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Aflatoxins – the invisible threat in foods and feeds

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The Facts

Aflatoxins are highly toxic fungal metabolites causing suppression of the immune system, growth retardation, liver cancer, and even death in humans and domestic animals. Aflatoxins also affect the rate of recovery from protein malnutrition, Kwashiorkor (Hendrickse, 1984), and exert severe nutritional interference, including in protein synthesis, modification of micronutrients, and uptake of vitamin A and D. Exposure in animals reduces milk and egg yields. The contamination of milk and meat is passed on to humans.

Green growth of *Aspergillus* fungus on maize cob. – IITA

Aflatoxins affect cereals, oilseeds, spices, tree nuts, milk, meat, and dried fruits. Maize and groundnut are major sources of human exposure because of their higher susceptibility to contamination and frequent consumption. The toxins are most prevalent within developing countries in tropical regions and the problem is expected to be further exacerbated by climate change (Cotty and Jaime-Garcia, 2007).

The aflatoxin-producing fungi (*Aspergillus* spp.) come in contact with crops in the field during crop development. They stay with the crops until their final use. If the environment where crops are stored is humid and warm, the fungi, which moved into storage with the crops, can proliferate and produce more aflatoxins. *Aspergillus* communities in different regions differ in their aflatoxin-producing ability. In some locations, they produce large concentrations; in others, they produce relatively lower amounts.

The high incidence of aflatoxin throughout Sub-Saharan Africa aggravates an already food insecure situation. Agricultural productivity is hampered by contamination, compromising food availability, access, and utilization. Unless aflatoxins in crops and livestock are effectively managed, marketable production and food safety cannot improve. Thus, the economic benefits of increased trade cannot be achieved. Aflatoxins cost farmers and countries hundreds of millions of dollars annually. These losses have caused crops to be moved out of regions, companies to go bankrupt, and entire agricultural communities to lose stability. Additionally, effective control must be achieved before many development activities aimed at achieving food security can be implemented, such as local food procurement strategies complementing food aid and school feeding programs, and ready-to-use therapeutic foods.

Aflatoxin Management

Contamination occurs before and after crop maturity. To ensure the greatest crop value and the lowest exposure of humans to aflatoxins, management must extend from field to fork. Currently, contamination is prevented by a combination of tools, such as post-harvest drying (where cost-effective), proper storage, shelling, de-hulling, sorting, early harvest, using regionally adjusted planting dates, and insect control. Pre-harvest management is unreliable. In 1989, farmers in the USA formed the Multi-crop Aflatoxin Working Group and joined with the US Department of Agriculture to increase research on aflatoxin management with an emphasis on breeding and transgenic crops. When the program was discontinued in 2008, commercially useful resistant crops still had not been developed, but there was an unexpected advance.

Biocontrol – a novel approach

A biological control technique greatly reduced aflatoxins in all the susceptible crops in a cost-effective manner and over a broad geographic area. Native strains of *A. flavus* that do not produce aflatoxins ("atoxigenic strains") are used to competitively exclude aflatoxin-producing strains from the crop environment.

CGIAR Systemwide Program on Integrated Pest Management (SP-IPM) is a global partnership that draws together the diverse IPM research, knowledge, and expertise of the international agricultural research centers and their partners to build synergies in research outcomes and impacts, and to respond more effectively to the needs of farmers in developing countries.

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Inoculated sorghum grains broadcast in the field. – R. Bandyopadhyay

The atoxigenic strains are inserted into a carrier (e.g. sorghum) which acts as a fungal food source and is applied to crops 2-4 weeks prior to flowering. For small fields the product can be tossed onto the crop by hand. The strain profile shifts from one dominated by aflatoxin producers to one in which atoxigenics dominate, resulting in reduced contamination of the crop. The positive influences of atoxigenic strains carry over between crops, providing additive effects across years. A single application benefits not only the treated crop but also crops in rotation. Additionally, because fungi move throughout the environment, as the safety level of fungal communities within treated fields improves, so does the safety of fungal communities in areas neighboring treated fields. The technology also brings benefits into storage. First, there are fewer aflatoxin-producers moving into the store, and secondly, the biocontrol agents stay with the crop until use. Thus, competitive exclusion in the field translates into a decreased risk of contamination during storage and transport.

A technology highly suitable and beneficial for small producers in Africa

Biocontrol in the field has proved a useful method for preventing aflatoxin contamination in maize and groundnut. The International Institute of Tropical Agriculture (IITA) conducted trials in Nigeria. Native atoxigenic strains reduced contamination by up to 99%. The National Agency for Food and Drugs Administration and Control (NAFDAC) gave IITA provisional registration to begin testing of the inoculum of a mixture of four strains under the trade name **afla**safe™. In 2009, maize farmers who applied **afla**safe™ achieved, on average, an 80% reduction in aflatoxin contamination at harvest and 90% after storage. Private and public sector engagement is now necessary to introduce the technology country-wide and at regional level, as with the widely used AF36 and Afla-Guard™ products in the USA.

When various aflatoxin management practices were evaluated, it was found that biological control is one of the most cost-effective solutions in Africa. Wu and Khlangwiset (2010) applied health-based analyses of cost-effectiveness to the method in Nigeria. Although the analyses examined only impacts on the incidence of liver cancer, the potential payoff is compelling. Estimating the cost-effectiveness ratio (CER) as the gross domestic product multiplied by disability-adjusted life years saved per unit cost, the study revealed that the CER of treating all maize fields in Nigeria rated between 5.1 and 9.2, rising to between 13.8 and 24.8 if treatment were restricted to maize for human consumption.

aflasafe™ to reduce aflatoxin contamination in maize. – R. Bandyopadyhay

The reality in future

Biocontrol is highly effective, but some contamination is inevitable. Thus, aflatoxin management cannot solely rest in biocontrol. It must be blended with traditional management as well as the redirection of contaminated crops to alternative uses to avoid human exposure. Governments and industry need to establish standard procedures for effective low-cost testing and alternative uses of contaminated products. Contamination levels >20 ppb are unsafe for human consumption but the crop may still be utilized for animal feed as long as contamination does not exceed 300 ppb in feed for mature beef cattle or 100 ppb in feed for swine. Other alternative uses include ethanol production. When such rules are established, the crop can be managed for maximum value without risking human exposure to unacceptable aflatoxin concentrations.

Further reading:

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SP-IPM, 2009. Advances in Preventing and Managing Contaminants in Foods, Feeds, and the Environment. IPM Research Brief No. 7. SP-IPM Secretariat, IITA, Ibadan, Nigeria. 40 pp. http://www.spipm.cgiar.org/ipm-research-briefs (accessed 29 September 2010).

Wu, F. and Khlangwiset P., 2010. Health economic impacts and cost-effectiveness of aflatoxin-reduction strategies in Africa: case studies in biocontrol and post-harvest interventions. *Food Additives and Contaminants* 27: 486–509.

About the author

Ranajit Bandyopadhyay is a plant pathologist at IITA based in Ibadan, Nigeria. He is responsible for IITA's Africa-wide research and development activities related to diseases of maize, soybean, cowpea, cassava, banana, and yam. His current research on mycotoxins focuses on developing an understanding of their occurrence, the bio-ecology of toxigenic fungi, policy and institutional issues, and methods to manage mycotoxins with focus on biological control and integrated management.

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