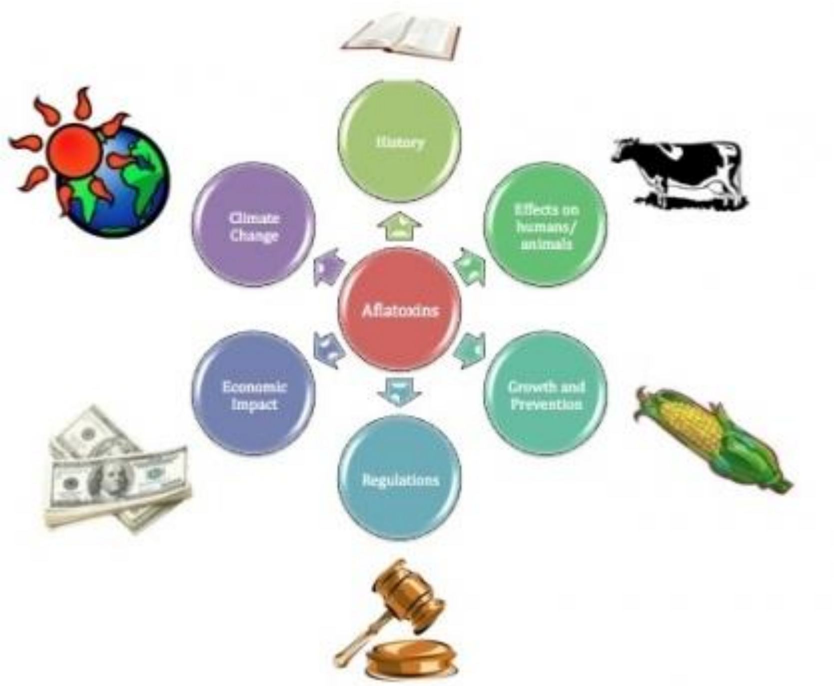
Aflatoxin Contamination



Background

Aflatoxin contamination is a common phenomenon produced by the fungus*Aspergillus flavus*, acting on food crops consumed in both developing countries and, occasionally, in the United States. Aflatoxin grows on corn and grain crops after harvest during the drying process. Outbreaks of aflatoxicosis (poisoning by aflatoxin) were first noted in the 1960s in England after more than 100,000 turkeys on poultry farms died after consuming contaminated feed. Currently aflatoxin contamination is "unavoidable" according to the U.S. Food and Drug Administration, and many countries have imposed regulatory limits of accepted concentrations on crops used for food and animal feed. Standards for animal feed are generally much lower than those of food used for human consumption. Aflatoxin contamination generally occurs on crops such as rice, corn, cottonseed, nuts, spices and figs and can occasionally be detected in milk, cheese and other foods and feeds. The extent of the contamination that occurs varies with geographic location, theagricultural practices of the farmers and the susceptibility of commodities to fungal activity during pre-harvest, storage and processing periods. Fungal growth on crops can begin before harvest and can increase from production and harvest conditions. Evolutionary history of aflatoxin suggests that the aflatoxin may be produced by the fungus as a defense mechanism.

Contamination

Aflatoxin is a secondary metabolite produced by *Aspergillus flavus* and *Aspergillus parasiticus* fungi. Growth occurs at temperatures between 24-35 °Celsius when the moisture content is around 7%. Fungal growth and aflatoxin contamination result from interactions between the fungus, the crop and the environment. Together, these factors determine the type and amount of aflatoxin produced. Insects are also important vectors for dispersal of fungus to survive much longer.

Other factors important to determining the likelihood of pre-harvest contamination include the genetic makeup of the plants, drought during crop growth, soil types and insect damage. Farmers can now use computer models to simulate the risk of contamination based on these factors.

Measurements

Careful sampling, sample preparation and analysis techniques are necessary to determine aflatoxin concentration at the parts per billion level. Generally, the entire sample taken from the crop must be ground and mixed so that the analytical test portion has a representative concentration of the toxin. Techniques used to measure amounts of aflatoxin present include solid-phase extraction, thin-layer chromatography, liquid chromatography and immunochemical methods which are highly specific antibody-based tests. Mass spectrometry is used to identify the exact type of aflatoxin present.

Effects

Aflatoxins most commonly affect crops that are consumed by humans, livestock and wild animals. Ingestion of this metabolite can lead to serious health problems in all species. One of the most significant health problems associated with aflatoxin is aflatoxicosis. Aflatoxins have also been linked to several other diseases. The severity of symptoms depends on the fungus species, the concentration of aflatoxins consumed, the duration of exposure, age, sex, weight, and the overall health of the infected person or animal. If a mother has aflatoxicosis she has the ability to expose her offspring through milk secretions. According to the FDA, Aflatoxins can lead to liver cancer and liver failure. Aflatoxins B1, M1 and G1 all cause cancer in animals. However, only aflatoxin B1 has been classified as a human carcinogen. The B1 toxin must be metabolized in order for it to be transformed into its carcinogenic form.

