility or exacerbation of symptoms associated with human immunodeficiency virus (HIV), tuberculosis, and malaria.

4 The weight of one microgram per kilogram is proportional to the weight of one grain of rice in a 50 kg bag. The level of contamination of aflatoxins is measured in parts per billion or micrograms per kilogram, often denoted as ppb or µg/kg.


In maize, mean concentrations of B1 ranged from 0 and 299 ppb, though one sample detected a mean of 2,433 ppb in maize-based, infant weaning food, which is of concern given the importance of good nutrition from conception to 2 years.

Contamination was found in pre-harvested maize, stored maize, prepared weaning foods, freshly harvested maize, prepared gruel, and corn snacks in six of Nigeria’s seven agro-climatic zones.

Five published studies assessing aflatoxin contamination in groundnuts reported means for total aflatoxins (including B1) ranging from 20 ppb to as high as 64,520 ppb.

Of the four samples that assessed B1 contamination in groundnuts, levels ranged from 0 to 2,820 ppb.

Aflatoxin contamination was reported among samples of roasted, boiled, and raw groundnuts, as well as groundnut cake (kulikuli).

The geographic breakdown of the available published data is shown in Figure 1. The published data however only reveal a snapshot of aflatoxin levels in one moment of time. As the data are limited, they cannot predict geographic susceptibility to aflatoxins, but do provide evidence to support the need for a national prevention, mitigation and control strategy.

**How serious are the risks of aflatoxin exposure in Nigeria?**

The economic and country assessment conducted in 2012 by Abt Associates in collaboration with representatives of the Mycotoxicology Society of Nigeria (MYCOTOXSON) and Nigeria’s National Agency for Food and Drug Administration and Control (NAFDAC) concluded that the largest impact of aflatoxins in Nigeria is on health, especially human. The assessment found little awareness about aflatoxins among farmers, rural traders, and consumers. Despite aflatoxin standards, unpackaged food and found bound for domestic consumption are not regulated. This means that aflatoxin-contaminated grain can easily enter the Nigerian consumption stream.

**Risk Characterization for Agriculture and Food Security**

Aflatoxin contamination can reduce the volume, value, and availability of safe, locally produced, or imported food. However, because aflatoxin contamination often does not cause visible damage to the crop, the perceived impact of aflatoxin contamination on agriculture and food security has so far been negligible. The market does not differentiate between aflatoxin-free and aflatoxin-contaminated food; therefore farmers do not incur any costs for mitigating aflatoxins. This in turn results in increased risk that aflatoxin-contaminated grains leave the farmers’ fields and enter the food and feed supply.

The lack of awareness among growers and buyers, combined with the often unobservable effects of aflatoxins, make it very difficult to incentivize and inform farmers of the risks associated with aflatoxins. Farmers are not aware of aflatoxins, nor of measures to control aflatoxins in the field, which begin with good agricultural practices (GAP). There is no set “agenda” for agricultural extension messaging about GAP and food safety that includes aflatoxins. Farmers rarely incur losses for aflatoxin-contaminated grain (or realize premiums for aflatoxin-free grain) due to lack of trader and consumer awareness.

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Aflatoxin-mitigating measures are not routinely practiced in Nigeria (except by some suppliers to the animal feed industry or certain exporters of groundnuts). Many farmers carry out basic sorting and culling of visibly damaged and moldy crops in order to realize the price premium associated with cleaner and unspoiled, dryer maize and groundnuts, but such practices cannot guarantee aflatoxin reduction.

Drying of maize, groundnuts, and other crops is typically done on the ground, although there is some evidence of use of brick and mud structures that are above the ground. Storage units are often self-made, and commodities are stored without means of monitoring the temperature and humidity of such local storage units. Despite efforts on the part of the Nigeria Stored Products Research Institute, there is little use of improved storage due to perceived and real lack of affordability.

