Country Assessment for Aflatoxin Contamination and Control in Nigeria

Preliminary Findings

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In support of: Partnership for Aflatoxin Control in Africa

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Preface

This country assessment was commissioned by the Meridian Institute, which is supporting the Africa-led Partnership for Aflatoxin Control in Africa (PACA) with funding from the Bill & Melinda Gates Foundation and the Department for International Development of the United Kingdom of Great Britain and Northern Ireland (DFID). Prevention and control of aflatoxin requires a comprehensive, systematic approach, involving a broad range of stakeholders in Africa and globally. PACA aims to provide consistent coordination and coherent leadership to the continental efforts on aflatoxin control. In support of continent wide efforts, the following brief provides an overview of the current status of aflatoxin contamination and solutions for Africa. More information is available at: http://www.aflatoxinpartnership.org.

Abt Associates Project Director John Lamb and Principal Investigators Tulika Narayan and Angela Stene (who were responsible for the economic and country analysis, respectively) wish to acknowledge and thank all of the individuals and institutions who contributed their valuable data, insights, and above all, professional and personal time in support of this activity. In particular, they would like to acknowledge, from Abt Associates, Anna Belova and Jacqueline Haskell, who provided analytical support for the economic analysis, and Carleen Ghio, who developed the maps.

We express our sincerest gratitude to Dr. A. A. Adesina, Honorable Minister of Agriculture and Rural Development, for his commitment to addressing the important issue of aflatoxins in Nigeria. We thank him for hosting and formally launching the Aflatoxin Stakeholders meeting in Abuja, November 5-6, 2012. We also express our gratitude to the Permanent Secretary of the Ministry of Agriculture (MOA) for ensuring that we used the new facility of the Agricultural Research Council and to the Director General of the Agricultural Research Council.

We wish to acknowledge the generosity and expertise that countless policy and institutional leaders of agriculture, trade, and nutrition; agricultural practitioners; policymakers; and researchers have shared with us. But we especially thank the following people for their work in informing this country assessment through research and collaboration. We thank Dr. Omowe Olusegun Atanda, President, Mycotoxicology Society of Nigeria; Reader (Food Microbiology and Safety) in the Department of Biological Sciences and Ag. Dean, College of Natural &Applied Sciences, McPherson University. We thank Bosede Oluwabamiwo, Technical Manager, Mycotoxin Laboratory/Central Laboratory, National Agency for Food and Drug Administration and Control (NAFDAC), for being a wonderful resource person and country contact point, and the Director General of NAFDAC for permitting her to take part in the countrywide assessment. We also express gratitude to Mrs Adetunji, modupeade Christianah, Federal University of Agriculture Abeokuta, Ogun State, for her tireless research in aflatoxin prevalence and farm-level constraints and opportunities to address aflatoxin at the farm and community level.

For her role in leading the organization of our stakeholders workshop, we thank Foluke O. Areola, Head of Department, Aquatic Resources Quarantine, Nigeria Agricultural Quarantine Service, Federal Ministry of Agriculture and Rural Development. She brings to the table her experience as the Past National and First Female President, Fisheries Society of Nigeria; and Facilitator, Agriculture and Food Security Policy Commission, Nigeria Economic Summit Group.

The authors have done their best to convey information, ideas, and findings as clearly and accurately as possible. Responsibility for any errors of commission, omission or interpretation rests solely with
the authors and Abt Associates Inc. None of this report should be construed as representing the views of the Meridian Institute as principal grantee, nor of the funding sources cited above.
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<table>
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<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>Body mass index</td>
</tr>
<tr>
<td>BMR</td>
<td>Basal metabolic rate</td>
</tr>
<tr>
<td>DALY</td>
<td>Disability Adjusted Life Year</td>
</tr>
<tr>
<td>EID</td>
<td>Establishment Inspectorate Division</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization of the United Nations</td>
</tr>
<tr>
<td>FAS</td>
<td>Foreign Agricultural Service</td>
</tr>
<tr>
<td>FDA</td>
<td>U.S. Food and Drug Administration</td>
</tr>
<tr>
<td>GAIN</td>
<td>Global Agriculture Information Network</td>
</tr>
<tr>
<td>GAP</td>
<td>Good Agricultural Practices</td>
</tr>
<tr>
<td>GI</td>
<td>Gastrointestinal</td>
</tr>
<tr>
<td>GMP</td>
<td>Good Manufacturing Practices</td>
</tr>
<tr>
<td>HACCP</td>
<td>Hazard Analysis and Critical Control Point</td>
</tr>
<tr>
<td>HBV</td>
<td>Hepatitis B virus</td>
</tr>
<tr>
<td>HCC</td>
<td>Hepatocellular carcinoma</td>
</tr>
<tr>
<td>HIV</td>
<td>Human immunodeficiency virus</td>
</tr>
<tr>
<td>IARC</td>
<td>International Agency for Research on Cancer</td>
</tr>
<tr>
<td>ICRI SAT</td>
<td>International Crops Research Institute for the Semi-Arid Tropics</td>
</tr>
<tr>
<td>IITA</td>
<td>International Institute of Tropical Agriculture</td>
</tr>
<tr>
<td>ISA</td>
<td>Integrated Surveys on Agriculture</td>
</tr>
<tr>
<td>LSMS</td>
<td>Living Standards Measurement Study</td>
</tr>
<tr>
<td>MOA</td>
<td>Ministry of Agriculture</td>
</tr>
<tr>
<td>MOH</td>
<td>Ministry of Health</td>
</tr>
<tr>
<td>NAFDAC</td>
<td>National Agency for Food and Drug Administration and Control</td>
</tr>
<tr>
<td>PAL</td>
<td>Physical activity level</td>
</tr>
<tr>
<td>SON</td>
<td>Standards Organization of Nigeria</td>
</tr>
<tr>
<td>TEE</td>
<td>Total daily energy requirement</td>
</tr>
<tr>
<td>USDA</td>
<td>United States Department of Agriculture</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
</tbody>
</table>
1 Introduction

Aflatoxins are naturally occurring poisons produced by certain fungi: *Aspergillus flavus* and *Aspergillus parasiticus*. There are several types of aflatoxins (B1, B2, G1, and G2) produced by these fungi, of which aflatoxin B1 is the most toxic. These aflatoxin-producing fungi are widely found in soil and colonize a variety of food commodities that are important to Nigeria, such as maize, sorghum, millet, oilseeds, spices, groundnuts, tree nuts, and dried fruit (Strosnider et al., 2006).

Aflatoxin contamination during crop development and maturiy depends on environmental conditions that are optimal for the growth of fungi. During crop development damage by pests (birds, mammals, and insects) or the stress of hot dry conditions can result in significant infections. Drought stress (elevated temperature and low relative humidity) increase the number of *Aspergillus* spores in the air, increasing the chance of contamination. In addition, other stresses (e.g. nitrogen stress) that affect plant growth during pollination can increase the level of aflatoxin produced by the *Aspergillus* fungi. The impact of drought on aflatoxin contamination is further exacerbated by the fact that drought stress can reduce the ability of crops to resist the growth of aflatoxin-causing fungus. At the time of harvest, high moisture and warm temperatures, inadequate drying and storage can increase the risk of aflatoxin contamination. Countries such as Nigeria that are located between 40ºN and 40ºS latitude all offer suitable growing conditions for the fungi, exposing their populations to risk of exposure.

Aflatoxins cause serious health effects in humans, leading to significant adverse impacts in the form of disease burden, and consequent impacts on a country’s agriculture, food security, and commerce.

*Aflatoxin contamination can reduce the volume and value of agricultural sector output, generally, and each of the four pillars of food security, specifically.* Contamination in staple crops can directly reduce the local availability of safe and nutritious food. Producers not able to comply with more stringent regulations will earn less, which reduces farm households’ capacity to access purchased food. Greater food insecurity can result from poor utilization if the food consumed is not nutritionally adequate or if it has deteriorated due to mold. The dependence of aflatoxin prevalence on climatic conditions places the stability of food security at risk as well.

*Aflatoxins are a global public health threat.* They are known to cause liver disease and are linked to suppression of the immune system, which lowers the body’s defenses against human immunodeficiency virus (HIV), malaria, and possibly other communicable diseases such as tuberculosis. They appear to interact in an adverse way (i.e., exhibit “co-morbidity”) with Hepatitis B. Acute exposure can lead to aflatoxin poisoning that can be fatal. Hundreds of deaths from aflatoxicosis have occurred in Africa, and many more mortalities may have occurred for this reason, but without proven attribution. Some experts suspect an association between chronic aflatoxin exposure and child stunting, apparently linked to gut health and the child’s capacity to utilize available nutrient intake. Stunting is widely recognized as a major human and development problem throughout Africa, because it lowers lifetime productivity and gross domestic product.

*Aflatoxins can impact domestic and international trade of commodities affected by it.* Many countries have established regulations to limit human and animal exposure to aflatoxins, typically expressed in parts per billion (ppb). Some have different limits depending on the intended use: the tightest applying to human consumption and exports, lower levels to animal and fish feed, and the lowest to industrial products derived from commodities such as maize and cottonseed. While regulation is clearly warranted to protect the consumer, food and feed safety regulations can result in
foregone revenues and profit from domestic commerce and international trade. Producers, traders, and processors incur operating costs as they strive to meet the standards. If they fail to comply, additional costs will arise from rejection of shipments; increased rates of sampling at borders; and in the worst case, loss of admissibility into foreign markets. While the regulatory control regime with respect to aflatoxins varies across most African countries, any or all such costs may occur if regulations are tightened or more strictly enforced. Similarly, actual costs of contamination will rise to the extent that consumers become more aware and demanding, or retailers apply higher private standards, or processors begin to test susceptible raw materials.

This country assessment is organized around the three pillars of the Program for Aflatoxin Control in Africa (PACA)—agriculture and food security, trade, and health—that are adversely affected by aflatoxins. This is a useful way to identify opportunities for aflatoxin control since the institutions, policy, and regulatory frameworks in countries are also organized along these three pillars.

The remainder of this report is organized as follows. Chapter 2 briefly presents a conceptual framework for conducting country assessments, while the subsequent chapters present the results of this particular assessment. Chapter 3 identifies the key crops of concern in Nigeria. Chapter 4 examines the prevalence of aflatoxin—both the distribution and degree of aflatoxin contamination—in these crops. Chapter 5 presents the current risks of aflatoxin contamination and exposure that exist in Nigeria. Chapter 6 analyzes the economic impact of aflatoxin contamination in Nigeria. Chapter 7 examines the opportunities for aflatoxin control in Nigeria, and Chapter 8 summarizes the avenues for further action.
2 Overview of the Conceptual Framework

The core steps in conducting a country assessment include:

**Step 1: Identify Key Crops of Concern.** It is desirable to focus the assessments on crops that are known to have high aflatoxin contamination in the target country, are either produced or consumed in large quantities and/or contribute significantly to gross national product. If information on aflatoxin contamination is not available then the focus can be on the crops that are known for their susceptibility high aflatoxin contamination globally and are produced and consumed in large quantities in the country of interest.

**Step 2: Determine the Prevalence of Aflatoxin.** Once the crop mix is identified, the next step is to assess the data on the distribution and degree of aflatoxin contamination in those crops. Here both available secondary data and published studies are reviewed for evidence. If resources permit and data are lacking, actual testing for aflatoxin levels can be conducted in areas that are primary producers of the crop of interest.

**Step 3: Characterize Risks of Aflatoxin Contamination and Exposure:** In this step, the core risk of aflatoxin contamination is established, i.e. whether the biggest impact is expected to be on the country’s agriculture and food security, trade or health. Final uses of aflatoxin-susceptible crops determine how the economic impacts are distributed, which can be helpful in narrowing down the focus of the analysis to the most significant areas of concern. Therefore in this step the main uses of the commodity in the country—whether for consumption, sale or trade are assessed.

In addition, the core aflatoxin risks are examined all along the value chain, beginning with pre-harvest and post-harvest contamination risks that directly impact agriculture, then considering risks of contamination and exposure in domestic commerce and international trade, and finally considering factors that directly affect human health.

