AFLATOXINS IN KENYA: AN OVERVIEW

THE AFLACONTROL PROJECT: REDUCING THE SPREAD OF AFLATOXINS IN KENYA AND MALI

WHAT ARE AFLATOXINS AND WHY ARE THEY DANGEROUS?

Aflatoxins are naturally occurring toxic substances found in maize, groundnuts, and other crops. They are produced by various species of Aspergillus fungi, which live in soil and are found in many parts of the world, including the southern United States, eastern Europe, and many developing countries. Agricultural produce is prone to aflatoxin contamination, particularly when produce comes into contact with soil during harvesting, threshing, and drying. Contamination can also occur when grains are in storage due to pest infestation and the poor conditions that lead to accelerated growth rates of Aspergillus fungi.

Aflatoxin is produced in minute quantities, but its potency, prevalence, and the ease with which it can permeate farmers’ fields and storage areas make this highly carcinogenic metabolite particularly dangerous. You cannot see, smell, feel, or taste aflatoxin in grains; laboratory testing is required to discover its presence. You can, however, avoid use of grains suspected to be contaminated or test them before using.

Acute exposure to high levels of aflatoxins leads to aflatoxicosis, which can result in rapid death from liver failure. In 2004, during the worst known outbreak of aflatoxicosis in Kenya, 317 cases were reported and 125 people died. The minimum level of aflatoxin exposure required to cause aflatoxicosis is not known, but the disease mostly affects children.

Chronic exposure to aflatoxins affects the incidence and severity of many infectious diseases. This type of extended aflatoxin exposure is implicated in the following for both animals and humans:

- Immunodeficiency and immunosuppression;
- Stunting and kwashiorkor, which causes an interference with the metabolism of micronutrients and immunosuppression (by negatively impacting the bioavailability of micronutrients) in children;
- Liver cancer, especially in people with hepatitis B or C; or
- Liver disease.

The Center for Disease Control has estimated that more than 4.5 billion people in developing countries are chronically exposed to aflatoxins in their diets. On May 10, 2010, the Government of Kenya issued a public safety alert after finding aflatoxins in maize in eastern Kenya and the coastal region above tolerable levels, causing considerable anxiety among maize and livestock producers and consumers.

This project note describes preliminary results from research conducted in the eastern and coastal regions of Kenya by the AFLACONTROL Project—a collaborative research project—to evaluate the prevalence of aflatoxins along the maize value chain and identify critical points where intervention strategies are likely to have the greatest impact. This project note is intended for the Kenyan Ministry of Agriculture, the Kenyan Department of Public Health, and other agencies or organizations dedicated to mitigating the problems associated with aflatoxin contamination in maize and preventing future outbreaks.

BOX 1: Maximum levels of Aflatoxin deemed safe for human and animal consumption in Kenya

<table>
<thead>
<tr>
<th>Aflatoxins can be highly toxic to animals as well as humans. When contaminated grain or feed is ingested by an animal, the toxin can also contaminate the meat, eggs, and milk produced, which can then infect the people who consume them. In cows, the aflatoxins B1 and B2 metabolize into the highly toxic M1 and M2 found in milk. In Kenya, the maximum level of aflatoxins allowable in maize intended for human consumption is 10 parts per billion, the same as that allowed by the World Food Programme. The European Union sets the level at 4 ppb (ppb). The U.S. Food and Drug Administration also sets maximum allowable levels of aflatoxins for other uses.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Beef cattle and swine used for breeding or mature poultry</strong> = 100 ppb</td>
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<tr>
<td><strong>Feeds intended for finishing swine of 100 pounds or greater</strong> = 200 ppb</td>
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<tr>
<td><strong>Feeds intended for finishing feedlot beef cattle</strong> = 300 ppb</td>
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<tr>
<td><strong>Milk</strong> = 0.5 ppb (since M1 is highly toxic)</td>
</tr>
</tbody>
</table>

1 Crops that are frequently affected include cereals (maize, sorghum, pearl millet, rice, wheat), oilseeds (peanut, soybean, sunflower, cotton), spices (chili peppers, black pepper, coriander, turmeric, ginger), and tree nuts (almond, pistachio, walnut, coconut). Dairy and meat are also affected.

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WHAT IS THE AFLACONTROL PROJECT?