Since healthy plants can better resist disease, the use of irrigation, fertilizers, and crop protection chemicals also matters in aflatoxin control. Yet only 2 percent of the area cultivated under maize is irrigated, and the area irrigated for groundnuts is negligible. Nationally, 20 percent of agricultural households use fertilizer for maize, and 6 percent use it for groundnuts. Six percent of households use pesticides for maize, and 2 percent use them for groundnuts; use of improved seeds is 10 percent for maize and 2 percent for groundnuts.\(^1\)

**Risk Characterization for Domestic and International Trade**

Nigeria’s NAFDAC enforces commodity standards and does laboratory testing to detect aflatoxins. However, this is only done for packaged foods and foods bound for the formal export market. The vast majority of foods consumed by the Nigerian population are not regulated for aflatoxins. Field research conducted by Abt Associates in the Niger, Kogi, and Ondo states found no evidence of testing for aflatoxins in the domestic maize and groundnut markets in Nigeria. Consequently, aflatoxin-contaminated grain can enter the domestic markets and the informal international markets (e.g., Chad and Niger for maize) due to low awareness about aflatoxins and their health impact among consumers and sellers.

There are no regulations governing aflatoxins in animal feed. However, some medium- and large-scale commercial growers of maize and groundnuts, as well as animal and fish feed markets, are vigilant about aflatoxin levels in the feeds due to observable effects of aflatoxins on animals (e.g., negative impacts on productivity and reproduction in poultry, even sudden death). Some of the large-scale livestock growers

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have access to diagnostic equipment, and have been able to confirm aflatoxins as an underlying cause of the lack of growth, productivity, and health of the animal. Many of the bigger medium- and large-scale livestock businesses use blending and feed testing to ensure that their composite feed blends do not exceed 20 ppb. Those that have laboratory capacity to test for aflatoxin contamination are not obligated by law to withdraw contaminated commodities from the market. As a result, known contaminated commodities have reportedly re-entered the food supply and may be sold at lower prices.

**Risk Characterization for Human Health**

Chronic exposure to aflatoxins is associated with several human health effects. Liver cancer has the strongest causal relationship,\(^\text{11}\) along with liver cirrhosis.\(^\text{12}\) Evidence also suggests a link between immunologic suppression,\(^\text{13}\) growth impairment, and stunting in animals and children.\(^\text{14}\) However, stunting is also correlated with poor nutrition and poor gastrointestinal function, and the interactions between contributing factors are not well understood. Despite these effects, consumers’ level of aflatoxin knowledge is still very low in Nigeria and exacerbates by some harmful practices such as consumption of *kulikuli*, lack of dietary diversity, and heavy reliance on aflatoxin-susceptible foods (e.g., maize-based porridge) during a child’s weaning.

The lack of controls and awareness mean that aflatoxin-contaminated crops easily enter the consumption stream, leading to the risk of adverse health impacts. Maize and groundnuts together account for 10 percent of the calorie intake (see Figure 2). There is some regional variation in diets: There is significant regional variation in diets with maize and groundnut contributing varied amounts in the North Central (11 percent), North East (22 percent) and North West (17 percent) regions. In the southern regions reliance on maize and groundnuts is low, although the climate is more conducive to higher aflatoxin contamination.

**What is the impact of aflatoxins in Nigeria?**

The largest impact of aflatoxin contamination in Nigeria is expected to be on human health. Economic impacts from consumption of aflatoxin-contaminated food by humans are due to the health impacts of aflatoxin toxicity.

- The dose-response relationship between aflatoxin exposure, measured in nanograms (ng) of aflatoxin per kilogram (kg) of body weight (bw) per day, and liver cancer incidence per 100,000 population is linear.\(^\text{15}\)
- The increase in the annual incidence rate of liver cancer is associated with HBV status.
- Aflatoxin contamination in maize and groundnuts in Nigeria at the levels reported in studies may cause as many as 7,761 liver cancer cases per year out of the estimated 10,130 total liver cancer cases.

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If Nigeria’s current maize and groundnut consumption, population figures, and HBV trends remain constant, aflatoxin contamination levels of 20 ppb would contribute to 2,305 liver cancer cases. The cost impact of these liver cancer cases would be between $112 and $942 million (in 2010 U.S. dollars).

In 2010, Nigeria’s GDP was $197 billion (in 2010 U.S. dollars), so the high estimate at 20 ppb constitutes roughly 0.5 percent of Nigeria’s GDP. Since cancer risk from aflatoxin exposure is sensitive to HBV prevalence, focusing efforts on HBV immunizations could reduce liver cancer cases from aflatoxins threefold.

What are the potential solutions for aflatoxin control?