**Step 4: Estimate Economic Impact from Aflatoxin Contamination** In this step the economic impacts on agriculture and food security, economic impacts resulting from market losses in both domestic and international markets, and economic impact resulting from the consumption of aflatoxin-contaminated food by humans are estimated. Depending on the finding from step 3 the analysis can focus on the most significant impacts.

**Step 5: Identify Opportunities for Aflatoxin Control.** In the final step, the institutional, legal, and regulatory framework that can support aflatoxin control in a country is described, and opportunities for aflatoxin control are identified. Specific control strategies that can be promoted in the country are also identified taking into account the best practices elsewhere.

Data availability and quality greatly influence the accuracy and usefulness of a country assessment. In Nigeria, the data came both from secondary sources and via a primary data collection effort of limited scope. Secondary data sources included FAOSTAT and CountrySTAT on production and export volumes of the commodity; the Living Standard Measurement Survey –Integrated Surveys on Agriculture (LSMS-ISA), 2010-2011; and a literature review of articles on aflatoxin prevalence and on control strategies, policies, standards and regulations affecting aflatoxin detection and control.
These secondary data were supplemented by in-depth qualitative data gathering in Nigeria in three districts—in the district capital and field sites. Semi-structured questionnaires were used to conduct interviews with key informants in the three districts with agriculture, health, and trade representatives as well as mothers, farmers, and commercial sector solution providers (see Annex A). Districts were selected from three different agro-climatic zones within Nigeria (see Exhibit 2-1). The sites were selected based on the high levels of aflatoxins in samples, and to provide a diverse geographic snapshot of a range of knowledge, attitudes, practices, and market and agro-climatic factors. Security was also a factor in site selection.

### Exhibit 2-1: Field Research Snapshot

<table>
<thead>
<tr>
<th>Districts</th>
<th>Agro-Climatic Zone with Characteristics</th>
<th>Mean B1 Aflatoxin Concentration</th>
<th>Primary Crops Produced [3]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mokwa, Niger</td>
<td>Southern Guinea Savannah</td>
<td>507 ppb [1]</td>
<td>Guinea Corn, Groundnut, Maize</td>
</tr>
<tr>
<td></td>
<td>Rainfall averaging between from 1000 mm to 1300 mm per year, and maximum</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>temperatures ranging from 26 to 38 °C.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lokoja, Kogi</td>
<td>Derived Savannah</td>
<td>288 ppb [1]</td>
<td>Cassava, maize, yam</td>
</tr>
<tr>
<td></td>
<td>Rainfall averaging between from 1300 mm to 1500 mm annually, and maximum</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>temperatures varying from 25 to 35 °C.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rainfall approximately 1421 mm; humid forest 28 to 32°C.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3 Identification of the Key Crops of Concern

Crops commonly affected by aflatoxin include maize, groundnuts, cottonseed, sorghum, millet, rice, Brazil nuts, pecans, walnuts, pistachio nuts, sesame and spices (particularly chilies), and products made from these crops. Nigerian agricultural data suggests that of these crops, maize, sorghum, millet and groundnut are important agricultural crops (see Exhibit 3-1). However, there is evidence that among cereals that are important in Nigerian diet – maize, sorghum and millet - the relative severity of aflatoxin contamination is greater in maize (Bandyopadhyay et al. 2007). There is evidence of high levels of contamination in Nigerian groundnut (see Exhibit 4-1). This country assessment focused on maize and groundnuts: the level of aflatoxin prevalence in these crops is high, and these crops are important component of Nigerian diets.

Exhibit 3-1: Nigeria's Key Agricultural Crops (2010)

Data Source: CountrySTAT (2012).
4 Prevalence of Aflatoxins

Aflatoxin contamination in maize and groundnuts is well above safe levels in Nigeria. Although data are not available for all regions in Nigeria, published prevalence data from Nigeria suggests that aflatoxin contamination in maize and groundnuts is considerably higher than the European Union (EU) aflatoxin standard (4 ppb) or the U.S. standard (20 ppb). A recent review of published articles reveals that the mean level of aflatoxin contamination in these two crops in Africa ranges as high as 300 ppb in maize and 48,000 ppb in groundnuts (see Exhibit 4-1).

Exhibit 4-1: Aflatoxin Prevalence Summary for Nigeria

<table>
<thead>
<tr>
<th>Region</th>
<th>Sample Type</th>
<th>B1 or Total</th>
<th>Prevalencea</th>
<th>Mean Concentrationb (ppb)</th>
<th>Range (ppb)</th>
<th>Citation Number</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maize</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humid Forest</td>
<td>Pre-harvest</td>
<td>B1</td>
<td>18%</td>
<td>22</td>
<td>3-130</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Pre-harvest</td>
<td>Total</td>
<td>18%</td>
<td>28</td>
<td>3-138</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Stored maize</td>
<td>Total</td>
<td>-</td>
<td>45e</td>
<td>0-900</td>
<td>2</td>
</tr>
<tr>
<td>Derived Savannah</td>
<td>Stored maize</td>
<td>B1</td>
<td>64%</td>
<td>267.32f</td>
<td>0-1,722</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Weaning foodc</td>
<td>B1</td>
<td>-</td>
<td>2,433g</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Southern Guinea Savannah</td>
<td>Stored maize</td>
<td>Total</td>
<td>-</td>
<td>56e</td>
<td>0-617</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Stored maize</td>
<td>B1</td>
<td>72%</td>
<td>299.6f</td>
<td>0-1,874</td>
<td>3</td>
</tr>
<tr>
<td>Northern Guinea Savannah</td>
<td>Stored maize</td>
<td>Total</td>
<td>0%</td>
<td>0h</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Stored maize</td>
<td>B1</td>
<td>20%</td>
<td>1.5f</td>
<td>0-8</td>
<td>3</td>
</tr>
<tr>
<td>Southern &amp; Northern Guinea Savannah</td>
<td>Freshly harvested</td>
<td>Total</td>
<td>17%d</td>
<td>36i</td>
<td>1.1-480</td>
<td>5</td>
</tr>
<tr>
<td>Mid-altitude</td>
<td>Stored maize</td>
<td>Total</td>
<td>-</td>
<td>83.8e</td>
<td>0-1,380</td>
<td>2</td>
</tr>
<tr>
<td>Sudan Savannah</td>
<td>Stored maize</td>
<td>Total</td>
<td>-</td>
<td>75.6e</td>
<td>0-1,506</td>
<td>2</td>
</tr>
<tr>
<td>Nigeria</td>
<td>Maize-based gruel</td>
<td>Total</td>
<td>25%</td>
<td>-</td>
<td>0.002-19.716</td>
<td>6</td>
</tr>
<tr>
<td>Nigeria</td>
<td>Corn snacks</td>
<td>Total</td>
<td>-</td>
<td>55-233j</td>
<td>10-1,070</td>
<td>7</td>
</tr>
<tr>
<td><strong>Groundnuts</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humid Forestk</td>
<td>Roasted</td>
<td>Total</td>
<td>-</td>
<td>23,290-61,240p</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Boiled</td>
<td>Total</td>
<td>-</td>
<td>30,740-54,830p</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Raw</td>
<td>Total</td>
<td>-</td>
<td>42,240-64,520p</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>Derived Savannahm</td>
<td>At market</td>
<td>Total</td>
<td>-</td>
<td>31.5q</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Peanut cake</td>
<td>B1</td>
<td>-</td>
<td>-</td>
<td>20-455</td>
<td>10</td>
</tr>
<tr>
<td>Southern Guinea Savannahn</td>
<td>At market</td>
<td>B1</td>
<td>100%</td>
<td>78h</td>
<td>74.03-82.12</td>
<td>11</td>
</tr>
<tr>
<td>Nigeria</td>
<td>Peanut cake</td>
<td>B1</td>
<td>100%d</td>
<td>-</td>
<td>2,820 (high)</td>
<td>12</td>
</tr>
</tbody>
</table>
### Footnotes:

a. Prevalence is defined as positive samples, unless otherwise noted.
b. Mean concentrations are means for all samples, unless otherwise noted.
c. Weaning food made with maize and either milk or soya. Note that these data are for Ibadan, Nigeria only.
d. Prevalence is defined as samples with >20 ppb aflatoxin.
e. Weighted average across male and female farmers.
f. Average across districts within zone (see Table 3 of the source paper).
g. Average across weaning foods that contain maize.
h. Mean across all samples.
i. Mean across samples where aflatoxin was detected, with a minimum detection limit of 1 ppb.
j. Range of means across: corn, corn cake, and corn roll snacks.
k. Data from Lagos State.
m. Data from Ibadan markets.
n. Data from Niger Delta.
o. Level of detection = 20 ppb for B1, 40 ppb for others.
p. Range across aflatoxin measurement methods. It is not clear whether the means are for all samples or only positive samples.
q. It was not clear from the article whether the means are for all samples or only positive samples.
r. Average across markets. It is not clear whether the means are for all samples or only positive samples.

### Citations:


The map below presents the average aflatoxin contamination using the data from published sources (see Exhibit 4-2). The groundnut contamination is generally higher in the southern states of Bayelsa and Rivers, while maize contamination is higher in Niger, Nassarawa, and Oyo.
Exhibit 4-2: Prevalence of Aflatoxin B1 in Maize and Groundnuts in Nigeria

The maps show the prevalence of aflatoxin B1 in various states of Nigeria, indicating areas with high and low contamination levels. The maps are color-coded to represent different concentration levels of aflatoxin B1 in maize and groundnuts. The states with the highest concentrations are highlighted, providing a visual representation of the contamination risk across the country.
5 Characterization of Risks of Aflatoxin Contamination and Exposure in Nigeria

Whether the risks of aflatoxin-contamination are greater on a country’s agriculture and food security, trade and/or health is determined by: (1) the uses of aflatoxin-contaminated crop (whether it used primarily for domestic human consumption or international trade); (2) levels of awareness about aflatoxins among farmers and consumer; (3) the application of tolerances within the food marketing systems and types of actions taken by regulators and buyers to mitigate the risk. If there is general awareness and use of aflatoxin controls in a country, and there are supporting regulations and institutions, then the human health impact of aflatoxin contamination will be low while the impact on agriculture, food security and trade will be high. On the other hand, if awareness is low –both among farmers and consumers – and there are inadequate regulations to control it, aflatoxin-contaminated grain will be traded freely, in which case the health impacts will be high.

Most of Nigeria’s maize crop is used for direct human consumption. In 2010/2011, for example, of the available 9,706 MT of maize, 78 percent was used for human consumption, 17 percent was used for feed and residual uses and a small percentage was set aside for re-planting (USDA FAS, 2012). Groundnuts are also primarily destined for human consumption. A share of groundnuts is used for making oil but the residual groundnut cakes, kulikuli, are part of the Nigerian diet. Only a negligible fraction of total groundnut production is exported. Average agricultural households report selling 41% of their maize produce, retaining 10% for seed, 1% for feed, and the residual 46% is used for own consumption or storage (based on analysis of 2009/2010 LSMS-ISA data). Our field research indicated that the majority of the maize sold in the market is for human consumption while the maize bran is processed for feed sector. Given that maize exports were banned, this implies that as much as 87% of maize produced by agricultural households is bound for human consumption, and 46% of that could be through own consumption.

The hazard of aflatoxin contamination in maize and groundnuts originates in farmer fields, but can then be controlled or get exacerbated at the post-harvest and storage stages. As the grain enters the domestic and international markets, the existence, content, and enforcement of regulations then affects the extent to which aflatoxin contaminated products are traded in the market. Finally, consumer perceptions and market’s response to those perception affects the risk that aflatoxin contaminated food is consumed resulting in adverse health impacts.

