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Aflatoxin Prevalance in the Developing World

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Overview

Aflatoxin is a naturally occurring carcinogen produced by the fungus *Aspergillus,* particularly *Aspergillus Flavus* and *Aspergillus Parasiticus.* Aflatoxin contamination places an economic and health burden on farmers throughout the developing world,[1] but reliable prevalence data are difficult to obtain. This report analyzes data from 25 primary research articles published within the last 15 years in order to provide a summary of aflatoxin contamination in the developing world.

Note that this review is focused on documented and estimated prevalence estimates in the field. There is a large body of literature presenting experimental data and characterizing the course of contamination or illness under experimental conditions; that literature is not summarized in this document. For the same reason, the literature relating to potential treatments for contamination and aflatoxicosis is not summarized here.

This report is divided into three parts, roughly aligning with phases of the agricultural value chain. Data for prevalence at the production and processing stage are presented first, followed by data for prevalence during storage, and finally by a summary of data for aflatoxin levels at consumption and point-of sale.

While differences in methods and research questions limit the potential for meta-analysis, the following broad conclusions are suggested by the literature:

- The **crops** widely known to be affected by aflatoxin are maize and groundnuts. There are limited data available about prevalence in other crops such as cassava, but maize and groundnuts are the most studied and generally thought to be the most important sources of aflatoxin exposure in the developing world.
- According to epidemiological estimates, the **geographic regions** most likely to be affected by aflatoxin are Southeast Asia and Sub-Saharan Africa.[2]
- The **agroecological conditions** most likely to contribute to aflatoxin contamination are: warm humid climates; irrigated hot deserts; and drought.[3]
- Contamination can occur **throughout the value chain**, during production, processing, storage, and point-of-sale. The areas most at risk for post-harvest contamination do not always align with the areas most at risk for pre-harvest contamination.[4]
- The **storage and processing** methods associated with contamination in certain cases include use of polyethylene bags,[5] use of mechanical shelling machines,[6] storage with cowpea or sorghum,[7] and storage for extended periods.[8]

When available, aflatoxin levels are reported in parts per billion (ppb) of the toxin itself. However, measurement indicators vary by study. Some analyses present colony-forming units (CFU) per gram (a measure of the fungi present rather than of the toxin) and some analyses report distributions rather than means.

Production & Processing

Aflatoxin-producing fungi in the soil used for crop cultivation may lead to aflatoxin contamination at the point of consumption. In a 2009 study of Nigerian soils in maize fields, Donner et al. found the *Aspergillus* fungi in all 55 soil samples studied, at levels ranging from 55-3736 CFU per gram. A 2010 ICRISAT study found *Aspergillus* fungi in each of 1053 soil samples from 952 farms throughout Malawi, with mean regional levels ranging from 828-16,108 CFU per gram.

Aflatoxin has also been detected in plants pre-harvest. A 1994-1995 survey in Benin found aflatoxins in pre-harvest maize from over 30% of 140 sampled fields, with a country-wide mean kernel infection rate of approximately 20% and a mean contamination level of approximately 140 ppb.[9] In 2001, researchers sampled pre-harvest maize from 103 farms in southwestern Nigeria, finding aflatoxin in 18.4% of the farm samples at a mean level of 28 ppb.[10]

The choice of maize variety may affect susceptibility to contamination. In a study of 25 farms in 5 districts of Senegal, the "Jaune de Bambey" variety had significantly higher mean aflatoxin levels as compared to two other varieties, the "Synthetic C" and "Early Thai" (133 ppb vs. 3.9 and 1.3 ppb).

In 25 maize samples from 5 districts in Senegal, unshelled and hand-shelled maize had significantly lower aflatoxin levels than did machine-shelled maize (4 and 8 ppb versus 120 ppb).[11]

Storage

Stored "egusi" melon seeds in Nigeria were contaminated with aflatoxin; in 359 seed samples taken from five different points within the storage container, contamination ranged from 25-36% depending on the region. Mean detected levels were 12.1-13.7 ppb.[12]

Udoh et al. (2000) tested aflatoxin levels in different maize storage systems in Nigeria, finding contamination in 33% of approximately 80 samples at levels of 56-126 ppb.[1] In their sample, storing maize in polyethylene bags was associated with a greater risk of aflatoxin contamination, while storing maize in bags hung over a fireplace decreased the likelihood of contamination, likely due to the drying effect of the smoke. Female farmers were more likely to dry their maize over a fireplace; the authors suggest that the difference is due to the generally smaller harvests for female farmers. Due to spatial constraints, the fireplace method is most suitable for lower volumes of maize.[13]

Kaaya et al. (2006) also found a correlation between fireplace storage and reduced likelihood of contamination in a sample from 120 maize farms in Uganda. Other storage practices associated with reduced contamination in that sample were sorting before storage; storage of maize in shelled form; storage of maize in bags; and use of improved granaries as storage structures.[14] Hell et al. (2000) sampled approximately 700 fresh and stored maize kernels from 300 farmers in Benin. Post-harvest, aflatoxin incidence across regions ranged from 9.9%-32.2% (N=443; cut-off was below 5 ppb). After six months of storage, the incidence increased to a range from 15.0%-32.2% (N=301; cut-off=5 ppb).