The Aflacontrol Project, facilitated by the International Food Policy Research Institute (IFPRI) and funded by the Bill & Melinda Gates Foundation, aims to reduce the risk of aflatoxin contamination of maize and groundnuts along each value chain.3 The project aims to increase understanding of the economic and health impacts of aflatoxin contamination and to identify and promote the most cost-effective methods and technologies available to reduce contamination of food and feed.

In Kenya, the project includes partners from the International Maize and Wheat Improvement Center (CIMMYT); the University of Pittsburgh (Pennsylvania, United States); the United States Uniformed Health Services; the Kenya Agricultural Research Institute (KARI); and ACDI/VOCA, a private, nonprofit organization that works in close association with the Eastern Africa Grain Council. Since May 2009, scientists from IFPRI, KARI and CIMMYT, in collaboration with ACDI/VOCA, have been collecting information about farming practices and the prevalence of aflatoxins along the maize value chain in three areas in Kenya: two areas of eastern Kenya considered high risk for aflatoxins (from Mbeere to Embu and in Makueni) and one low-risk region in southwestern Kenya (Homa Bay, Rongo, and Kisii). (Map 1)

Scientists from KARI and CIMMYT, with ACDI/VOCA, have collected samples of maize from along the value chain on a monthly basis for contamination testing since September 2009.4 This project note refers to samples collected between September and December 2009. Results from the following season will be presented in 2010 as they become available. Researchers from IFPRI, CIMMYT and KARI have also undertaken a qualitative value chain analysis for maize in both regions.

3 The Aflacontrol Project is working on the maize value chain in Kenya and the groundnut value chain in Mali. This note is specific to work in Kenya. A similar document will be produced for Mali.

4 Other research activities undertaken in the context of the study include analyses to estimate the economic impacts of Aflatoxin in terms of health consequences and livelihoods, identify critical control points, and evaluate various control strategies, based on an understanding of knowledge, attitudes, perceptions, and practices along the value chain regarding aflatoxin contamination and its control.

HOW ARE LEVELS OF AFLATOXINS ALONG THE MAIZE VALUE CHAIN MEASURED AND ANALYZED?

Samples are being collected from farmers and from markets, located along transects in each of the three regions covered by the project, so as to capture a range of agroecological zones. The first maize analyzed by the Aflacontrol Project came from farmers’ fields in Makueni, sampled during the second harvest in late 2009. Sampling was repeated for each farmer to see if aflatoxin levels increased over time and under different storage techniques. Two to three weeks after harvest, samples were taken from cobs still drying on the ground, and, ultimately, monthly samples of each maize variety grown were taken at all stages of the value chain, including farmers’ stores, retailers, mills, and warehouses. Post-harvest samples were also collected from the upper eastern and southwestern study sites, and readings from a global positioning system were recorded for each sample to map out aflatoxin prevalence.

In 2009, 540 samples were collected. These samples are not representative of the population as a whole because aflatoxin testing was limited to the few farmers who had a successful harvest in spite of the 2009 drought. The harvest in early 2010, however, was very successful, so the pre-harvest and post-harvest samples taken from all sites on the same monthly basis in 2010 are expected to be more representative.

Maize samples were prepared and tested according to CIMMYT and ICRISAT protocols at the ICRISAT laboratories in Nairobi using the ELISA procedure (see http://programs.ifpri.org/afla/afla.asp for method details). Since moisture content is a critical factor in

BOX 2: What factors contribute to aflatoxin contamination in maize?

Soil: Grain may be contaminated through direct contact with the Aspergillus fungi spores present in soil or by windborne spores that can infect maize cobs still on the plant.

Moisture: Moisture in the grain itself or from relative humidity is a very important factor in fungal growth and, thereby, aflatoxin formation. The relative humidity levels most favorable for fungal growth are between 65 and 80 percent; Aspergillus flavus, in particular, only grows when relative humidity in the air is above 85 percent or moisture content in the grain is above 16 percent.

Temperature: The rate of fungal growth depends on the temperature of the grain. Fungal growth is slow and minimal in cool-to-cold grains but fast and extensive in warm grains. The optimal temperature for Aspergillus flavus growth is 25°C–28°C.

Oxygen: Most fungi will not grow in anaerobic conditions where the oxygen content is below 5 percent.