5.1 Agriculture and Food Security – Risks of Contamination on Farmer Fields

Use of Good Agricultural Practices that promote plant health, reduce moisture content and reduce susceptibility to aflatoxin-causing fungus can mitigate or minimize the risk of aflatoxin contamination. Targeted aflatoxin control measures such as biological control (Aflasafe™), precision drying of grains and nuts, and hermetic storage can significantly reduce the risk of aflatoxin exposure. Our field research suggests that the use of good agricultural practices is low in Nigeria. Poor, rural farmers use only those agricultural inputs they considered vital, and only if they can afford it. Drying of maize, groundnuts and other crops is typically done on the ground. Storage units are self-made and commodities are stored in piles without means of monitoring the temperature and humidity of such local storage units. To remedy this, the government is beginning to address food security and post-
harvest losses through a nascent federal grain reserve, to be established with modern silos in the six geopolitical areas.

Analysis of nationally representative data also confirms our qualitative findings from field research (see Exhibit 5-1). Nationally, 10% of agricultural households use commercial seeds for maize and 2% use commercial seeds for groundnuts. Use of pesticides is as low as 6% for maize and 2% for groundnuts. Use of fertilizer is relatively more at 20% for maize. Only 2% of the area cultivated under maize is irrigated and negligible area is irrigated for groundnuts. This is similar to findings of a recent report that finds only 3% of cultivated area in Nigeria is irrigated. (Takeshima et al., 2010).

Exhibit 5-1: Pre-Harvest Risk Factors for Aflatoxin Contamination in Nigeria

<table>
<thead>
<tr>
<th>Zone and Income Group</th>
<th>Use of Commercial Seeds</th>
<th>Use of Pesticides</th>
<th>Use of Fertilizer</th>
<th>Use of Irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Percent of Agricultural Households)</td>
<td></td>
<td></td>
<td>(Percent of Cultivated Area per Household)</td>
</tr>
<tr>
<td></td>
<td>Groundnut</td>
<td>Maize</td>
<td>Groundnut</td>
<td>Maize</td>
</tr>
<tr>
<td>By Zone</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Central</td>
<td>2%</td>
<td>8%</td>
<td>2%</td>
<td>5%</td>
</tr>
<tr>
<td>North East</td>
<td>4%</td>
<td>7%</td>
<td>3%</td>
<td>10%</td>
</tr>
<tr>
<td>North West</td>
<td>4%</td>
<td>7%</td>
<td>5%</td>
<td>8%</td>
</tr>
<tr>
<td>South East</td>
<td>0%</td>
<td>21%</td>
<td>0%</td>
<td>4%</td>
</tr>
<tr>
<td>South South</td>
<td>0%</td>
<td>6%</td>
<td>0%</td>
<td>1%</td>
</tr>
<tr>
<td>South West</td>
<td>1%</td>
<td>11%</td>
<td>0%</td>
<td>4%</td>
</tr>
<tr>
<td>National</td>
<td>2%</td>
<td>10%</td>
<td>2%</td>
<td>6%</td>
</tr>
</tbody>
</table>

Data Source: LSMS-ISA Nigeria, 2010-2011

Awareness among farmers about the causes and consequences of aflatoxin contamination was lacking in the three states where the field research was conducted. There is no set “agenda” for extension messaging on aflatoxins (or mycotoxins) or even more broadly on food safety or good agricultural practices. Extension messaging responds to problems raised by urgent issues such as insecticide damage. Even if a policy on integrating aflatoxin and food safety in GAP were introduced, lack of resources for extension and general systemic challenges and rural poverty hamper extension efforts as low stipends, unrealistic workloads (e.g., up to 800 households per 1 extension worker) and poor road hinder the reach of extension workers. Farmers, on their own, do basic sorting (easier in the case of groundnuts) to realize the price premium associated with cleaner and unspoiled maize and groundnuts. The prices are also higher for dryness for both products. These incentives work in favor of reducing the probability of aflatoxin contamination but neither do they guarantee it, nor do they imply that farmers and traders incur losses for carrying aflatoxin-contaminated grain (or realize premiums for aflatoxin-free grain). Consequently, there is significant risk that aflatoxin contaminated grain can leave farmer’s fields. This suggests that there are real opportunities for aflatoxin control in the agriculture sector. These are discussed in detail in Section 7.2.
5.2 Trade – Risk for Contamination in Markets

The Standards Organization of Nigeria (SON) has set standards for maximum aflatoxin (and mycotoxin) concentrations for several aflatoxin susceptible products: maize, groundnuts, sorghum, millets groundnut and maize products. Nigeria’s National Agency for Food and Drug Administration and Control (NAFDAC) enforces these standards and has laboratory capacity to conduct aflatoxin testing. However, it does so for only packaged foods and foods bound for the formal export market. Insofar as a large majority of these aflatoxin susceptible foods are consumed in unpackaged form, the national food safety system does not address a large share of food consumed by its citizens.

Likewise, the Ports Inspectorate Division monitors imports and exports of packaged and labeled food but inspections for unregulated or unpackaged food products is done only voluntarily. National Quarantine Service (NAQS) is also involved in monitoring exports and imports and has capacity for mycotoxins and aflatoxin testing. Packaged food products go through another layer of scrutiny at the manufacturing stage by the Establishment Inspectorate Division (EID) that inspects companies for their good hygiene practices and good manufacturing practices. However, again there is no systematic mechanism for testing the food safety of unpackaged foods.

Our field research in Niger Kogi and Ondo, found no evidence of testing for aflatoxins in the domestic maize and groundnuts markets in Nigeria. Consequently, aflatoxin-contaminated grain can enter the domestic markets and the informal international markets (e.g. Chad and Niger for maize). Interviews with kulikuli sellers at the oja oba market in Akure (Ondo State) indicated that visibly mouldy groundnuts are usually rejected, but even the rejects may be sold by suppliers to others at a lower cost. The major challenge with most of the sellers and farmers is that of low awareness about aflatoxins and its health impact. At grain stores in Mokwa (Niger state), some maize sellers indicated that if mold maize was discovered in a bag destined for sale, the maize would be washed, sundried and re-bagged and returned to sale. This practice (which is not effective in reducing aflatoxin) was also prevalent at Iddo (a market in Lagos).

On the other hand, aflatoxin control in the Nigerian animal and fish feed market is working much better. Even though there are no regulations on aflatoxin in this sector, the commercial feed formulators are vigilant about aflatoxin levels in the feed. Several medium and large scale commercial sector feed and livestock handlers revealed high levels of vigilance in ensuring that their feed is tested for aflatoxins, either by a company-lab or by outsourcing the tests. Their tolerance level is 20 ppb for grains. Some Nigerian feed suppliers and buyers also add aflatoxin binders to their feed. Unfortunately, since there is no mandate for withdrawal and destruction of contaminated commodities, grain deliveries rejected by large commercial operations will likely be sold by a trader to smaller feed manufacturers that do not test for aflatoxins.

5.3 Health – Risk of Aflatoxin Contamination in Consumption

The last point of aflatoxin contamination and control occurs at the point of consumption. If consumers are aware of aflatoxin risks, they can control exposure by demanding aflatoxin-free supply

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1 Standard for maize grit aflatoxin B1 2ppb (NIS 718:2010); standard for kulikuli (groundnut) cake total aflatoxin 4ppb, aflatoxin B less than 2ppb (NIS 594:2008); standard for maize grain mycotoxin 20ppb (no mention of aflatoxins, NIS 253:2003).
of the affected crop or by shifting consumption to crops that are less susceptible to aflatoxins, or by demanding aflatoxin-free crops. Greater awareness amongst farmers would also imply reduced aflatoxin exposure insofar as their own consumption comprises a large fraction of the consumption.

Yet field research suggests that consumers’ level of aflatoxin knowledge is still very low in Nigeria and exacerbated by some harmful practices. For example some farmers (outside of Lagos) reported believing that moldy maize may produce better Ogi-maize based porridge. Other behavioral risk factors include consumption of kulikuli. However, a study of kulikuli samples purchased monthly (April to November) from four Ibadan markets sites found that in all but two of the samples aflatoxin B$_1$ concentrations were between 20 ppb and 455 ppb (Akano and Atanda, 1990).

Other factors that can lead to increased exposure include heavy reliance on maize-based porridges during a child’s weaning stage. Infants are also fed cereal based infant food mixed with other products such as soybean which is also prone to aflatoxin contamination. Several household meal preparation processes (hulling, sorting, threshing, culling) can be promoted reduce the contamination levels of maize, groundnut and other susceptible crops.

In summary, in Nigeria the lack of aflatoxin control in agriculture sector and the lack of enforcement of aflatoxin standards in the domestic market mean that aflatoxin-contaminated maize and groundnuts (and other products) can easily enter the consumption stream leading to the risk of adverse health impacts. A majority of the maize and groundnuts produced are consumed domestically further enhances the risk, particularly because consumers are not aware of the problem. There may be some reduction in this risk because of the sorting and processing that the products undergo before consumption. Nevertheless, the impact of aflatoxin contamination in Nigeria is expected to be the greatest on health, while the impact on agriculture and trade is probably minimal.

The next section presents the economic impacts of aflatoxin contamination on Nigerian Agriculture and food security, trade and health.
6 Economic Impact from Aflatoxin Contamination

6.1 Agriculture and Food Security

The biochemical risk of aflatoxin contamination begins at the time of planting, and can be mitigated or worsened by harvesting, handing, storage, processing, and transport practices. Control measures (or their absence) taken along the supply chain can directly affect the availability of aflatoxin-free crop to households for both own consumption and sale that contributes to farm household income. The sum total of action and inaction can impact all four elements 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 supply of safe food as well as associated price determination).

In Nigeria the direct impact of aflatoxin contamination on agriculture and perceived food security is negligible because aflatoxin contamination often does not cause visible damage to the crop. In the current market environment, Nigerian farmers do not have to discard harvest because of aflatoxin contamination, nor do they face lower prices for aflatoxin-contaminated food. Because the market does not differentiate between aflatoxin-free and aflatoxin-contaminated food, farmers also do not incur any costs for mitigating aflatoxin. In fact, as discussed in detail in Section 5.1 above, the use of good agricultural practices is low. This increases the risk of aflatoxin contamination in grains so that the entire impact of aflatoxin contamination is on the third pillar of food security – utilization of food. Nationally, maize and groundnuts contribute 10 percent of the calorie intake of Nigerian diets (see Exhibit 6-1 and Exhibit 6-2). There is significant regional variation in diets: in the North Central, North East, and North West regions, the combined contribution of maize and groundnuts in Nigerian diets is 11 percent, 22 percent, and 17 percent, respectively. In the southern regions reliance on maize and groundnuts is low, although the climate is more conducive for higher aflatoxin contamination.
Exhibit 6-1: Share of Maize and Groundnuts in Calorie Intake of Nigerian Households

Share of Maize and Groundnuts in Calorie Intake of Nigerian Households

*Data Source: Nigeria 2010-2011 General Household Panel Survey component of the Living Standards Measurement Study Integrated Surveys on Agriculture project.*

Exhibit 6-2: Calorie Intake Share of Foods by Key Zones in Nigeria

<table>
<thead>
<tr>
<th>Zone</th>
<th>Maize</th>
<th>Groundnuts</th>
<th>Rice</th>
<th>Sorghum</th>
<th>Millet</th>
<th>Cassava</th>
<th>Yam</th>
<th>Oil and fats</th>
<th>Milk and milk products</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Central</td>
<td>10%</td>
<td>1%</td>
<td>13%</td>
<td>10%</td>
<td>3%</td>
<td>16%</td>
<td>16%</td>
<td>13%</td>
<td>1%</td>
<td>18%</td>
</tr>
<tr>
<td>North East</td>
<td>18%</td>
<td>4%</td>
<td>11%</td>
<td>19%</td>
<td>13%</td>
<td>2%</td>
<td>2%</td>
<td>11%</td>
<td>1%</td>
<td>19%</td>
</tr>
<tr>
<td>North West</td>
<td>16%</td>
<td>1%</td>
<td>15%</td>
<td>21%</td>
<td>17%</td>
<td>1%</td>
<td>2%</td>
<td>13%</td>
<td>1%</td>
<td>14%</td>
</tr>
<tr>
<td>South East</td>
<td>1%</td>
<td>1%</td>
<td>23%</td>
<td>0%</td>
<td>0%</td>
<td>23%</td>
<td>5%</td>
<td>18%</td>
<td>2%</td>
<td>28%</td>
</tr>
<tr>
<td>South South</td>
<td>0%</td>
<td>1%</td>
<td>11%</td>
<td>0%</td>
<td>0%</td>
<td>38%</td>
<td>8%</td>
<td>15%</td>
<td>1%</td>
<td>26%</td>
</tr>
<tr>
<td>South West</td>
<td>1%</td>
<td>0%</td>
<td>22%</td>
<td>0%</td>
<td>0%</td>
<td>19%</td>
<td>13%</td>
<td>16%</td>
<td>1%</td>
<td>28%</td>
</tr>
<tr>
<td>National</td>
<td>9%</td>
<td>1%</td>
<td>16%</td>
<td>10%</td>
<td>7%</td>
<td>14%</td>
<td>7%</td>
<td>14%</td>
<td>1%</td>
<td>21%</td>
</tr>
</tbody>
</table>

*Data Source: LSMS-ISA Nigeria, 2010-2011*

Although currently there is no impact of aflatoxin contamination on household food availability and food access, it is useful to consider the roles that maize and groundnuts play in households’ agricultural income and the extent to which own and purchased groundnuts contribute to their...
availability. In the North Central, North East, and North West zones, groundnut and maize sales contribute a reasonable share of households’ agricultural income (see Exhibit 6-3). Therefore, any differential prices for aflatoxin-contaminated grain could have a measurable impact on household incomes. In the North East, maize and groundnuts together account for 27% percent of agricultural households’ income. In the North West, the contribution of these two crops is 20 percent. Not surprisingly maize and groundnuts do not comprise a large share of agricultural incomes for agricultural households in the south.