Groundnuts in storage are also susceptible to aflatoxin. In Mali, samples from 52 granaries over a three-year period had high incidences of aflatoxin, particularly from June on.[15] Exact levels were not reported.

Consumption & Point-of-Sale

Liu et al. (2007) use food consumption data in combination with published country-level estimates to extrapolate aflatoxin exposure for each world region. While their estimates may be weakened by a lack of recent and large-scale data, the regional approach provides a useful context for interpreting country-level prevalence estimates. In their model, the region with the highest per capita/per day aflatoxin consumption is Africa, with an estimated range of 10-180 micrograms aflatoxin ingested for each kilogram of body weight. Southeast Asia is also vulnerable, with an estimated average daily intake of 30-100 micrograms/kilogram body weight, and average intake in Latin America is estimated at 20-50 micrograms/kilogram body weight. For comparison, the upward bound of the estimated ranges for North America and Europe is 4 micrograms per kilo body weight per day.

Unprocessed food items

In Benin and Togo, researchers obtained household samples of the maize and groundnuts consumed at the time of the study. Aflatoxin contamination was as high as 14.4% for maize (N=504, range = 7.6-27.7 ppb) and 2.9% for groundnut (N=175, range = 12.5-528.3).[16]

[1] Total N was not reported.

Maize samples were obtained from 243 vendors in 65 Kenyan markets during the 2004 aflatoxicosis outbreak. Within the sampled maize, 55% had aflatoxin levels greater than 20 ppb.[17] However, given the timing of the study, it is difficult to know whether those levels were representative of typical maize in Kenya.

In a small (N=13) sample of maize from markets in Brazzaville, Congo, 25% of samples were contaminated by aflatoxin, with a mean of less than 2 ppb but an upper bound of 120 ppb.[18] The same study sampled 38 types of cassava products from markets in Congo and Tanzania, finding levels of aflatoxin from 0.3 to 4.4 ppb in cassava chips and flour, and from 0.1 to 13.0 ppb in stored cassava samples.

In Western Kenya, mean aflatoxin levels in 621 maize samples ranged from 2.26 ppb (own-produced) to 5.76 ppb (received as gift); proportion over 10 ppb ranged from 5%-27% depending on the source.[19]

Processed food items

A small sample of processed maize (in the form of flour) in Morocco had a high incidence of aflatoxin; 80% of 20 samples tested positive, with levels between 0.23-11.2 ppb.[20] In contrast, only 18% of wheat flour samples in the same study tested positive, and the upward bound of the range for wheat flour was 0.15 ppb.

Processing has been linked to changes in aflatoxin levels in rice; a study of 78 rice samples from four mills in the Philippines found that rough rice had an average aflatoxin level of 4.32 ppb, which decreased to 1.03 ppb after one polish and 0.57 ppb after a second polish.[21] Groundnuts processed into flour had high levels of aflatoxin (over 25% of market samples with levels over 100 ppb) in one study in Malawi; this may be due in part to the use of discolored or otherwise low-grade groundnuts for flour rather than for sale in whole-nut form.[22] In contrast, roasted groundnuts in Bangladesh tested at a mean of 13 ppb, while raw groundnuts tested at 65 ppb.[23] Processed groundnut products in Indonesia showed high aflatoxin contamination; 58 out of 95 samples were contaminated in a range of 2.0-249.0 ppb. Nearly 40% of the contaminated samples had levels over 4.0 ppb.[24]

In a sample of cassava and yam chips from 20 villages in Benin (N=100 cassava & 100 yam) no detectable amounts of aflatoxin were found. The chips remained aflatoxin-free after three months of storage, though A. flavus colonies were detected in some samples.

Animal Feed

In 130 samples of poultry feed from two factories in Argentina, 48% tested positive for aflatoxin, with a range of 10-123 ppb. [25] Poultry feed in Morocco was also contaminated, with 67% of a small sample testing positive (range 0.05-5.38 ppb, N=21).[26] In 66 samples of mixed-grain poultry feed in Reunion, 36% had detectable levels of aflatoxin, up to a high of 22 ppb.

Please direct comments or questions about this research to Leigh Anderson, at eparx@u.washington.edu

[1] Strosnider et al., 2006

[2] Liu et al., 2007

[3] Cotty & Jaime-Garcia, 2007; Aletor, 1990
[4] Monyo, 2010
[5] Udoh et al., 2000
[6] Madiallacké Diedhiou et al., 2010
[7] Manjula et al., 2009
[8] Hell et al., 2000; Soler et al., 2010
[9] Setamou et al., 1997
[10] Bankole & Mabekoje, 2003
[11] Madiallacké Diedhiou et al., 2010
[12] Bankole et al., 2004
[13] Udoh et al., 2000
[14] Kaaya et al., 2006
[15] Soler et al., 2010
[16] Egal et al., 2005
[17] Lewis et al., 2005
[18] Manjula et al., 2009
[19] Hoffman et al., 2010

[20] Zinedine et al., 2007
[21] Sales et al., 2005
[22] Monyo et al., 2010
[23] Dawlatana, 2002
[24] Noviandi et al., 2001

[25] Dalcero et al., 1998
[26] Zinedine et al., 2007