Pests: Insect and pest damage to grain creates wounds through which fungal infection can occur and can lead to increased aflatoxin contamination.
the development of the fungi that produce aflatoxins, grain moisture content was recorded at both the time of sampling and before processing for aflatoxin analysis. From the 2009 samples, 341 were positive for aflatoxins.

In all three regions where the Aflacontrol Project collected samples, the moisture content of the maize stayed relatively constant at less than 13.5 percent—the level recommended to avoid the growth of mold. In spite of this, 52 percent of the 341 samples analyzed were contaminated with aflatoxin, and 24 percent were above the legal limit for human consumption of 20 ppb. Aflatoxin contamination was highly variable between sites and over time.

Levels of contamination among samples collected from farmers’ stores in south western Kenya were very low while aflatoxin contamination above 20 ppb was found in both areas studied in the eastern province (see Figure 2).

- In Kisii, 33 percent of samples collected from farmers’ stores one month after harvest were contaminated but the aflatoxin level was below the 20 ppb legal limit.
- The proportion of samples with aflatoxin levels greater than 20 ppb was higher in Makueni than in Embu or Mbeere.
- Contamination levels above 3,000 were found in both eastern sites; Embu and Makueni each had individual samples with aflatoxin levels greater than 9,000 ppb.

*Figure 2*: Percent of maize samples from markets with aflatoxin levels > 20 ppb, Sept – Dec 2009 (1 and 2 months post harvest)

In the market samples, highly variable aflatoxin contamination levels were found in both eastern and south western sites (figure 3) with maximum levels of 3,479 ppb in Makueni; 3,442 ppb in Kisii; 255 ppb in Mbeere; and only 21 ppb in Embu. The variability in these results emphasizes the importance of ensuring an adequate sample before extrapolating data to the broader population.

These results also suggest that contaminated maize may be entering the market from farther afield. There needs to be a better understanding of how maize flows along the value chain, and greater monitoring of maize entering markets is important to protect consumers from purchasing contaminated maize. Due to the high levels of suspect maize available in marketplaces, sampling at the trade level is being expanded to cover areas that are potential sources of such maize within the transient survey areas.

*Figure 3*: Percent of maize samples from farmers’ stores and markets with aflatoxin levels > 20 ppb, Sept – Dec 2009 (1 month post harvest)

WHAT PRACTICES AND STRATEGIES CAN MITIGATE AFLATOXIN CONTAMINATION ALONG THE MAIZE VALUE CHAIN?

Unfortunately, the presence of aflatoxins in food products cannot be completely eliminated; it can, however, be controlled in order to avoid causing harm to humans. While current levels of aflatoxins in maize in Kenya are high, preventive practices along the length of the maize value chain can help reduce the risks faced by farmers and consumers.

**Pre-harvest:** *Aspergillus* fungi often infect plants that are subject to stress, such as drought or pests, although many field conditions can lead to fungal colonization. Late planting, lack of crop rotation, inadequate irrigation or soil nutrients, and poor crop-residue management can increase susceptibility to aflatoxin contamination. Conversely, treating soils with lime and good farming practices—such as timely planting, weeding, and pest and disease control practices—reduce plant susceptibility to aflatoxins.

Maize varieties that have a good husk cover with ears that droop at physiological maturity are recommended as the best type for farmers in Kenya to avoid pre-harvest aflatoxin contamination. These varieties avoid moisture penetration while in the field before the crop is harvested.

Additionally, research is underway to develop pre-harvest biocontrol techniques and breeds of maize that are resistant to aflatoxins. Biocontrol techniques, such as using nontoxicogenic strains of Aspergillus that do not produce aflatoxins to outcompete their toxin-producing sister strains, have been developed in Nigeria by the International Institute for Tropical Agriculture.

**Harvest:** Timing of harvest is a critical issue in terms of aflatoxin accumulation. For example, long rains can prevent maize from drying properly, which can result in harvesting before the maize has reached maturity. On the other hand, in drought conditions, fear of theft may drive people to harvest too early.

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Note (Figures 2 and 3): Due to drought, data were taken only from a small sample within each area so should not be taken as fully representative of the areas studied. In addition, maize sampled at the markets may have come from other areas; no data on the sources of the market maize are available.
With improperly dried maize, there is a high likelihood of kernel damage by pests, increasing the likelihood of fungal growth. Harvesting at the right time can effectively mitigate some risk.