** Exhibit 6-3: Percentage Contribution of Groundnut and Maize Sales to Household Income by Region **

<table>
<thead>
<tr>
<th>Zone/Quintiles</th>
<th>Total Agricultural Income (USD/household)</th>
<th>Percentage Contribution of Groundnut Sales</th>
<th>Percentage Contribution of Maize Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Central</td>
<td>404</td>
<td>2.1%</td>
<td>9.5%</td>
</tr>
<tr>
<td>North East</td>
<td>174</td>
<td>15.6%</td>
<td>11.0%</td>
</tr>
<tr>
<td>North West</td>
<td>241</td>
<td>3.0%</td>
<td>11.7%</td>
</tr>
<tr>
<td>South East</td>
<td>64</td>
<td>0.2%</td>
<td>14.4%</td>
</tr>
<tr>
<td>South South</td>
<td>109</td>
<td>0.5%</td>
<td>6.7%</td>
</tr>
<tr>
<td>South West</td>
<td>702</td>
<td>0.2%</td>
<td>5.3%</td>
</tr>
<tr>
<td><strong>National</strong></td>
<td><strong>255</strong></td>
<td><strong>2.8%</strong></td>
<td><strong>9.1%</strong></td>
</tr>
</tbody>
</table>

*Data Source: LSMS-ISA Nigeria, 2010-2011*

Next, we consider the extent to which households rely on own and purchased maize for their consumption needs (see Exhibit 6-4). We consider only maize consumption because that is an important crop for households’ food security. We find that the majority of households in the North rely on own produced maize for consumption. Therefore, aflatoxin contamination can have a direct impact on households’ food security by reducing the availability of safe food.
Exhibit 6-4 Percentage of total maize consumption that comes from own consumption by zones and income types for agricultural households

<table>
<thead>
<tr>
<th>Zone/Income Group</th>
<th>Groundnut Consumption</th>
<th>Maize Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total (g/household/week)</td>
<td>Percentage from Own Production</td>
</tr>
<tr>
<td>North Central</td>
<td>129</td>
<td>71%</td>
</tr>
<tr>
<td>North East</td>
<td>1,018</td>
<td>68%</td>
</tr>
<tr>
<td>North West</td>
<td>258</td>
<td>64%</td>
</tr>
<tr>
<td>South East</td>
<td>47</td>
<td>3%</td>
</tr>
<tr>
<td>South South</td>
<td>91</td>
<td>10%</td>
</tr>
<tr>
<td>South West</td>
<td>25</td>
<td>0%</td>
</tr>
<tr>
<td>National</td>
<td>266</td>
<td>62%</td>
</tr>
</tbody>
</table>

Data Source: LSMS-ISA Nigeria, 2010-2011

6.2 Trade

6.2.1 Domestic

In Nigeria the regulatory standard for aflatoxin in maize and groundnuts for human consumption is set at 10 ppb by the Standards Organization of Nigeria (SON). NAFDAC has the mandate to enforce these standards but actual enforcement is limited to packaged foods in the domestic market, which constitute a negligible fraction of maize and groundnut production in Nigeria.

Aside from regulatory action, another reason that producers may incur losses from aflatoxin contamination is if consumers are aware of the adverse impacts of aflatoxins and are not willing to buy (or pay less for) aflatoxin contaminated grain. Yet awareness about aflatoxins (and other mycotoxins) is very low among Nigerian consumers. Our interviews with traders and farmers in Kogi, Ondo and Niger confirmed that farmers do not receive a higher price for aflatoxin-free commodities, nor do traders seek aflatoxin-free maize and groundnuts. On the other hand, well-dried grain that is free from insect attack and without chaff does attract higher prices. This price differential is between NGN 20 and NGN 40 per kilogram of maize in Nigeria. Groundnut price differentials are largely based on the size of the grain, low moisture, and percentage of unspoiled nuts. The price differential between good quality and bad quality groundnuts can be NGN 5-NGN 25. Although dryer and insect-free maize and nuts are associated with lower aflatoxin presence, the current price differentials are not as result of aflatoxin contamination and cannot be attributed as a cost resulting from it. Consequently, we conclude that for Nigeria the domestic market impact of aflatoxin contamination in maize and groundnuts is negligible because there is no enforcement of existing

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2 In Kogi the price differential for good and poor quality groundnuts can be NGN 5 per kg, while in Niger state the difference can be between NGN 20 and NGN 25 per kg; in Niger state the difference can be as much as NGN 40 or a 50% differential in price based on dryness and quality and in Ondo the differential can be between NGN 15 to NGN 30.
regulations on aflatoxins on majority of groundnuts and maize that are traded unpackaged, and there is lack of awareness about the adverse health impacts of aflatoxin.

6.2.2 International Trade Impacts

As early classical theorists Ricardo and Heckscher point out, gains from trade stem from specialization in production according to a country’s comparative advantage. This improves allocation efficiency because resources can be shifted to the production of the good(s) a country produces best, resulting in improved welfare in the country and all trading nations. It follows that if aflatoxin contamination in a country means that the country no longer has a comparative advantage in producing the commodity—either because control strategies are not available, or because the management costs related to the controlling the problem are high—trading in that commodity may not be welfare enhancing; the commodity may instead be traded domestically.\(^3\) Thus, in the long run, as the market adjusts to new knowledge about aflatoxin, the welfare losses may not be significant, and may only be incurred in the short run.

In Nigeria, groundnut trade has settled into a long run equilibrium where the majority of the groundnuts are consumed domestically or traded informally across borders where international regulations are not enforced.\(^4\) In 1963 Nigeria accounted for 42 percent of shelled groundnut exports (see Exhibit 6-5). Since then Nigeria has relinquished the lead exporter position to China, USA and Argentina largely because of the neglect of agriculture sector during the oil price shocks of 1973-74 and 1979. Undoubtedly there are gains to be had by entering the international market for groundnuts, some of which cannot be accessed because of aflatoxin contamination. Government of Nigeria recognizes this and in September of this year, it has signed a three-year collaborative program with ICRISAT to replicate ICRISAT’s success in helping Malawi re-enter the European groundnut export markets through low-cost aflatoxin test kits and improving yields through disease resistant groundnuts.

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\(^3\) Developed countries have domestic regulation along with access to control strategies and are not excluded from international trade. Instead, developed countries face economic costs of managing aflatoxin by establishing and enforcing regulations, testing for aflatoxin, and controlling for it. Robens and Cardwell (2003) assess the impact of managing mycotoxin and the cost of testing in the United States. Since this framework is written in the context of developing countries, it will not go into further detail in estimating these costs.

\(^4\) Nigerian maize exports to Chad and Niger do not figure in official statistics and are in large quantities. http://www.inter-reseaux.org/IMG/pdf_Nigeria_s_Cereal_Economy_-_Summary_No2.pdf.
In the short run, Nigeria may incur some costs because of rejection of groundnut and maize consignments, however small they may be. A review of the EU alerts and border rejections suggests that between 2007 and 2012, 2 maize consignments and 13 consignments of groundnut and groundnut-related products were detained because of aflatoxin levels above EU regulations (see Exhibit 6-6).

### Exhibit 6-6: EU Alerts of Border Rejections/Detainment of Nigeria-Originating Imports Due to Aflatoxin Contamination (2007–2012)

<table>
<thead>
<tr>
<th>Year</th>
<th>Groundnuts</th>
<th>Kulikuli (1)</th>
<th>G.nut oil</th>
<th>Maize</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>3</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>2012</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Source: EU notifications were provided by Mrs. Folasade of NAFDAC’s Mycotoxin Laboratory on 8/30/12.

Notes: (1) Groundnut/peanut paste.

Data Source: FAOSTAT (2012).
Maize is an important staple crop for Nigeria and grown largely for own consumption; therefore, in the long run this crop will continue to be produced even if there are no international markets that it can reasonably access. There will be realized losses if any excess production cannot be sold in the international market. However, because maize is an important crop for food security, its export is often prohibited. Currently, maize export is prohibited in Nigeria. Historical data for maize production and exports indicate that exports are a negligible share of total maize production in Nigeria, particularly in recent years (see Exhibit 6-7). Given these export bans and generally low volume of exports, aflatoxin contamination is not likely to result in significant international trade loss.

**Exhibit 6-7: Maize Exports as Share of Total Production in Nigeria**

![Maize Exports as Share of Total Production in Nigeria](chart)

Data Source: FAOSTAT (2012).

### 6.3 Health

For reasons explained earlier, the largest impact of aflatoxin contamination in Nigeria is expected to be on human health. Economic impacts/damages due to consumption of aflatoxin-contaminated food by humans come from health impacts of aflatoxin toxicity. To determine these impacts, it is necessary to conduct a quantitative risk assessment for aflatoxin and then value the estimated damages to human health. A risk assessment is a four-step process consisting of (1) determination of the health effects associated with exposure to aflatoxin (hazard identification); (2) determination of the health effects at different levels of exposure (dose-response analysis); (3) determination of the levels of aflatoxin that people are exposed to (exposure assessment); and (4) determination of the extra risk for the identified health effects to occur in the exposed population (risk characterization). The risk assessment steps in Exhibit 6-8 are shown in blue. Once the risk characterization is complete, it is possible to estimate the

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economic impacts from aflatoxin exposure. These next steps are shown by the red arrows and boxes in Exhibit 6-8.

**Exhibit 6-8: Approach to Estimating the Economic Impact of Aflatoxin Contamination**

- **Hazard Identification**: What health effects are associated with exposure to aflatoxin?
- **Dose-Response Assessment**: What are the health effects at different levels of exposure?
- **Risk Characterization**: What is the extra risk of the identified health effects in the exposed population?
- **Exposure Assessment**: How much aflatoxin are people exposed to?
- **Valuation**: What are the costs associated with these impacts?
- **Economic Impact**: What is the economic impact of exposure to aflatoxin for the population of interest?

