How to Reduce Aflatoxin Contamination in Groundnuts and Maize

A Guide for Extension Workers

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ICRISAT
INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

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Acronyms

ICRISAT : International Crops Research Institute for the Semi-Arid Tropics

EU : European Union

CRS : Catholic Relief Services

USFDA : United States Food and Drug Administration

FAO : Food and Agriculture Organization

Ppb : Parts per billion

MRL : Maximum Risk Levels

Foreword

In Eastern and Southern Africa, groundnut and maize are important crops chiefly grown by smallholder farmers. A major constraint to increased productivity and market competitiveness is the contamination by fungal toxins also called mycotoxins. These toxins, the most common of which is aflatoxin, are produced by *Aspergillus flavus and A. parasiticus.* These fungi are free-living organisms. In sub-Saharan Africa, mycotoxin contamination is widespread in staple crops such as groundnut, maize, millets, wheat, rice, sorghum, and soybean and in processed food and feed such as milk and meat products derived from contaminated crops.

Due to its harmful effects on human and animal health, aflatoxin contamination has gained global significance in the last four decades. Consumption of aflatoxin-contaminated food products retards growth and productivity in both humans and animals. Furthermore, poor nutrition, usually attributed to food insecurity, may be exacerbated by exposure to aflatoxins, which can increase prevalence of liver-associated diseases, especially among those who are immunocompromised.

This manual is designed to help address the threat posed by exposure to aflatoxins in farming communities in Malawi. It is designed to equip extension staff with information that they can use to train farmers who, in turn, will train fellow farmers. We sincerely hope that it will provide the needed technical support to help fight this deadly problem and improve the well-being of the people.

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1. Introduction

1.1 What are aflatoxins?

Many agricultural commodities are susceptible to several diseases caused by fungi, viruses and insect pests. These diseases may also contaminate the crops with deadly toxins. Fungi are of particular concern. Many fungi are free-living organisms capable of surviving in the environment (soil, air and water) and can easily find their way into crop products especially when the weather conditions are suitable. Many of these fungi are free-living organisms and can survive in the environment even without the crops we grow. The toxins produced by fungi are called mycotoxins (Myco=fungus; toxin=poison).

Groundnut infected with Aspergillus flavus.

The fungi *Aspergillus flavus* and *Aspergillus parasiticus* are the most common source of food contamination the world over. These fungi produce a special mycotoxin called aflatoxin (From *Aspergillus flavus* toxin), which, when consumed via contaminated crops/products can cause several harmful health effects on humans and livestock.

1.2 Effects of aflatoxins

Food products that are commonly contaminated by aflatoxins include cereals (maize, sorghum, pearl millet, rice and wheat), oilseeds (groundnut, soybean and sunflower), spices (chillies, black pepper, coriander, turmeric and ginger), tree nuts (almond, pistachio, walnut and coconut) and milk from cattle that have eaten contaminated feeds. Aflatoxin cannot be destroyed by cooking. Aflatoxin contamination of food products have two major effects. Firstly, eating contaminated food has several harmful health effects and secondly, aflatoxin contamination affects the quality of the grain which leads to reduced markets for contaminated grains.

Health effects: Eating food contaminated with aflatoxins leads to aflatoxin poisoning also called aflatoxicosis. Regular consumption of low dosages for a long time (Chronic exposure) leads to liver damage, immune suppression, malnutrition and stunted growth in children, while sudden high-level ingestion of the toxin (Acute exposure) can lead to death.

Income losses: Groundnut, maize and other crop products are important as a source of income when sold locally or exported, particularly to the European Union (EU). To protect humans from the harmful effects of mycotoxins, especially aflatoxin, the European Commission has proposed maximum allowable limits for aflatoxin in certain foods. The permissible limit of aflatoxin in foods for human consumption is 4-30 ppb, depending on the country involved (FDA 2004; Henry et al. 1999). In the United States, 20 ppb is the maximum aflatoxin residue limit allowed in food for human consumption (FAO 2003). Due to aflatoxin contamination the food products cannot be exported leading to financial losses. For example Malawi lost as much as 42% of its groundnut exports in 2005 (Diaz-Rios and Jaffe 2008).

Maximum risk levels of acceptance for total aflatoxin contamination by different countries and organizations.

Country/Organization	Maximum Risk Limit (MRL) in ppb
European Union	4
USA	20
RSA	15
Japan	0
Codex Alimentarius Commission	15

2. Aflatoxin Management in Groundnut

2.1 How crops get contaminated

Aflatoxin-producing members of *Aspergillus* are common and widespread in the environment. Crops are particularly susceptible to infection by *Aspergillus* following prolonged exposure to a high-humidity environment or damage from stressful conditions such as drought, a condition that lowers the barrier to entry (Harris et al. 1976). The fungi can enter (colonize and contaminate) at any point of the crop value chain. The entry or infection points for these aflatoxin-producing fungi could be at any/all of these three stages:

- Preharvest entry of fungus (during plant growth).
- Entry of fungus during harvest.
- Postharvest entry of fungus (after harvest and during processing).

