MANAGEMENT OF AFLATOXINS IN CEREALS, LEGUMES AND TUBERS

Training Manual for AT Uganda Training of Trainers

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Introduction

Aflatoxins are produced by the moulds *Aspergillus flavus and Aspergillus parasiticus. A. flavus* is common and widespread in nature and is most often found when certain grains are grown under stressful conditions such as drought. This mould is found widely on inadequately dried food and feed grains in subtropical and tropical climates throughout the world. It occurs in soil, decaying vegetation, and grains undergoing microbiological deterioration and invades all types of organic substrates whenever and wherever conditions are favourable for its growth.

Aflatoxin recognition as potent carcinogens and immuno-suppressing toxins in some animals and man has made them subjects of government legislation as well as valuable tools in the study of cancer. There are four major aflatoxins: B_1, B_2, G_1, G_2 plus two additional metabolic products, M_1 and M_2 that are of significance as direct contaminants of foods and feeds. The aflatoxins M_1 and M_2 were first isolated from milk of lactating animals fed aflatoxin contaminated preparations; hence, the M designation. The B designation of aflatoxin B_1 and B_2 resulted from the exhibition of blue fluorescence under UV-light, while the G designation refers to the yellow-green fluorescence of the relevant structures under UV-light.

It should be noted that it is difficult to eliminate aflatoxins completely from food after they have developed, although some reduction may occur during processing. Aflatoxins persist under extreme environmental conditions and are even relatively heat stable at temperatures above 100^oC, the boiling point of water.

Aflatoxins can enter the human and animal dietary system by indirect or direct contamination. Indirect contamination of foods or feeds can occur when an ingredient of a process has previously been contaminated with the toxin producing moulds and although the moulds may be killed or removed during processing, aflatoxins may often remain in the final product.

Foods affected

The occurrence of aflatoxins has been reported in staple foods as well as processed products. They have been occasionally detected in milk, cheese, maize, groundnuts, cottonseed, sorghum, wheat, rice, soy bean, cassava, dry fish and a variety of other foods and feeds. Example of foods contaminated in Uganda (Table 1).

Table 1. Aflatoxin contamination in selected foods in Uganda

Food	Levels (ppb)	Comments
Maize	0 - 700	At farm level, storage up to 3 months (0-20 ppb); storage 4 months +, including traders (> 20 ppb)
Groundnuts	0 – 120	At farm level (storage in shells (0 – 15 ppb), at market level (> 20 ppb); Processed (unroasted) > 30 ppb.
Cassava chips	10 - 30	Preliminary results, analysis not comprehensive
Soybean	0 - 40	Preliminary results, analysis not comprehensive

Consequences of exposure to aflatoxin

There are a range of possible consequences of exposure to aflatoxins, largely determined by the dose, the duration of exposure, and the animal involved. In all cases, the young of species are much more susceptible than the adults, and nutritional factors can be an important factor.

- Acute illness and death
- Cancers
- Immune system suppression
- Nutritional illnesses

Factors affecting fungal growth and aflatoxin production

The main factors affecting fungal growth and aflatoxin production on a given food are moisture, temperature, pH, and the environment. Production of aflatoxins is optimal at relatively high temperatures, so contamination is most acute and widespread in warm, humid climates like those of Uganda. Warm temperatures (32^{o} to 38^{o}C) favour the infection of grains more than cool temperatures (21^{o} to 26^{o}C). *A. flavus* will only grow when the moisture content exceeds 9%, at 80-85% relative humidity and above. *A. flavus* grows best between 10^{o}C and 45^{o}C at a relative humidity of 75% or more although the optimum conditions for aflatoxin production are between 25^{o}C and 30^{o}C, at 85% relative humidity. Aflatoxigenic moulds may invade agricultural products during plant growth (preharvest), harvest and afterwards (postharvest).

- ***Module 1. Preharvest and harvest***

Aflatoxin contamination of foods and feeds highly depends on environmental conditions that lead to mould growth and toxin production. Insect and bird damage, drought, stress and excessive rainfall encourage preharvest mould growth and aflatoxin production. Contamination of maize by moulds occurs primarily in the field.

At preharvest stage, drought-prone soils in which crops like groundnut is grown year after years are hot spots for aflatoxin contamination. Prolonged drought/moisture stress (3-4 weeks) during grain/seed filling and maturation stages triggers aflatoxin contamination. In USA, maize exposed to drought stress in the field had more *Aspergillus flavus* infected kernels than maize in irrigated plots.