**Hazard Identification** is based on several studies that have found evidence that *chronic exposure* to aflatoxin is associated with several human health effects, including liver cancer (IARC, 2002), liver cirrhosis (Kuniholm et al., 2008), immunologic suppression (Williams et al., 2004), and growth impairment (Khlangwiset et al., 2011). High levels of exposure (i.e., *acute exposure*) may result in acute aflatoxicosis. We do not include this endpoint in our assessment because the dose-response relationship has not yet been developed and the frequency of such high exposures is unknown (Wu et al., 2011). We develop numerical estimates of health impacts due to aflatoxin exposure only for liver cancer (hepatocellular carcinoma, HCC), because this is the only endpoint for which a dose-response relationship was established and accepted by the Joint FAO/WHO Expert Committee on Food Additives (World Health Organization, 1998). There is evidence that supports the association between aflatoxin exposure and stunting in animals and humans (Khlangwiset et al., 2011 and Gong et al. 2002). However stunting is also correlated with poor nutrition and poor gastrointestinal function, and the interactions between contributing factors are not well understood. Because the latter problems are common in sub-Saharan Africa, it is difficult to ascertain whether aflatoxin exposure by itself causes stunting in the absence of malnutrition and/or poor GI function, or if there is a synergistic effect where aflatoxin exposure amplifies the effects of malnutrition and poor GI function on growth impairment. Nevertheless, because the evidence for the association is strong, preliminary estimates of the economic impact are estimated using Gong et al. (2002).

**Dose Response** relationship between aflatoxin exposure, measured in nanograms (ng) of aflatoxin per kilogram (kg) of body weight (bw) per day, and HCC incidence per 100,000 population is linear. Further, consistent with other carcinogens, *it is assumed that the dose-response relationship does not have a threshold, meaning that any aflatoxin exposure level can cause a risk*. Cancer potency (i.e., an increase in annual HCC incidence rate per unit change in aflatoxin exposure) varies across populations by HBV status: There is a 30-fold higher liver cancer risk for HBV-positive individuals.
Specifically, in HBV-positive populations, aflatoxin HCC potency is 0.3 cancers/year per 100,000 population per one ng/kg-bw/day, while in HBV-negative populations, aflatoxin HCC potency is 0.01 cancers/year per 100,000 population per one ng/kg-bw/day (World Health Organization, 1998).

**Exposure assessment**, or determining the exposure of Nigerians to aflatoxins, requires information on the amount of aflatoxin-contaminated food consumed by individuals, the concentration of aflatoxin in the food, and the body weight of the individual. It is important to note that in the case of HCC, the dose response is defined for aflatoxin B1. Hence we consider the prevalence of aflatoxin B1 only in our analysis. Body weight is important because the same amount of consumption can have different health impacts for people with different weights.

\[
\text{Exposure (ng/kg-bw/day)} = \frac{\text{Amount Consumed (g day)} \times \text{Aflatoxin Concentration (ng/g)}}{\text{Body Weight (kg)}}
\]

Information on consumption was derived from the LSMS surveys for Nigeria that provide household-level weekly consumption of various food items and several individual characteristics (e.g., age, sex, height, and/or weight). To allocate household consumption to individuals and obtain estimates of individuals’ daily intake of maize and groundnuts, we used the Adult Male Equivalent approach that has been applied to develop inputs for food fortification and other nutrition program evaluations (Neufeld et al., 2012). This approach uses individuals’ age and sex, reference body weights from the World Health Organization (WHO), basal metabolic rate (BMR) based on body weight, and physical activity levels (PAL) to calculate total daily energy requirements (TEE).6

Exhibit 6-9 presents the estimated average consumption of maize and groundnuts in grams per person. For our health estimates we estimated the average consumption per person per kilogram of body weight using LSMS-ISA (2012). In general, maize consumption is greater in the North. The consumption of groundnuts and maize is the greatest in the North East, suggesting that the risk of aflatoxin contamination at a given prevalence level is likely to be the largest in this region.

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6 **WHO reference weights:** We use the weights provided by Weisell and Dop (2012) for adult men and women and WHO weight-for-age tables for children aged 0-9 years. For children aged 10-17 years, weight-for-age tables are not available. Therefore, we estimate body weight based on body mass index (BMI) and height at each age, using WHO reference tables. Note that the estimated weights (based on BMI) for age 17 would be higher than the adult weights given by Weisell and Dop (2012). Therefore, we truncate weights at 64 kg for males and 55 kg for females. **BMR equations:** BMR equations are provided in Schofield (1985) for adults and Table 5.2 of FAO (2004) for children. **PAL:** We assume a PAL value of 1.75 based on Weisell and Dop (2012). **TEE equations:** The equations for TEE are from Section 4.2 of FAO (2004) for children and from Section 5.3 of FAO (2004) for adults.
Using aflatoxin concentration in maize from studies (see Exhibit 6-10), contamination averages, weighted by maize production. For groundnuts we calculated simple averages because some prevalence data came from states that did not report significant groundnut production. There is a fair degree of uncertainty in the data. For example, the majority of the groundnut information came from the South. Therefore, the estimates for prevalence in the North are based on a regional groundnut production-weighted average of the prevalence. Based on this imputation approach, contamination was greatest in the South East, because in the available literature the majority of the high prevalence values was reported for this region. For maize the prevalence data come from the northern regions,
which are the maize-growing regions of Nigeria. However, there are no prevalence data for the North East, South, and South East regions.

**Exhibit 6-10: Regional Mean B1 Contamination in Groundnuts and Maize in Nigeria**
**Risk characterization** involves estimating the population cancer risk, which is equal to the aflatoxin exposure as calculated above times the HCC potency, which is an average of HBV status-specific HCC potencies weighted by HBV prevalence in Nigeria:

\[
\text{Population Risk (cancers/year/100,000)} = \text{Exposure} \times \frac{\text{Share of HBV-positive} \times \text{HBV-positive HCC Potency} + \text{Share of HBV-negative} \times \text{HBV-negative HCC Potency}}{	ext{HBV prevalence}}
\]

To derive the annual number of HCC cases that occur due to aflatoxin exposure, we multiplied the estimated population risk by the region-specific population (expressed in 100,000s).

**Disability Adjusted Life Year (DALY) lost.** Under assumption that all estimated HCC cases result in death within the same year, we estimated annual Disability Adjusted Life Years (DALYs) lost due to aflatoxin contamination-related HCC cases. DALY is an epidemiological measure of disease burden expressed in the number of healthy life years lost due to death or disability caused by disease. We used regional estimates of total liver cancer deaths and total liver cancer DALY’s from the Global Burden of Disease project (WHO 2008) to derive a DALY value for an HCC case in Nigeria.

**Monetized Health Impact.** Assuming again that all estimated HCC cases result in death within the same year, we also monetized the total aflatoxin-related liver cancer burden using a transfer approach proposed by Hammitt and Robinson (2011). Specifically, we started with an estimate of willingness to pay for small changes in mortality risk—i.e., the value of a statistical live (VSL)—developed for the U.S. This value was adjusted for differences in income per capita between U.S. and Nigeria. Following recommendations in Hammitt and Robinson (2011), we used several income elasticity values (1, 1.5, and 2) for the transfer and bound the derived VSL estimate (from below) using the present value of future consumption (at 3% discount rate).

**Health Impact Estimates.** The region-specific number of HCC cases, DALYs and VSL attributable to aflatoxin contamination in maize and groundnuts are presented in and a corresponding map is presented in Exhibit 6-12. At the national level, we estimate that aflatoxin contamination in maize and groundnuts results in 7,761 liver cancer cases resulting in a total burden of 100,965 DALYs. The impact of contamination is greater in the North East and North Central regions. The North East consumes the largest quantity of maize and groundnuts; the North Central region has the highest prevalence of aflatoxin in maize, and also consumes a reasonable quantity of maize. We estimate a

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7. Note that in each region, population risk was characterized separately for males and females by estimating sex-specific maize and groundnut consumption, HBV prevalence, and population.

8. We derived sex-specific HCC DALY estimates using WHO’s AFR D region data. The estimated value for males was 12.3 DALYs per HCC case and the estimated value for females was 13.8 DALYs per HCC case.

9. This U.S. VSL is 4.8 million of 1990 U.S. dollars at 1990 income levels (US EPA, 2010). It was adjusted for inflation and income growth between 1990 and 2010. The updated U.S. VSL value used in our calculations was 8.9 million of 2010 U.S. dollars.

10. The Purchasing Power Parity (PPP) based GNI per capita for 2010 (from the World Development Indicators Database, [http://data.worldbank.org/indicator](http://data.worldbank.org/indicator)) were used in all calculations. The U.S. PPP-based GNI per capita was $47,360 (in 2010 U.S. dollars) and the Nigeria PPP-based GNI per capita was $2,170 (in 2010 U.S. dollars).
high VSL estimate of $409,000 per HCC death (using income elasticity of 1) and a low VSL estimate of $49,000 per HCC death (based on the present value of future consumption).\textsuperscript{11} Using these VSL estimates, the monetized total aflatoxin-related liver cancer burden, at the baseline aflatoxin contamination levels as well as baseline maize and groundnut consumption patterns, was estimated to be between $380 and $3,174 million (in 2010 U.S. dollars).

**Exhibit 6-11 Health Impact of Aflatoxin Contamination in Nigeria: HCC Cases, DALY and Monetized Health Impact**

<table>
<thead>
<tr>
<th>Region</th>
<th>Maize Mean (g/day)</th>
<th>Groundnut Mean (g/day)</th>
<th>Population in 2010 (in thousands)</th>
<th>HCC Cases\textsuperscript{a} (cancers/year)</th>
<th>DALY (in millions)</th>
<th>VSL (low) (in millions)</th>
<th>VSL (high) (in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Central</td>
<td>102</td>
<td>7</td>
<td>22,571</td>
<td>3,698</td>
<td>48,161</td>
<td>$181</td>
<td>$1,513</td>
</tr>
<tr>
<td>North East</td>
<td>167</td>
<td>37</td>
<td>21,066</td>
<td>3,075</td>
<td>39,987</td>
<td>$151</td>
<td>$1,258</td>
</tr>
<tr>
<td>North West</td>
<td>170</td>
<td>11</td>
<td>39,854</td>
<td>221</td>
<td>2,864</td>
<td>$11</td>
<td>$90</td>
</tr>
<tr>
<td>South East</td>
<td>9</td>
<td>7</td>
<td>18,235</td>
<td>258</td>
<td>3,375</td>
<td>$13</td>
<td>$105</td>
</tr>
<tr>
<td>South South</td>
<td>1</td>
<td>11</td>
<td>23,352</td>
<td>163</td>
<td>2,115</td>
<td>$8</td>
<td>$67</td>
</tr>
<tr>
<td>South West</td>
<td>13</td>
<td>1</td>
<td>30,763</td>
<td>346</td>
<td>4,462</td>
<td>$17</td>
<td>$142</td>
</tr>
<tr>
<td>National</td>
<td>84</td>
<td>12</td>
<td>155,842</td>
<td>7,761</td>
<td>100,965</td>
<td>$380</td>
<td>$3,174</td>
</tr>
</tbody>
</table>

**Notes:**
\textsuperscript{a} Estimated annual HCC cases due to aflatoxin (central estimate).
\textsuperscript{b} In 2010 U.S. dollars.