2.1.1 Preharvest contamination

Fungus growth and aflatoxin contamination that occurs in the field during crop growth is called preharvest contamination. Preharvest infection is usually influenced by farming practices that make crops susceptible to infection, including the following:

- **Repeated cultivation of host plants:** Repeated cultivation of the same crop or susceptible crops species on the same piece of land supports rapid buildup of *A.flavus* populations leading eventually to preharvest contamination of crops in field.
- **Late planting:** Late planted crops will usually be affected by end-of-season drought as well as insect pest attacks, especially termites. Such insect-damaged pods create easy entry points for the fungus.
- **Drought:** Under drought stress the groundnut pods crack and facilitate entry and growth of *Aspergillus*.
- **Termite attack and poor field hygiene:** Using fields with a history of termite infestation provides an environment that supports pod damage by termites and eventual easy entry by the fungus. Unweeded fields also support termite and pest damage of developing pods, increasing chances of *Aspergillus* infection.

Termite nest in a field.

- **Plant density and poor water management:** Low plant population and limited ground cover leads to soil erosion, loss of soil moisture and destruction of soil structure that could aggravate the effects of droughts. These conditions predispose the land to increased *A. flavus* buildup.

2.1.2. Contamination during harvest

The manner in which a crop is handled during harvesting will determine the extent to which it is predisposed to infection. Some of the predisposing conditions that favor fungal infection during harvesting include:

- **Poor harvesting techniques:** Groundnuts are often harvested using hand hoes that can easily damage the nuts, creating easy entry points for the fungus. Groundnuts and bambara nuts can get infected with *Aspergillus* from the soil if they are harvested with soil adhering to the pods. Crops like maize, sorghum, millet and sunflower, usually harvested and dried on bare ground, may also easily get attacked by fungi present on the ground.
- **Premature harvesting:** Immature crops have high moisture content, a condition that favors fungal infestation. Harvesting immature nuts increases opportunity for infection by fungi.

Groundnut pods damaged during harvesting.

2.1.3. Postharvest contamination

The predisposing factors to infection after harvesting the crop include:

- **Improper drying:** Drying on roofs or on the floor exposes the grains to moisture that leads to growth of fungus.
- **Improper shelling:** Practices like sprinkling water on pods to soften the shells to make shelling easy and also to improve the weight of the nuts to get more market value lead to *Aspergillus flavus* infection and aflatoxin contamination. Another bad practice is threshing of groundnuts in a sack.
- **Poor curing techniques:** Overdrying nuts results in the cracking of the pod and seed coat, thus exposing the nuts to infection.
- **Poor stripping:** Stripping groundnuts together with soil carries the fungus into storage and that provides a conducive environment for fungal infection and aflatoxin contamination.

A farmer sorting groundnuts. This process can reduce infection levels to acceptable standards.

- **Sorting:** Poor grading especially the wounded nuts before storage is a source of contamination. Wounded, broken, shrivelled and cracked kernels need to be separated from healthy kernels before storage.
- **Poor storage conditions:** Storing groundnuts with high moisture content and poor storage (at household level, market/shops) that expose grains to winter rains, high humidity during the night and poor air circulation that enhances high temperatures leads to fungus growth.
- **Use of airtight containers:** Using non-porous nylon bags and other airtight storage materials decreases insect pest attack and subsequently infection by fungus.
- **Poor transport**: Transporting the grains in vehicles with open roofs can expose the grain to sudden rain and moisture which leads to fungus growth.

2.2. How to reduce aflatoxin contamination

Fungal growth and aflatoxin contamination in crops occur due to several factors: some are environmental in nature while others are crop management related. Farmers have minimal control on environmental factors; however, they can improve agricultural practices used in crop production to reduce fungal infection, growth and aflatoxin production.

2.2.1. Crop management practices that reduce infection in the field

These approaches target minimization of preharvest infection by fungi. They aim at providing crops with the best possible growth environment so as to avoid infestation by insects, drought and subsequently infection by fungi.