Aflatoxicosis manifests either as an acute or chronic disease. Acute aflatoxicosis occurs when a large amount of Aflatoxin is consumed in a short amount of time. Acute effects include hemorrhages, severe liver damage, edema, gastrointestinal dysfunction, alteration in digestion, disruption of absorption and metabolism of nutrients and sometimes even death. Animals often show signs of depression, loss of appetite and diarrhea when affected by acute aflatoxicosis.

When small amounts of aflatoxin are consumed over a long period of time, individuals will experience chronic aflatoxicosis, which can occur with as little as 1 ppb. Aflatoxin binds to nucleic acids and reduces efficiency of protein production. Chronic aflatoxicosis can be hard to identify, and the symptoms include slower metabolic rates, decreased growth, reduced immune function, and liver damage. Livestock affected with aflatoxicosis can be easier to diagnose as their growth rate visibly slows and their egg and milk production decreases. Liver damage can be recognized by the increase of yellow within the whites of the eyes of the infected animal (which can also signal other causes of liver dysfunction). Further, some studies on animals show greater aflatoxicosis susceptibility in small animals.

Humans and animals react similarly to aflatoxins, although the symptoms tend to vary. Humans will experience pulmonary edema, convulsions, coma, vomiting, death with cerebral edema and fatty involvement of the liver, kidneys and heart. Once again, symptoms vary depending on age, sex, and overall health. Further, aflatoxin can have an increased effect when the individual is already infected with other diseases of the liver such as Hepatitis B or parasite infestation.

Research into the relationship between Hepatitis B and aflatoxin contamination is ongoing and studies suggest that humans infected with Hepatitis B are more susceptible to aflatoxin contamination. The countries with the highest number of people infected with Hepatitis B are developing countries (WHO) where risk of contamination of aflatoxin is also very high.

Aflatoxins and the Food Industry

Food consumption exposes humans and animals to aflatoxins. The highest risk of aflatoxin contamination is associated with peanuts, corn, cottonseed, and other grain-based foods. Corn is of concern because of its importance in the food industry. Additionally, aflatoxin is often a problem in climates where corn is grown. Other food sources that are occasionally contaminated with aflatoxins include spices, nuts, almonds, and dairy products. Dairy product contamination usually occurs as a result of farm animals consuming aflatoxin-contaminated feed. A recent incident of aflatoxin food contamination occurred in October of 2011. Proctor and Allan East Africa, a cereal manufacturer, recalled 25 tons of contaminated Unimix (a high-protein mix containing corn flour) destined for relief efforts in drought-affected areas of Kenya [1].

Aflatoxin contamination is tightly regulated. For example, the action level for United States Commerce is 20 parts per billion (ppb) for corn. If corn exceeds the limit, federal agencies may prohibit sale or seize the product. For animal feed, the aflatoxin limit depends on the type and purpose of the animal. The following are aflatoxin action levels for different products:

Product	**Action Level**
Food for human consumption (including corn, peanuts, etc)	20 ppb

Milk	0.5 ppb
Animal feeds that are not cottonseed meal or corn	20 ppb
Corn/grain feed for immature animals, dairy animals, or feed with unknown destination	20 ppb
Corn/grain feed for mature poultry, breeding swine, or breeding beef cattle	100 ppb
Corn/grain feed for finishing swine at least 100 pounds	200 ppb
Corn/grain feed for finishing beef cattle	300 ppb
Cottonseed meal for swine, poultry, or beef cattle	300 ppb

Adapted from the USDA Aflatoxin Handbook (2002) and FDA Guidance for Industry (2000).

The Food and Agriculture Organization/World Health Organization (FAO/WHO) Codex Alimentarius is a set of international food standards and guidelines suggested for trade. The World Trade Organization (WTO) Agreement on Sanitary and Phytosanitary Standards recommends that its members adjust their standards to match this international standard, including for aflatoxins. However, the European Union has historically imposed much stricter aflatoxin regulations.

The United States, along with other developed countries, generally use regulations effectively to limit aflatoxin consumption. Effective quality-control procedures and regulations are possible partially due to large-scale industries and economies of scale. However, regulation enforcement is frequently unfeasible in developing countries due to food insecurity and small-scale industries. Food security is an issue because people may have limited or no alternative food sources aside from their aflatoxin-contaminated crops. Traded food from other countries is uncommonly consumed, so the regulation of Codex does not apply.*Testing foods within many developing countries for contamination is difficult and unlikely. Consumed food in developing countries is often produced, prepared, and stored by families who may not consider aflatoxin contamination to be an issue. Additionally in some places the least contaminated food may be used for trade leaving the most contaminated foods for human and animal consumption.*

Prevention

Farmers in the USA and developing countries take contamination factors into account when trying to prevent fungal activity, but in the end, their ability to prevent contamination comes down to their ability to invest in production, drying and storage facilities. Even if farmers are able to invest, they still experience some losses when their aflatoxin concentrations do not meet even the more relaxed standards allowed for animal feed.