Over maturity of the crop has been identified as the potential factor for aflatoxin contamination. Delayed harvest not only leads to yield loss but also reduces crop quality.

Mechanical damage during harvesting is a big problem in crops like groundnuts, sweet potato and cassava. In most instances, aflatoxins are formed after harvest, particularly when harvesting takes place during unseasonal rains. ***(Ref: Fig. 1).***

Fig 1. Women harvest groundnuts using hand hoes in Mubende district

Prevention strategies (Do's and Don'ts)

- Rain-fed agriculture a major constraint. Hence may not avoid drought sometimes
- Follow recommended agronomic practices
- Timely planting and harvesting always singled out
- Avoid field drying especially maize and groundnuts
- Careful harvesting to avoid mechanical damage
- Control stresses caused by pests and diseases
- Do not keep immature and damaged produce along with healthy ones.
- Prior to harvest, cleaning of all harvesting, handling, and drying equipment and storage containers should be done.

- ***Module 2: Drying practices and moisture content management***

The drying stage is all-important to reduce attack and damage from insects and fungi. Traditional drying techniques in Uganda involving bare ground drying are a major source of fungal contamination. They are slow, time consuming and labour intensive involving lots of crop handling, and due to rains that normally persist at harvesting, it is difficult to achieve the recommended moisture level for safe storage. In addition, the crop is persistently exposed to soil contamination which is the source of fungi. Inefficient and slow drying process under the humid conditions enhances aflatoxin contamination greatly ***(Ref: Fig 2 – 8)***

Fig. 2. Groundnuts heaped in the house after harvesting

Fig. 3. Soiled fresh groundnuts stored in bags prior to drying

Fig. 4. Drying sorghum, millet and sweet potato chips on bare ground eastern part of Uganda

Fig. 5. Drying maize on bare ground in central part of Uganda

Fig. 6. Drying coffee on bare ground in eastern part of Uganda

Fig. 7. Drying of groundnuts on bare ground

Fig. 8. Drying cassava chips along Tirinyi road, eastern part of Uganda

Prevention Practices (Do's and Don'ts)

- Do not dry produce in contact with soil. Use clean sheets or raised structures ***(Ref: Fig 9 – 12)***
- Dry uprooted produce prior to stacking
- Dry as soon as possible (in developed countries, drying is with 48 hrs)
- Sundry grain to bring down its moisture below 13%
- Do not dry diseased/infected produce along with health ones.

Fig. 9. Cassava chips dried on used polybag sheets

Fig. 10 Drying maize grains on polyethylene sheet in eastern part of Uganda

Fig. 11. Drying rack constructed from local materials

Fig. 12. Drying groundnuts on a rack

- ***Module 3: Primary processing (Shelling, threshing, winnowing/cleaning)***

Mechanical damage to foodstuff during shelling, threshing and winnowing makes them much more vulnerable to invasion by storage moulds, including *A. flavus*. Under any given environmental conditions fungal growth may be several times faster in damaged compared to intact produce. Cracks and breaks in maize or groundnut pods and testa are caused mainly during shelling by beating, although insect feeding may also be responsible for breaks in the pericarp ***(Ref: Fig. 13 – 14)***.

Fig. 13. Groundnut kernels (sound and broken) in a bag delivered to the market in Kampala.

Fig. 14. Sound kernels (in a metallic container) and broken kernels (spread on plastic sheet) during sorting of mixed grains from a plastic bag

Prevention Practices (Do's and Don'ts)

- Separate out immature pods as well as those infested with pests and diseases
- At household level, manual shelling is recommended.
- Use hand shellers for maize
- Do not shell by beating or trampling

- Do not spray water on dry pods while using mechanical sheller. Instead, adjust (where possible) the space between blades and the sieve according to pod size to reduce breakage.
- Remove shrivelled, discoloured, mouldy and damaged grains from the lot including nuts with damaged testa and put them in new polybags.
- Remove dust, and foreign material which can provide source of contamination

- ***Module 4. Postharvest Storage***

The fundamental reason why produce is stored dry is to increase storability and in part, prevent growth of storage fungi. If commodities are stored incorrectly, that is, in an improperly dried state or under high humidities with inadequate protection, fungi will inevitably grow. Duration of storage is an important factor when considering aflatoxin formation. The longer the retention in storage the greater will be the possibility of building up environmental conditions conducive to *A. flavus* proliferation and production of aflatoxin.