\textsuperscript{11} All values are in 2010 U.S. dollars.
Exhibit 6-12: Annual Cancer Cases and Disability Adjusted Life Years Lost Because of Aflatoxin Contamination in Maize and Groundnuts in Nigeria

Analysis of Sensitivity to Assumptions about Aflatoxin Prevalence Levels. There is a substantial amount of uncertainty in the aflatoxin prevalence data, to which the outcome of our analysis is quite sensitive. Therefore, we calculated the range of impacts for different levels of aflatoxin prevalence, using the current maize and groundnut consumption patterns, HBV prevalence rates, and 2010 regional population estimates in Nigeria. Exhibit 6-13 and Exhibit 6-14 show that even at low prevalence rates at around 10 ppb, the total annual cancer cases attributable to aflatoxin contamination are estimated to be 1,152 nationally. At 20 ppb, which is the regulatory limit for maize and groundnuts for human consumption in the United States, the total annual cancer cases attributable to aflatoxin contamination are 2,305. Exhibit 6-13 also shows a range of the monetized total aflatoxin-related liver cancer burden, at different assumptions about contamination levels. At prevalence rates of 10 ppb, the monetized burden is between $56 and $471 million (in 2010 U.S. dollars), while at 20 ppb the monetized burden is between $112 and $942 million (in 2010 U.S. dollars). It is noteworthy that in 2010, Nigeria GDP was $197 billion (in 2010 U.S. dollars), so the high estimate at 20 ppb constitutes roughly 0.5% of Nigeria GDP.
Exhibit 6-13: Sensitivity of Health Impacts to Changes in Aflatoxin Prevalence

Analysis of Sensitivity to Assumptions about Aflatoxin Prevalence and Food Intake Levels. Since we consider aflatoxin burden only from maize and peanuts, it is useful to assess the sensitivity of these results to different levels of food intake (this could be generalized to any food item) and at different levels of aflatoxin prevalence. Following Shephard (2008), in Exhibit 6-14 we report the annual number of HCC cases estimated to occur due to aflatoxin contamination in Nigeria at several aflatoxin prevalence (AFB1) and food intake levels. Exhibit 6-14 shows that, given the 2010 regional population estimates, the age and sex distribution, and the sex-specific HBV prevalence, aflatoxin contamination of even 10 ppb would imply that 1,152 liver cancer cases could be attributed to aflatoxin. This amounts to more than one-tenth of 10,130 liver cancer deaths that were estimated to occur in 2010 in Nigeria.12

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12 The estimate was derived using the 2010 Nigeria population estimate and 2004 liver cancer incidence rate (6.5 deaths per 100,000 population) estimated for Nigeria by the Global Burden of Disease Project (WHO 2008).
Exhibit 6-14: Estimated HCC Cases Attributable to Aflatoxin Contamination in Nigeria for Ranges of Aflatoxin Prevalence Levels and Ranges of Food Intake Levels

<table>
<thead>
<tr>
<th>AFB1 Level (ppb)</th>
<th>Levels of Food Intake by Person Weighing 60kg (g/person(60kg)/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>124^1 10     50  100  150  200  400</td>
</tr>
<tr>
<td>1</td>
<td>115 9 46 93 139 185 371</td>
</tr>
<tr>
<td>2</td>
<td>230 19 93 185 278 371 742</td>
</tr>
<tr>
<td>5</td>
<td>576 46 232 464 695 927 1,854</td>
</tr>
<tr>
<td>10</td>
<td>1,152 93 464 927 1,391 1,854 3,709</td>
</tr>
<tr>
<td>20</td>
<td>2,305 185 927 1,854 2,781 3,709 7,417</td>
</tr>
<tr>
<td>100</td>
<td>11,524 927 4,636 9,271 13,907 18,543 37,085</td>
</tr>
</tbody>
</table>

Notes:
1. Estimated Intake of Maize and Groundnuts in Nigeria (g/person(60kg)/day)

Estimated number of liver cancer cases in Nigeria is 10,130 (derived using the 2010 Nigeria population estimate and 2004 liver cancer incidence rate -- 6.5 deaths per 100,000 population-- estimated for Nigeria by the Global Burden of Disease Project, WHO, 2008). Therefore, the plausible values of HCC cases attributable to aflatoxins is bolded.

Analysis of Sensitivity to Assumptions about HBV Prevalence. We also assessed the impact reducing HBV prevalence on the number of aflatoxin-related liver cancer cases. We find that, if the HBV prevalence is reduced to zero, at the same levels of aflatoxin contamination as well as maize and groundnut consumption that were used to derive our baseline Nigeria, the number aflatoxin-related liver cancer cases from aflatoxin contamination could be three times smaller (2,175 HCC cases per year as compared to 7,761 HCC cases per year).

In summary, aflatoxin contamination in maize and groundnuts in Nigeria at the levels reported in studies can be causing as many as 7,761 liver cancer cases per year out of the estimated 10,130 total liver cancer cases. There is significant uncertainty in the extent of aflatoxin contamination in Nigeria. A sensitivity analysis of estimates assuming different contamination levels suggests that even at aflatoxin contamination at 20ppb at the current consumption levels of maize and groundnuts, the estimated population in 2010 and current HBV prevalence rates, 2,305 liver cancer cases can be attributed to aflatoxins. At prevalence rates of 10 ppb, the monetized burden is between $56 and $471 million (in 2010 U.S. dollars), while at 20 ppb the monetized burden is between $112 and $942 million (in 2010 U.S. dollars). It is noteworthy that in 2010, Nigeria GDP was $197 billion (in 2010 U.S. dollars), so the high estimate at 20 ppb constitutes roughly 0.5% of Nigeria GDP. Since cancer risk from aflatoxin exposure is sensitive to HBV prevalence, focusing efforts on HBV immunizations could reduce liver cancers cases from aflatoxins three times.
7 Opportunities for Aflatoxin Control in Nigeria

This section considers the regulatory framework governing aflatoxin control, which is key to setting a compelling tone and useful direction for central- to field-level prevention and mitigation strategies involving both public and private stakeholders and straddling the health, agriculture, and trade sectors. The section also highlights—in the form of suggested areas or types of intervention—viable control strategies that have either already gained traction or have promise in Nigeria.

7.1 Institutional, Policy, and Regulatory Environment and Related Opportunities

Nigeria’s regulatory structure for setting and enforcing aflatoxin standards spans several core ministries. The Standards Organization of Nigeria (SON), which is part of the Ministry of Trade, sets standards for food products and processes, as well as food-related enterprises. SON also sets standards for metrology, testing, and certification. Using mainly these standards, the National Agency for Food and Drug Administration and Control (NAFDAC), which is housed within the Ministry of Health (MOH), regularly inspects, tests, and certifies all commodities and foods sold for export and all packaged foods regardless of destination. The National Quarantine Service under the MOA monitors seeds, plants, and fish bound for import and export.

Within NAFDAC, the Ports Inspectorate Division monitors imports and exports of regulated foods and other goods. However, unpackaged/non-labeled bulk foods, which are primarily those traded domestically, are not regulated. NAFDAC’s Establishment Inspectorate Division (EID) inspects food processing and exporting companies for their Good Hygiene Practices and Good Manufacturing Practices (GMP), and asks to view Hazard Analysis and Critical Control Point (HACCP) plans. EID collects samples for NAFDAC laboratory analysis before exports are permitted. The EID in Lagos conducts 10-20 premise inspections a day and also carries out sampling on the market. Large sweeps are conducted if unregistered products are found in markets or stores.

Gaps and opportunities in the current institutional and regulatory framework governing aflatoxin control and mitigation are described below.

Setting and publicizing clear division of roles and responsibilities may yield greater regulatory efficiencies. Researchers and agricultural practitioners consulted in the field stressed confusing mandates and duplication of effort. Setting clear parameters such as assigning responsibility for standard setting and dissemination to SON and for enforcement to NAFDAC may yield greater efficiencies and less confusion in mandates. Many agencies cite the need for expensive laboratory equipment that is not available under the current budgetary allocations.

Each agency should also agree on a coordinated, risk-based surveillance strategy to communicate and isolate threats to the food system. The Good Agricultural Practices (GAP) approach to agriculture and HACCP and GMP approaches to manufacturing are often absent. Verification and dissemination of research data and information for the application of GAP and HACCP at relevant points of the food safety system are poor. Research data are not widely disseminated, and the response to food-borne illnesses is poorly coordinated. These problems are partially due to constrained resources, which reduction in duplicative mandates can help address, as can enhanced systems for information sharing.
Changing the mandates of SON, NAFDAC, and other specialized agencies to regulate raw commodities destined for domestic consumption is key to addressing the public health impacts of aflatoxin in Nigeria, which derive mainly from local production and consumption. Most raw commodities bound for domestic consumption are not governed by the SON regulations. As the majority of Nigeria’s population relies on either their own production or local markets, the benefits of product testing (of export and packaged foods) are only reaped by international consumers and those who are able to pay for packaged foods. Launching a commodities exchange board or warehouse receipts system with pre-storage drying and contaminant testing can be one way of monitoring the quality of crops bound for domestic use.

Set procedures for withdrawal of contaminated samples and explore alternative uses for contaminated products. There are no reported procedures for withdrawing aflatoxin-contaminated samples. On the rare occasions that aflatoxin-contaminated commodities have been detained, they usually leak back onto the market and are sold inexpensively. Without guidelines or a market for alternative uses of aflatoxin-contaminated products, this leakage will continue.

Increase free, web-based public access to the codes and standards regulating food commodities, processes, and enterprises. Communication to consumers on the quality and safety features of the food system will better inform purchase decisions. Public awareness starts at the point of sale through proper labeling, but can be reinforced through industry promotion and media reporting. Even before that, government needs to publicize the existence of codes and standards, and make them readily available in hardcopy and digital form. Some countries make these standards freely available to the public via a national government website, which is a practice recommended in order to increase compliance among interested parties.

Strengthen the institutional mandate for cross-ministerial collaboration in shifting production and consumer demand for food quality. As of August 2012, MOH was revising the food safety code, and SON was crafting mycotoxin policy. This regulation should be harnessed to increase the mandate for cross-sectoral collaboration for extension messaging, particularly at the rural field level. Currently, nutritional counseling does not actively promote GAP as a way to enhance food safety, nutritional, and health status. Especially in rural health outposts serving a large proportion of subsistence farmers, the opportunity to advise patients on the health implications of food and crop safety should be increased. Increased collaboration between agro-dealers, health, and extension workers as well as rural community organizations can further strengthen the adoption of GAP, the accompanying agricultural inputs, and overall consumer demand for high-quality foods.

7.2 Aflatoxin Control Strategies in Agriculture

As noted above, control strategies at the pre-harvest stage can prevent contamination from ever entering the food supply. However, control strategies must either be directly affordable to the poor, or subsidized in the name of the public good, since much of the subsistence farming subsector will never be affected by formal quality control mechanisms.
Bio-controls such as the IITA-developed Aflasafe can reduce aflatoxin levels in soil and among treated crops, even after poor storage.\(^{13}\) IITA’s investigation of farmers’ willingness and ability to pay for the product (estimated at approximately NGN 1,600/hectare treated) is also informing the Aflasafe commercialization plan being developed by Doreo Partners.

Scale public and private sector initiatives to increase access and adoption of agricultural inputs and continue to scale targeted input vouchers for the poorest farmers. Demand for inputs is high, but access and affordability often prohibit adoption. Farmers indicated that pests were among the biggest threats to crop loss. Nationally, use of improved seeds for groundnuts (2%), maize (10%), pesticide use (2% to 6%), and irrigation (0-2%) can be heightened. Yet certain zones (e.g., South East) show use of improved maize seeds above the national average (21%). Factors that allow for this increased use need to be replicated in other areas to improve ease of access and use of agricultural inputs.

Use national data on agricultural stressors to inform market-based solutions to address localized threats. Drought-resistant seeds may have highest demand in the North East, where up to 29% of farmers face poor rains. Meanwhile, the market demand for insecticide is likely to be highest in the South East, where pest invasions affect the highest proportion (13%) of farmers (see Exhibit 7-1).

**Exhibit 7-1: Agricultural Stressors by Region**

<table>
<thead>
<tr>
<th>Zone/Income Group</th>
<th>Poor Rains</th>
<th>Flooding</th>
<th>Pest Invasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>By Zone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Central</td>
<td>17%</td>
<td>8%</td>
<td>4%</td>
</tr>
<tr>
<td>North East</td>
<td>29%</td>
<td>13%</td>
<td>7%</td>
</tr>
<tr>
<td>North West</td>
<td>16%</td>
<td>15%</td>
<td>3%</td>
</tr>
<tr>
<td>South East</td>
<td>10%</td>
<td>4%</td>
<td>13%</td>
</tr>
<tr>
<td>South South</td>
<td>4%</td>
<td>3%</td>
<td>1%</td>
</tr>
<tr>
<td>South West</td>
<td>4%</td>
<td>2%</td>
<td>1%</td>
</tr>
</tbody>
</table>

*Data Source: LSMS-ISA 2010-2011*

Capitalize on mobile technologies and banking services to design business models for agricultural inputs that serve the poor: Currently only 15% of farmers access government extension source. The advent however of mobile technologies combined with public private partnerships to agro-dealers fills this gap innovatively. One project that capitalizes on both PPPs and mobile technologies to reach the poor includes the Ministry of Agriculture’s Growth Enhancement Support program, which subsidizes half the cost of seed and fertilizers to impoverished farmers using agro-dealers and SMS (text message) vouchers for distribution. This model as of October 2012 had engaged 900 agro-dealers and was continuing to grow in size. Through Mobile banking, local banks, input providers, and agro-dealers are paid out of a Central Bank of Nigeria (CBN) -based escrow

\(^{13}\) Several studies have found significant levels of aflatoxin from the competitive use of fungus including a 60-87% reduction (Dorner et al., 1999), a 70-91% reduction (Dorner and Horn, 2007), and an 80% reduction (Cline, 2005).
account once the farmer has paid the agro-dealer the (50%) balance of the value of the input. For these initiatives to be successful, however, farmers also need extended, affordable credit to purchase the inputs needed to cope with natural stresses such as drought and pests, mobile banking and access to credit should be extended. To date, the initiative is small, but it represents one innovative way in which effective inputs (e.g. bio-controls, drought resistant seeds), could possibly be commercially distributed on a scale that surpasses the reach of conventional extension.