**Drying:** At the household level, maize is either dried on the cob or shell before drying. Once shelled it may be dried on the ground or on plastic or cloth tarp. Grain dried in direct contact with soil is more susceptible to contamination by fungi that produce aflatoxins. The simple use of a tarp can prevent some level of aflatoxin contamination. But very few of the farmers surveyed who own a tarpaulin were found to use it because, during focus group surveys, most farmers associated the risk of aflatoxin contamination with inadequate drying but not specifically with the importance of avoiding contact between the maize and the soil. It is important to promote not just awareness of Aflatoxins among consumers but also an in-depth knowledge of the problem.

**Storing:** To avoid contamination with aflatoxin, maize must be stored in conditions that prevent exposure to and growth of Aspergillus fungi, such as maintaining cool air temperatures and low humidity. Once maize is dried, it is stockpiled and placed either directly on the floor, in baskets, or in traditional or polypropylene sacks; storage containers should be airtight to create anaerobic conditions that can help to prevent mold growth. Ideally, sacks or baskets are then placed in granaries with wood floors because storing maize in direct contact with the ground can lead to moisture from condensation. If metal silos are used, grain is placed loosely inside. Focus group surveys found, however, that many farmers keep bags of maize stacked on the floor of their houses instead due to fear of theft. Although they do not like to store maize for long—due to high risk of crop loss from large grain borer, maize weevil, and mold—using airtight sacks on elevated platforms is preferable during any length of storage. But it is not currently practical in all places as many farmers do not have access to the technology.

**Preserving and sorting:** Using ash, acetic acid, or phostoxin (currently used minimally, as it is highly restricted in Kenya and much of East and South Africa), or acetic in storage units can prevent pests, and removing potentially contaminated kernels can reduce the likelihood of contamination. Many farmers surveyed in the Aflacontrol Project manually removed maize that appeared discolored or moldy at the household, but the discarded maize could still enter the food chain as animal feed. Other farmers reported mixing moldy maize with fresh maize to decrease the level of mold consumed. Others reported consuming moldy maize they produced as they knew it was safe, but they claimed they would never consume moldy maize from stores as that was unsafe.

**Trading and selling:** Traders often inspect maize and offer payment based on the percentage of mold in the bags they inspect. Traders will then either store the maize in the bags it arrived in or further air it out on tarps on the ground. Maize is then placed either directly on storehouse floors or back in bags, sometimes with pesticides. The storage period depends on the size of the operation, but there is typically a quick turnover of maize. In some places, traders may come to the producers directly to buy their maize.

Maize may be sold in local markets or transported to larger towns or large-scale millers in urban areas. Informal interviews found evidence of little or no testing for aflatoxins in markets.

**WHAT ARE THE NEXT STEPS?**

Analysis within the maize value chain in Kenya revealed that awareness of the chronic health impacts of aflatoxins is lacking among both producers and consumers. While number of low-cost technologies exist (for pre-harvest, harvest, and post-harvest) to prevent and detect aflatoxin contamination, application of such safety practices and strategies is limited for a number of reasons, including the decline in available farm land; the impossibility of rotations; and limited availability of information, resources, technology, and infrastructure for optimal drying, storage, and testing.

Farmers and consumers are unlikely to adopt new methods unless the following takes place: (1) they are aware of cost-effective mitigation techniques; (2) they are aware of the impact of aflatoxins on health, trade, and livelihoods; (3) there are real incentives (positive and punitive) to investing labor and resources toward mitigating aflatoxin contamination; and (4) there are alternative uses for contaminated grains and alternative sources of food, particularly when faced with chronic food insecurity.

**Key areas for future research, investment, and development for the reduction of aflatoxins in developing countries include:** development of maize varieties and hybrids with tolerance to infection by *Aspergillus* fungi and, subsequently, to aflatoxin accumulation; increasing awareness among producers and consumers of the health and economic impacts of aflatoxin contamination; creating market incentives to implement aflatoxin-mitigation techniques (e.g., through a market premium for aflatoxin-free food); developing and promoting cost-effective technologies to reduce contamination along the entire maize value chain; promoting alternative uses for grains infected with aflatoxin (for example, in biofuels); developing low-cost sampling and testing technologies; improving the intensity of testing to reduce the amount of contaminated maize entering the market place; and strengthening institutions that are responsible for food-safety regulation..

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