The Nigeria country and economic assessment helped identify opportunities for aflatoxin control in the three sectors of concern—agriculture, trade, and health. In November 2012, Nigerian stakeholders also came together at the aflatoxin stakeholders workshop (co-organized by the Ministry of Agriculture and Rural Development and Abt Associates) to identify priority control strategies in these three sectors.16

Action plans that support adoption of the priority control strategies were sketched out by small groups in this workshop for five topic areas: Agriculture (Pre-Harvest), Agriculture (Post-Harvest), Trade, Health, and the cross-cutting area of Policy Reforms.

Based on a review of the literature and consultation with Nigeria’s cross-sectoral stakeholders the following recommendations have been compiled:

**Priority Control Strategies for Agriculture: Pre-Harvest and Post-Harvest**

- Use good agricultural practices for planting, harvest, and post-harvest handling. Evaluate how these recommendations affect labor burdens on men vs. women and recommend labor-sharing strategies for both.
- Use and promote affordable sale of bio-controls such as Aflasafe™, which has been proven to reduce aflatoxin levels in soil.
- Incorporate messages about aflatoxin mitigation into the national agricultural extension messages. Emphasize the importance of sorting and discarding crops with physical flaws and deformities (e.g., visible mold or damaged shells). This can be an effective way of removing some of the contamination, particularly in groundnuts where physical flaws are more visible.17
- Promote use of insecticides to help keep plants healthy and able to resist fungus, especially in aflatoxin-prone areas. If resources are available also promote use of irrigation, fungicides and herbicides.
- Adopt moisture-control measures such as tarp drying, drying with natural fibers rather than humidity promoting materials (plastic bags), and promote above-ground storage and improved community storage.
- Promote research on safe disposal and alternative use of unsafe commodities, such as biofuels or blended feeds (which in the aggregate conform to safe maximum levels) and finishing feeds, which can have slightly higher levels (300 ppb) of aflatoxins without harming the animal.
- Conduct further research on processes such as use of aflatoxin-resistant planting materials including conventional and transgenic breeding, ammoniation, and commercial processing techniques for mitigating aflatoxin contamination.
- Ensure that information and aflatoxin-mitigating inputs are distributed with channels, times and locations that are accessible to female and male farmers.

**Priority Control Strategies for Trade**

- Expand food safety and aflatoxin regulations to raw commodities bound for domestic production.
- Shape the marketplace to improve awareness of the presence and risks of aflatoxins in the food and feed system and create market-based incentives for safer food. Promote awareness campaigns to increase demand for aflatoxin-safe products and incentivize adoption of aflatoxin control strategies along the value chain.
- Widely, publicly disseminate specifications for acceptable aflatoxin limits by working with rural trade groups and commodities associations and through regional and international trade fairs.
- Educate/persuade retailers and consumers to demand and recognize safer practices by suppliers.
- Provide technical support to improve capacity of medium to large traders and enforcement agencies to recognize the national enforcement agency’s “mark of quality.”
- Collaborate with existing agriculture development projects, such as the Markets II project, to promote safe production through Aflasafe, improved seeds, and other agricultural inputs.
- Set standards for animal feed at higher levels than for commodities destined for human consumption; use a grading system to ensure safe levels for both.

**Priority Control Strategies for Public Health**

- Reduce co-morbidity effects through achieving universal coverage of the hepatitis B vaccine.
- Reduce excessive caloric dependence on susceptible products by promoting dietary diversity.
- Conduct advocacy campaigns among major institutional representatives from the health field to shore up awareness and coordinated efforts that include the health sector.
- Conduct multi-sectoral behavioral change campaigns for food safety, especially among pregnant and lactating women, caregivers of infants, and immune-compromised individuals.
- Place special focus on monitoring foods used for pregnant women and infants/children (porridge, complementary foods).
- Carry out more regular testing of aflatoxin levels in major foods.

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Establish reference laboratories for mycotoxin studies in the six geopolitical zones.

For animal health: promote use of chemical toxin binders and anti-caking agent (e.g., NovaSil) in animal feed and regulate aflatoxins in animal feed. Do a better job of increasing awareness through animal science associations.

Conduct population mapping of the exposure to aflatoxins using biomarkers.

Establish the relationship between the incidence of aflatoxins, levels of biomarkers, and incidence of primary liver cancer in the Nigerian population.