Use the global research agenda on aflatoxin to inform and complement domestic research, and vice versa. Finally, international investigations of other control strategies such as aflatoxin-resistant planting materials, including conventional and transgenic breeding and ammoniation, can inform Nigeria’s own research agenda. Encourage expansion of community and household storage to protect crops from moisture and temperatures which can exacerbate aflatoxin growth. The Nigerian Stored Products Research Institute conducts ongoing research in affordable community and household crop storage. Through public private partnerships, NISPRI, micro-credit agencies and local fabricators of storage and drying can expand access to safe post-harvest handling to reduce aflatoxin levels as well as other post-harvest losses.

Ensure that all control strategies are inclusive of women’s participation: Women are integral to the role of aflatoxin control strategies in Nigeria. In rural areas of Nigeria, women make up 60-80% of the agricultural labor force. A gender in decision making study conducted in Nigeria’s northern state of Kaduna (a major maize producing state), found that among 10 major farming decisions, women were consulted for less than 20% of them, aside from decisions about whether to access credit. Only 1 to 2.5% of women in the study sample made final decisions about farm operations. Notably, however, women did make final decisions about storage and marketing practices of their rural farm produce, as noted in the table excerpted from the authors’ paper (Ogunlela and Mukhtar, 2009). Those strategies outlined above which involve access to credit, storage and inputs must be designed with a gender lens to ensure that interventions are rolled out in ways that are conducive to women’s involvement.

7.3 Aflatoxin Control Strategies for Trade

Nigeria’s animal feed industry has demonstrated that when buyers and sellers (with ability to pay) are incentivized financially for higher quality feed, they will pay for feed binders to reduce the effect of aflatoxin contamination on poultry, fish, and livestock. To date, no other agricultural input that

14 Personal communication, Tola Sunmonu, email correspondence, October 9, 2012.
15 Conventional seed breeding for aflatoxin resistance has reduced aflatoxin by >70% and 82–93%)
Transgenic breeding for aflatoxin resistance has reduced aflatoxins by 47% in maize (Khlangwiset, 2011a).
16 Placing maize crops in a sealed container for 1-2 weeks and applying ammoniation gas could reduce aflatoxin levels by 90% (Nyandieka et al., 2009).
17 To prevent the harmful effects of aflatoxins in animals, chemical compounds and polymers known as “binding agents” can be added to animal feed for pennies on the metric ton of animal feed. These binders can neutralize up to 90% of contaminants from maize during processing (Whitlow, 2006).
reduces aflatoxin’s negative impact has been as successfully introduced and adopted as binders in animal feed.

Use economic incentives to shift behaviors. Experienced livestock traders report significant economic impacts on their animals of aflatoxin exposure, which greatly affects productivity, growth, and reproduction. Yet because the symptoms of aflatoxin exposure are often attributable to other diseases, small-scale farmers require educational campaigns on aflatoxins. In Nigeria, some commercial vendors of toxin binders have proactively offered free workshops about causes and consequences of aflatoxins in livestock. Informing the market base has increased revenues for this product. There is, however, still room to increase market share for toxin binders. Not all of the top five animal feed sellers use these inputs. Toxin binders, which are usually added along with other vitamins and minerals, and liver tonics, may increase the cost of a high-quality, blended feed by 5%.18

Explore alternative uses for aflatoxin-contaminated crops. In a country as food insecure and populous as Nigeria, crops are rarely discarded. When contaminated crops are rejected by one player, another, poorer market base is ready to buy and use the crop at a lower cost. The United States Food and Drug Administration (U.S. FDA) has set regulations on use of contaminated products that can be blended with uncontaminated products or other ingredients to make the composite feed safe for animal consumption (Dohlman, 2008; U.S. FDA, 2000; Rowe, 2007). This strategy has been employed by some Nigerian commercial feed companies as an economically efficient way of incorporating inexpensive protein sources (e.g., kulikuli) into composite blends that are safe for animal consumption.

Research from the USDA also shows that feeds with higher levels of contaminants can be used for finishing animals bound for slaughter. The USDA has set higher limits for aflatoxin contamination in finishing feed, which can be used up to 2 weeks before slaughter. Upper bounds for finishing feed can be safely set at 300 ppb for cattle; 200 ppb for swine; less than 100 ppb for breeding cattle, swine, and mature poultry; and less than 20 ppb for dairy cows and young animals (Dohlman, 2008; US FDA, 2000; Rowe, 2007).

Evidence from the livestock and animal feed industry can inform quality control strategies in crops bound for domestic consumption. Social marketing campaigns that raise demand for higher quality commodities must be paired with input distribution and storage programs. These campaigns should enhance the reach and capacity of the inspection authorities, extending the authority of the commodities exchange board to certify grains as inspected.

Encourage expansion of warehouse receipts and the commodities exchange board to enhance and regulate the quality and safety of food bound for domestic consumption. The nascent commodities exchange board in Nigeria is attempting to build six warehouses throughout the geographic zones and equip them with aflatoxin detection laboratories, industrial drying equipment,
and moisture/temperature gauges. This initiative if fully launched can increase and incentivize the supply of higher quality foods. Until this program is fully established, communities on a smaller scale can also launch their own warehouse receipts system to incentivize higher quality production. The programs above should also include trader education via broader, free dissemination of commodities standards.

### 7.4 Aflatoxin Control Strategies for Health

**Expand universal coverage of the HBV vaccine.** Since there is co-morbidity between high aflatoxin levels in the body and Hepatitis B, the HBV vaccine can serve as one of the most important public health interventions available for reducing the risk of cancer related to aflatoxin exposure. Reducing prevalence of HBV to zero in Nigeria could reduce liver cancer levels threefold. The HBV vaccine (which costs $0.32 to $0.90 per dose) (WHO, 2012) is now fully integrated into Nigeria’s expanded immunization program, but vaccination coverage still has room to improve. One article in 2008 noted that HBV vaccine coverage in one rural area increased from 41% to 58% through the duration of a multi-year community based, vaccination program (Odusanya, 2008).

**Improve dietary diversity, with emphasis on fruits and vegetables that are less likely to be contaminated.** Exhibit 6-1 demonstrates that Nigerians consume a wide variety of foods, but many of these (e.g., maize, groundnut, yam, edible oils) are susceptible to aflatoxin contamination. Improving demand for high-quality foods (as described above), while expanding consumption of fruits and vegetables that are not susceptible, would reduce overall exposure levels, while improving the quality of the overall diet.

**Carry out joint campaigns between the Ministries of Health and Agriculture to raise consumer demand and incentivize good agricultural practices as well as better household feeding/weaning and food use/preparation practices.** The Ministries of Health and Agriculture could promote joint behavioral change campaigns. Increasing the practice of exclusive breastfeeding among infants younger than 6 months can help reduce direct exposure to aflatoxins through the use of Ogi, a local maize-based porridge, as a common weaning food. Further, reducing consumption of high-risk foods (e.g., kulikuli or “kunu,” a maize-based beverage consumed in the North) that are susceptible to high concentrations (20 ppb up to 455 ppb aflatoxin have been observed), can be an important public health strategy, even when testing facilities are not available. Promoting reduced consumption of these food products among pregnant and lactating mothers would also help reduce infant exposure to aflatoxin during the first 1,000 days from conception to 24 months, which has a critical bearing on a child’s lifelong nutritional status (Akano and Atanda, 1990).

The Ministries of Health and Agriculture could promote joint behavioral change campaigns for minimizing aflatoxin exposure though dietary diversity as well as household farming and livelihood practices such as sorting, winnowing, dehulling of maize, drying above the ground, and using hermetic storage to reduce contamination levels in farm products for own use.

**Upgrade the food safety control and practices in accordance with local context.** Nigeria’s trading partners have in recent years been concerned about high aflatoxin levels in melon (59), ogbono (13), and durum beans (9), which together have comprised 81 of 102 EU trade alerts issues on Nigerian crop exports over the past 5 years (EU, 2012).
Improve the current surveillance and risk communication on food safety infringements. NAFDAC and SON could collaborate to ensure that official and private food safety standards reflect the GMP and HACCP approach. Further, they could train private sector companies and public sector institutions to use the inexpensive rapid test kits to proactively withdraw contaminated products from the market. These rapid test kits can also be used more frequently by trained users in markets, at assembly points, at export points, and prior to processing to enhance the availability of quality control throughout the value chain.

Consider local food consumption levels in food safety standards. MOH should upgrade codes to reflect ranges of consumption of different commodities (e.g., Average Daily Intake) while considering the tolerance level of the consumer. MOH could write country-specific standards that account for consumption patterns building on the Codex Alimentarius, consistent with the World Trade Organization Sanitary and Phytosanitary Agreement.

Explore avenues for further research. Chemopreventive agents such as Oltipraz, green tea polyphenols, and Sulforaphane can trigger detoxifying enzymes or inhibit enzymes required for the activation of procarcinogens. Enterosorbents such as Novasil® clay or calcium chlorophyllin can also be used to treat acute aflatoxicosis. They prevent absorption (and thus the toxic effects) of aflatoxins by capturing aflatoxins in the gastrointestinal tract and facilitating their elimination.19

19 Some enterosorbents may be appropriate for treatment for acute outbreaks of aflatoxicosis, but not for chronic treatment due to cost and possible side effects (Khlangwiset, 2011a). Chemopreventive agents may be more viable for preventive use, and further research is ongoing. Some enterosorbents may be more appropriate only to address acute aflatoxicosis and may not be suitable for daily or ongoing use. Continued research on side effects and long-term effects of chemopreventive agents and enterosorbents is ongoing. Green tea polyphenols, which have lowered contamination in human blood levels, are viewed as potentially viable and affordable dietary inhibitors (Khlangwiset, 2011a). Studies have shown a 43% lower AFM1 in humans and > 15% lower aflatoxin albumin adducts at 500 mg dose at costs of approximately $0.20–$1 per day (Strosnider et al., 2006).
8 Avenues for Further Action and Conclusion

Aflatoxins, some of the most toxic mycotoxins, are carcinogens that also have other severe health effects. These include immunosuppression, which affects resistance to communicable diseases such as HIV, as well as apparent impairment of nutritional uptake, which in turn is associated with child stunting. Via feed that is made with contaminated raw materials such as maize or cottonseed, aflatoxins can also affect the health, nutritional status, and productivity of some animal and fish species. Contamination of foodstuffs can also interfere with commerce and trade, with negative consequences for export and domestic sales and the economic growth that can derive from them. Lastly, aflatoxin contamination of a range of plant products—including many cereals, spices, oilseeds, coffee, and cocoa—lowers agricultural output, market acceptance, sales values, and farmer incomes.

Although evidence is spotty, aflatoxins are believed to impact virtually all countries in Africa, since they are all located within the affected band of 40°N to 40°S latitude, and have areas/seasons that contribute to the growth of the two species (*Aspergillus flavus* and *Aspergillus parasiticus*) of the fungus that can produce this toxic metabolite. At least one country in Africa has had recurring episodes of aflatoxicosis that have led to hundreds of deaths, and many other African countries are now recognizing that there are chronic high levels of contamination in key staple crops consumed by large percentages of the population, especially the poor and rural dwellers.