Several prevention methods exist while the crops are growing. Farmers can provide irrigation to prevent desiccation or use biotechnology to introduce genes that have the ability to prevent the formation of aflatoxin. Since aflatoxin formation is affected by associated growth of other molds and microbes, farmers may soon be able to inoculate the fields with alternate/nonaflatoxigenic strains of fungi to prevent aflatoxin contamination. Research still needs to be done to determine if these practices will have long-term effects on crop safety and improve human health related to aflatoxins.

In order to prevent fungal activity on crops harvests must be performed swiftly and crops must be adequately dried before they can be put into storage. Most contamination takes place during crop storage. Even if commodities are dried well (<10% moisture) they can still develop localized pockets favorable to aflatoxin growth because of moisture generated by insect respiration, rodent infestation and condensation from the environment.

During processing of commodities there are three main methods that can be employed to reduce aflatoxin contamination: dilution, decontamination and separation. Dilution involves mixing highly contaminated grain with minimally contaminated grain to decrease the concentration. Decontamination is when grains are treated with ammonia, other alkaline substances or processed using irradiation, microbial inactivation and fermentation practices to denature aflatoxin. Separation is the process of removing contaminated pockets of grain from the rest of the crop. This practice only works when there is heavy concentration of only a small fraction of the seeds. Sometimes poorer farms in developing countries end up eating the contaminated food themselves or feeding it to their animals.

These prevention practices usually only occur in developed countries because of the time and money investments required. In developed countries, operations are performed on a large scale so it is possible for adequate equipment to be purchased and time to be spent on processing. In developing countries insect damage to crops is not controlled with herbicides or pesticides, and drought is common because irrigation is not an option. Harvesting is done without machinery and the drying process is inefficient and largely dependent on the weather which increases the risk of aflatoxin contamination.

Research is currently being performed on two other practices that could reduce the amount of aflatoxin contamination. Chemoprotection works by changing the biochemical processes of aflatoxin to promote detoxification of the contaminant rather than focusing on exposure. Enterosorption is the process of adding a binding agent to food to prevent the contaminant from being absorbed while the food is being digested. This method has been used mainly in the animal feeding industry.

Economic Cost

Economic implications of aflatoxin regulation include the costs of production loss, trade loss, testing, regulation, etc. In 2003 the Council of Agricultural Science and Technology estimated that mycotoxins (all fungal toxins, including aflatoxin) cause a crop loss of $932 million yearly in the United States alone. Furthermore, the cost of regulation and testing averages $466 million yearly [2]. In 2001, it was estimated that African countries lost an annual $670 million when trying to meet European Union standards compared to Codex standards [3]. Livestock and poultry producers also lose some profit when aflatoxin-contaminated feeds result in animal death, slower growth rates, or other negative health effects [4].

The Effects of Climate

Two studies by R.R. Paterson and N. Lima suggest that aflatoxins are expected to spread and become more problematic with future climate conditions. There are many climatic reasons for an increase in aflatoxins, including an increase in temperature, humidity and moisture, and rainfall [5]. Further, an increase in carbon dioxide (CO_2) will also have a large impact on plant growth, which could increase the spread of plant borne diseases. Most plants are limited by atmospheric CO_2, and the rise in CO_2 may increase plant biomass, increasing the risk for insect damage and fungal growth. However, the research is ongoing and one other study shows that plant biomass could decrease in some species [6].

Currently, many cases of aflatoxin poisoning are in developing countries where there are fewer regulations on food and where temperatures are warmer and humidity is higher. Current data from R.R. Paterson and N. Lima suggest that due to a rise in extreme temperatures, many countries in regions that are currently susceptible to drought, such as sub-Saharan Africa, Asia and Latin America, may actually see a decrease in aflatoxin due to lower crop yields. Also, an increase in temperature could lead to an increase in plant stress and an increase in the number of plants that are more susceptible to disease, which might suggest that the crops that are grown in developing countries are even more prone to containing aflatoxin-producing fungus.

Climate change may also influence impact aflatoxin contamination in temperate climates. The IPCC climate predictions suggest that temperate regions, such as North America and Europe may have warmer summers and less predictable rain patterns or more extreme weather. In the studies by R.R. Paterson and Lima, they address that the two climate variables that are important predictors of aflatoxin are warm nighttime temperatures and precipitation immediately before or during the harvest. Precipitation prior to a harvest increases the water content in crops, which means that it is much more difficult to keep crops dry or free of fungal growth. Further, warm nighttime temperatures allows for greater insect activity, which can increase the spread of fungus.

Research on the connection between climate change and aflatoxin is ongoing, and much more research is needed in order to truly understand the global impact of climate change on aflatoxins and on the global food supply.

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