### Priority Control Strategies for Policy Reforms

- Work within the public and private structures that have been set up to address food safety, agricultural production, mycotoxin detection, and quality assurance.
- Network with MYCOTOXSON to identify a secretariat of a central clearinghouse for new and existing research, strategy discussions, and initiatives. Require that research be entered into the central database.
- Focus on promoting an institutional response, but recognize that policy champions within those institutions will be necessary to forge progress.
- When designing action plans consider women’s access and ability to participate in the proposed solution. Recommendations may require financing, or time and labor, and access to information that pose barriers for women’s participation. Consult women’s groups and practitioners to ensure that gender dynamics are considered and used to inform strategies.
- Promote behavioral change communication and ensure these initiatives extend to rural areas.
- Use existing networks of agricultural and health extension, as well as commercial sector networks to disseminate information and affordable solutions to the poor.
- Establish locally acceptable guidelines for alternative uses for aflatoxin-contaminated products. Consult international (U.S. Department of Agriculture) guidelines on alternative use for animal feed or bio-fuel.
- Mainstream GAP and other food-safety-friendly measures within extension efforts.
- Mainstream a sampling testing program for aflatoxin-susceptible commodities.
- Enhance investments in laboratory capacity and availability of rapid test kits, trained users, documentation of results, and withdrawal of contaminated products to enable greater separation of contaminated crops in markets, at assembly points, at export points, and prior to processing.

### Conclusion

This brief was designed to share the results in Nigeria of a country and economic assessment based on a new methodology for assessing the situation, outlook, and needs of any developing country. Its purpose was to establish the evidentiary basis for policy and institutional reform, then stimulate regulatory improvement and concerted action by both public and private stakeholder groups, and ultimately to foster behavioral change by actors within value/supply chains, as well as consumers.

While solutions for aflatoxin control are readily available at all stages of food production, resources are scarce in comparison to the many development challenges that Nigeria faces. Interventions must be prioritized based on country-led perceptions of risk to vulnerable populations, reward in terms of prevention or mitigation, capacity to pay, and degree of political and institutional support.

Mitigation strategies should be multi-sectoral in nature, supported by relevant public and private sector institutions and respected professionals that represent plant and animal agriculture, human and animal health, and trade. Ideally, their actions should be coordinated through an entity that can meld and reconcile competing interests, champion the cause, and provide continuity of attention over time. The recent stakeholder workshop held in Abuja, which concluded the country and economic assessment effort undertaken by Abt Associates Inc., gave participants the opportunity to review the country assessment findings and discuss recommendations for the country.

There was overwhelming agreement on creating broad-based awareness about mycotoxins generally and aflatoxins in particular, while simultaneously embarking on prevention, control, and mitigation strategies appropriate to each affected sector. If consumers’ awareness increases, resulting in changes in effective demand and price penalties for contaminated product, both retailers and suppliers will try
to respond to the resulting market signals. However, because some interventions depend on the existence and enforcement of suitable regulatory controls, it is also important to establish and maintain a regulatory framework that is backed by political support and adequately resourced to enforce it. The workshop identified key areas for policy reform that will create a proper enabling environment for aflatoxin control. One key recommendation includes ensuring that commodities destined for domestic consumption would be regulated along with foods that are packaged or bound for export.

Behavioral change communication was also seen as key, and consumers, traders, and retailers alike should be provided with information on aflatoxin contamination, its underlying causes, and prevention strategies. It is also important to recognize that incentives and disincentives matter. If consumers’ awareness increases, resulting in changes in effective demand and price penalties for contaminated product, both retailers and suppliers will try to respond to the resulting market signals. However, because some interventions depend on the existence and enforcement of suitable regulatory controls, it is also important to establish and maintain a regulatory framework that is backed by political support.

Unless well planned, some control strategies or specific measures may have unintended consequences on sensitive segments of the population. These may include increases in the relative price of safe food for consumers, decreases in farmer income, diversion of contaminated product back into rural households that have nowhere to sell it and too much caloric need to destroy it, and differential impacts on source areas that are prone to high levels of prevalence. It follows that careful consideration of winners and losers under conditions of tighter or broader control is necessary, coupled with compensatory actions to balance different public objectives.

With its high level of professional capacity in all aspects of aflatoxin detection, mitigation, and control, Nigeria is well positioned to be a leader in the region and continent for aflatoxin mitigation. Coordination of these professional actors through institutional collaboration within the public sector and professional networks will be key in Nigeria’s path toward progress in aflatoxin prevention, mitigation, and control.

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