This report demonstrates that the cost of inaction related to aflatoxin control in Nigeria is high, and are manifested largely as human health impact. We estimate that in Nigeria, at the reported aflatoxin prevalence rates and average consumption of maize and groundnuts from nationally representative data, 7,761 liver cancer cases out of 10,130 liver cancer cases in 2010 can be attributed to aflatoxin contamination. Even at average aflatoxin contamination at 20ppb and consumption level of 200g per 60-kg person intake of food, 3,709 liver cancer cases, or more than a third of the reported liver cancers cases in 2010 can be attributed to aflatoxins. Assuming that all the cancer cases result in death our upper-bound estimate of the monetized value of these cases can be as high as 0.5% of Nigeria’s GDP in 2010.

While a range of 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. So it makes most sense to prioritize interventions 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. While this report describes solutions generically, customization to local circumstances is desirable. Patterns of behavior by producers, traders, processors, retailers, and consumers do have an impact on the degree of utilization of inputs and services that might lessen the problem.

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, commerce 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.
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.

Finally, this country assessment as well as another pilot carried out in parallel in Tanzania, points the way toward a new methodology for assessing the situation, outlook, and needs of any developing country, in order to establish the evidentiary basis for policy and institutional reform; regulatory improvement; concerted action by both public and private stakeholder groups; and ultimately behavioral change by actors within value/supply chains, as well as consumers.
9 References


Adetunji M.C. (2012) Atanda, O.O; and Ezekiel, C.N. Unpublished PhD Dissertation analyzing aflatoxin B1 samples in 5 regions. Dept. of Food Science and technology, Federal University of Agriculture Abeokuta, Ogun State.


## Appendix A – Participants Interviewed

<table>
<thead>
<tr>
<th>District</th>
<th>Sector/Institution</th>
<th>People Interviewed</th>
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</table>
| Minna, Niger     | MOH                                 | • State Hospital  
• HIV unit  
• Immunology unit  
• Nutrition unit  
• Dept. of planning, monitoring and evaluation  
• Director of produce and pest control  
• Deputy Director of Extension Services, veterinarian  
• Livestock and fisheries development, specifically in charge of public/private partnership and MDG programme  
• Focus group discussions with mothers  
• Operations manager  
• Senior Lecturer  
• Grain seller at Mokwa central market  
• Posho Miller  
• Input supplier of animal feed, post-harvest equipment and agro-chemicals (Herbicides, Insecticides, Fertilizers, Seeds and Sprayers).  
• Focus Group Discussions:  
  o 1 FGD with Kampala village, Minna with the Bakobgadagatu women co-operative group.  
  o 1 FGD with male farmers at Kampala village in Bosso Local.  
  o Farmers at Beji Village, Bosso Local Government,  
• 1 male farmer, Ndayako village, producer of melon, groundnut, beans, yams, cocoyams, rice, maize, guinea corn, etc.  
| Minna, Niger     | National Strategic Food Reserve Dept. | • Operations manager                                                                                                                                                                                                     |
| Minna, Niger     | Federal University of Technology    | • Nutrition unit  
• HIV/AIDS representative  
• State epidemiologist  
• Kogi State ADP, Rural Institution Development unit (RID)  
• Agricultural Extension officers at the Kogi State Agricultural Development Program:  
• Deputy Director Root Extension Program, Local government/state trade office,  
• ADP veterinarian expert,  
• ADP women in agriculture leader,  
• MOA-Director of Produce, the director of Agric. Services, Director Home Economics Ministry  
• Director, nurses at Hospital Akure, General Hospital Akure  
| Akure, Ondo state | State MOH                           | • Director, nurses at Hospital Akure, General Hospital Akure                                                                                                                                                             |
| Akure, Ondo state | Ministry of Agriculture             | Engineer and manager of the Federal Agricultural rural development national food reserve agency storage complex, Akure Ondo State ADP  
• Post harvest Handling and engineering unit of the Director  
• Head of training  
• Director of crop science  
• Director planning,  
• Deputy Director Engineering,  
• DD Extension  
• Director fisheries  
• MOA-Director of Produce, the director of Agric. Services, Director Home Economics Ministry  
• Director, nurses at Hospital Akure, General Hospital Akure  

Niger state State radio/ broadcasting corp'n
Lokoja, Kogi State MOH  
• Nutrition unit  
• HIV/AIDS representative  
• State epidemiologist
Lokoja, Kogi Agriculture officials  
• Kogi State ADP, Rural Institution Development unit (RID)  
• Agricultural Extension officers at the Kogi State Agricultural Development Program:  
• Deputy Director Root Extension Program, Local government/state trade office,  
• ADP veterinarian expert,  
• ADP women in agriculture leader,  
• MOA-Director of Produce, the director of Agric. Services, Director Home Economics Ministry  
• Director, nurses at Hospital Akure, General Hospital Akure
Akure, Ondo state State MOH  
• Director, nurses at Hospital Akure, General Hospital Akure
Akure, Ondo state Ministry of Agriculture  
• Director, nurses at Hospital Akure, General Hospital Akure  
• MOA-Director of Produce, the director of Agric. Services, Director Home Economics Ministry  
• Director, nurses at Hospital Akure, General Hospital Akure

Minna State Gen’l Hospital  
Focus group discussions with mothers
• Operations manager
• Senior Lecturer
• Grain seller at Mokwa central market
• Post harvest Handling and engineering unit of the Director
• Head of training
• Director of crop science
• Director planning,  
• Deputy Director Engineering,  
• DD Extension  
• Director fisheries
<table>
<thead>
<tr>
<th>District</th>
<th>Sector/Institution</th>
<th>People Interviewed</th>
</tr>
</thead>
</table>
| Akure, Ondo state        | Commercial Sector                | • Produce and supply feed for different animals like poultry, fish, dog, piggery etc  
• Agrochemical seller (herbicides, pesticides and fertilizers in small quantities (ammonia), he is a vendor the shop owner was not available, dryers, silo, maize sheller  
• Elder Oladimeji Success (Teedy Engineering),  
• Groundnut cake (kulikuli) sellers in Adedeji market Oja Oba Akure |
| Akure, Ondo state        | Focus Groups                     | • Mothers/female farmers who are mothers of children under 5 at Olorunferanmi community, Adofure area  
• Nursing mothers interviewed at the Akure General Hospital  
• Farmers groups: Cassava farmers in Ago Oluwarefami  
• Cocoa farmers cooperative. |
| Lagos                    | NAFDAC                           | • Ports Inspectorate Division  
  • Director  
  • Director, Enforcement  
  • Deputy Director, Food  
• Establishment Inspectorate Division  
  • Head, EID  
  • Assistant Directors  
  • Deputy Directors  
• Central Laboratory Complex  
  • Head of Laboratory  
  • Deputy Director |
| Lagos                    | Standards Organization of Nigeria| • Director, Product Certification  
• Director, Enforcement  
• Director, Tech S  
• Deputy Director, Testing  
• Head, Mycotoxins Testing Laboratory  
• Head, Food Safety  
• S Head, Food Technologist  
• Head, Tech. Operation South  
• Head of CODEX  
• Library and Information Services |
| Alausa-Ikeja, Lagos      | Chromogene International Ltd     | • Technical Sales Executive (Food & Feed) |
| Ikeja, Lagos             | O.M. Simons Nigeria Ltd          | • Chairman |
| Lagos                    |                                  | • Regulatory Affairs Manager |
| Lagos                    | Animal Science Association of Nigeria | • President |
| Ibadan                   | Nigerian Stored Products Research Institute | • Deputy Director (Food)  
• Senior Research Officers  
• Research Officers |
| Ibadan                   | International Institute of Tropical Agriculture | • Mozambique aflatoxin expert  
• Plant Pathologist (Aflasafe)  
• Regional Coordinator, Aflasafe Project  
• Researcher (part time/student)  
• Cassava Breeder/Geneticist  
• Research Admin Manager  
• Coordinator, Aflatoxin Mitigation in Southern Africa  
• Visiting Scientist |
<p>| Ibadan                   | Fataroy Steel Industry Limited   | • Storage fabricator |</p>
<table>
<thead>
<tr>
<th>District</th>
<th>Sector/Institution</th>
<th>People Interviewed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ibadan</td>
<td>Nigeria Agric Quarantine Service</td>
<td>• Manager</td>
</tr>
<tr>
<td>Ibadan</td>
<td>Process Concepts and Technologies Ltd</td>
<td>• Engineer</td>
</tr>
<tr>
<td>Oyo state</td>
<td>Federal MOA and Natural Resources</td>
<td>• Seed Scientist</td>
</tr>
<tr>
<td>Osogbo</td>
<td>Fountain University</td>
<td>• Professor and Previous president, Nigeria Mycotoxicology Society</td>
</tr>
<tr>
<td>Lagos</td>
<td>Animal Care Services Konsult (Nig) Ltd</td>
<td>• Principal Manager (Tech. Lab Services)</td>
</tr>
<tr>
<td>Kaduna</td>
<td>Punch (newspaper)</td>
<td>• Chief Correspondent</td>
</tr>
<tr>
<td>Abeokuta, Ogun</td>
<td>Ogun State Agricultural Development Programme</td>
<td>• Deputy Director, Technical Services/SMS Livestock</td>
</tr>
<tr>
<td>Abuja</td>
<td>MOA</td>
<td>• Women in Agriculture Expert&lt;br&gt; • Head of Extension&lt;br&gt; • Team lead of extension under the Agenda for Transforming Agriculture Initiative&lt;br&gt; • Other leader of extension under the ATA initiative&lt;br&gt; • Zonal Extension Officer</td>
</tr>
<tr>
<td>Abuja</td>
<td>Export Promotion Council</td>
<td>• Expert on aflatoxin and import/export&lt;br&gt; • Director, Product Development&lt;br&gt; • Director, Industrial Plants and Equipment Department</td>
</tr>
<tr>
<td>Abuja</td>
<td>Federal MOH</td>
<td>• Chief Nursing Officer, National Cancer Control Programme&lt;br&gt; • Medical Officer, National Cancer Control Programme&lt;br&gt; • Director, Food Safety Programme, Dept. of Food and Drug Services&lt;br&gt; • Scientific Officers&lt;br&gt; • Consultants involved in food safety legislative review&lt;br&gt; • Head, Department of Family Health</td>
</tr>
<tr>
<td>Abuja</td>
<td>Raw Materials Research and Development Council</td>
<td>• Focus group with leadership by Dr. Anthony Negedu</td>
</tr>
<tr>
<td>Abuja</td>
<td>National Agricultural Seeds Council</td>
<td>• Agricultural Engineer&lt;br&gt; • Principal Agricultural Crop Specialist&lt;br&gt; • Seed Analyst</td>
</tr>
<tr>
<td>Abuja</td>
<td>Nigeria Atomic Energy Commission</td>
<td>• Gamma Irradiation Facility Technology Centre&lt;br&gt; • Director RA&amp;S Nuclear Tech Centre&lt;br&gt; • Deputy Director&lt;br&gt; • Dep Director Nuclear Tech Centre</td>
</tr>
<tr>
<td>Abuja</td>
<td>University of Abuja, Department of Crop Science</td>
<td>• Mycologist</td>
</tr>
<tr>
<td>Abuja</td>
<td>Federal Science &amp; Technical Education (STEP-B Project)</td>
<td>• Technical Officer,</td>
</tr>
<tr>
<td>Abuja</td>
<td>Raw Materials Research and Devp Council</td>
<td>• Deputy Director, Advanced Materials</td>
</tr>
<tr>
<td>Abuja</td>
<td>Planning and Information Service Dept.</td>
<td>• Director</td>
</tr>
<tr>
<td>Abuja</td>
<td>Medical Lab Science Council of Nigeria</td>
<td>• PhD student trying to analyze all mycotoxins in maize around Abuja&lt;br&gt; • Medical Lab Scientist</td>
</tr>
<tr>
<td>Abuja</td>
<td>Security and Commodities Exchange</td>
<td>• Mycotoxin Head/Quality Assurance</td>
</tr>
</tbody>
</table>