In most parts of Uganda, traditional means of crop storage are not yet improved. Storage structures, whether traditional or modern, should maintain an even, cool and dry internal atmosphere; they should provide protection from insects, rodents, and birds; should be easy to clean and should be water proof and protected from flooding. These recommendations were made in view of *A. flavus* infection and aflatoxin production in stored maize and groundnuts ***(Ref: Fig 15 – 18)***

Fig. 15. Granary used for storage of food in Kumi district of Uganda

Fig 16. Improved crib used to store maize in Iganga district

Fig 17. Maize storage using grass-thatched crib in Mubende district

Fig 18. Inadequate storage of grains and flour at a retail market in Kampala

Prevention Practices (Do's and Don'ts)

- Properly dry the produce to safe storage moisture content
- Produce should be placed in a container that will maintain suitable environment and prevent or restrict moisture pick-up and insect/rodent infestation.
- Use new/clean gunny or polybags to store the produce.
- Do not heap produce ***(Ref. Fig 19)***
- Put only clean grain into containers
- Bags should not be placed directly on floor
- Maintenance of proper storage facilities (well-ventilated, dry and low RH) and care not to expose produce to moisture during transport and marketing.
- Control insect and rodents during storage
- Do not mix new with old stock produce
- Grain should be accessible throughout the storage period for additional treatment if necessary (e.g. use of synthetic pesticides).

Fig 19. Heaping maize cobs during storage in central part of Uganda

Regulatory Control of Aflatoxin

Legal limits for aflatoxin B_1 in foodstuff range from 0 – 30 mg/kg (ppb). Recommended limits for total aflatoxins in foods range from 5 – 20 ppb and Codex Committee proposed a level of 10 ppb. The present FDA administration action guideline is 20 ppb total aflatoxins for all products intended for feed or food. However, the permitted level of aflatoxins in food products by the World Health Organization (WHO) is 0 ppb for children, 20 ppb for adults and 55 ppb for animals. In many countries, the tolerance levels for aflatoxins in foodstuffs are in the range 5 – 50 ppb. For Uganda, the Uganda National Bureau of Standards (UNBS) has set total aflatoxin levels at 10 ppb for most products.

Recommendations for traders to manage aflatoxins

- Always purchase new or current season produce. Avoid purchasing produce stored for more than six months.
- The company should establish its own purchasing system rather than dealing with middlemen. This may involve purchasing produce directly from farmers.
- Always check grain quality condition before acceptance. These include:
    - Moisture content (not more than 13%); use moisture meters
    - Presence of diseased/mouldy and discoloured grains
    - Presence of broken kernels
    - Presence of soil contaminated grain
    - Presence of foreign matter (soil, dust, chuff and stones).
    - Presence of insects and insect damaged grain.
- Sorting and cleaning to remove the above-mentioned poor condition grain should be done prior to processing. Do not process poor quality grain ***This behaviour is common for groundnut processors and hence their products are heavily contaminated with aflatoxins***
- Unshelled groundnuts (those still in shells/dry pods) are better to purchase than shelled nuts since the shell protects them against mould invasion.
- If grain moisture content of delivered grains is greater than 13%, (but should not be more than 15%) immediate further drying of produce should be done on a clean surface, to reduce moisture content to 10 – 13%.
- Grains purchased should not be stored for more than three months.
- The grains should be stored in new interwoven polypropylene bags stacked in a moisture and rodent proof store (no rodents and insects)

- The store must be routinely cleaned to remove spilled grains and other foreign materials.
- Regular inspection of raw materials and the processing premises should be carried out by an expert from the department of Food Science and Technology, Makerere University.
- Proper packaging of the finished products in moisture-tight containers is recommended.
- On-spot mould and aflatoxin tests in the raw and finished products must be carried out.
- The company should strive to get the Quality Mark from the Uganda National Bureau of Standards.

Conclusion

Aflatoxin management procedures should involve farmers, traders (wholesalers and retailers), processors, and policy makers especially those involved in inspection and regulatory control. However, awareness of aflatoxin and causal factors by all stakeholders is the key in effective management of the problem.