- **Early planting**: Early planting helps plants to escape end of season drought that in general predisposes pods to cracking and entry by *A. flavus*.
- **Maintaining field hygiene:** Timely weeding helps to retain soil moisture needed for proper plant growth and avoidance of dry conditions that predisposes developing pods to cracking. Termite control is also very important to prevent damage to developing pods, especially as the crop matures.
- **Harvesting of water in the field:** Drought conditions while the crop is growing in the field is a prerequisite to fungal contamination and subsequent aflatoxin contamination. Farmers should ensure that they retain moisture in

Use of box ridges to improve rainwater harvesting.

their fields. The use of tied ridges (box ridges) can improve water penetration into the soils, thereby reducing exposure of the developing crop to *A. flavus* infestation. Box ridges should be put in place early in the cropping season to capture enough rainwater and reduce effects of end-of-season drought. Mulching also helps to retain water in the field.

- **Soil amendments:** Application of lime to the crop supports development of strong shells (pod resistance). Strong shells provide the first line of defence against pest and fungal attack.

2.2.2. Crop management practices that reduce infection during harvesting

These are management practices that reduce contamination of pods and grain by reducing and/or avoiding exposure of grain to fungi.

- **Harvesting at the right stage:** Premature kernels have high moisture content and support fungal infection and growth, and aflatoxin contamination. Therefore, harvesting at the right time when the crop is mature will minimize the exposure of the crop to extreme heat, sudden rain or drought, which also influence infection.
- **Avoiding injuries to pods:** Care should be taken when using hand hoes to avoid injury to the pods. Proper harvesting of groundnuts ensures that the hoe is focused at the plant's rooting zone to avoid damaging pods or kernels.
- **Removal of soil:** It is important to remove all the soil attached to the pods during harvesting to avoid carrying the fungus into stores and processing facilities.

2.2.3. Crop management practices that reduce contamination after harvest

Postharvest handling of crops is another major point of contamination that if well managed will minimize infection of harvests by fungus and minimize aflatoxin contamination. Management practices may be implemented at two levels.

At the household level

- **Proper drying:** Drying on roof or on soil leads to the absorption of moisture and supports fungal growth that leads to aflatoxin contamination. The use of Mandela Corks (ventilated stacking) is one of the best methods for curing the groundnuts and is specifically preferred for its ability to minimize the direct exposure of groundnuts to the sun. Mandela Corks should be stacked on a raised platform, leaving a hollow space in the middle to allow air circulation inside the structure.

Mandela Corks support slow curing of harvested groundnuts.

- **Proper shelling:** Sprinkling water on pods to shell the groundnut leads to fungal accumulation and aflatoxin production. It is therefore always better to avoid wetting pods during shelling. The use of mechanical shellers can also reduce labor cost.
- **Grading and sorting:** Fungi readily invade kernels with cracked or damaged pods or seed coats. Removal of such damaged, discolored, small and shrivelled pods reduces the amounts of infected produce in the lot.
- **Proper storage:** Entry of insects and moisture into storage lots allows the entry of fungus and eventually aflatoxin contamination. Grains should be stored in a dry and secure place where the entry of insects and moisture is not possible.

Tips to minimize storage contamination

- Store grains in cool dry conditions.
- Stack gunny bags on wooden planks to avoid dampness.
- Ensure the storage has good roofing to prevent groundnuts from getting wet if it rains.
- Ensure the storage rooms are hygienic to avoid the contamination from the previous lot.
- Using good packaging materials for storage, gunny bags are most appropriate for groundnuts. If nylon bags are used additional perforations need to be made to facilitate air circulation or store in them only for a short time.
- Ensure groundnuts are not exposed to pest and rodents to minimize damage.
- Ensure good aeration in the storage room.

Demonstration of a hand-operated groundnut sheller.

At the processors' level

- **Sorting before shelling:** Loose shelled kernels, shrivelled, damaged or discolored pods are at higher risk for aflatoxin contamination than are large, mature and well-filled pods. Sorting alone can reduce contamination and keep it within the acceptable levels.
- **Grading after shelling:** After shelling, all kernels must be sorted into various grade categories based upon size, and it is better to pass through electronic color sorters to remove discolored or damaged and shrivelled kernels.
- **Avoid using grade-outs:** Grade-outs usually have higher amount of toxins and should not be used for consumption and animal feed. Consuming the grade-outs with high aflatoxin content will expose humans or animals to very high levels of aflatoxin that may lead to sudden death.

3. Aflatoxin Management in Maize

Maize, like other cereals growing above ground, gets infected with airborne fungal spores and aflatoxin contamination during plant growth (preharvest), during harvesting and after harvest during handling (postharvest). Improper practices during cultivation will carry the fungus to the postharvest processing and storage stage. Improper storage also leads to fungus attack and aflatoxin contamination. Like any other crop, maize can get contaminated with not only aflatoxin but also fumonisin and other mycotoxins which are harmful for humans. The aflatoxin management practices for maize is similar to that for any other crop except for a few specific practices described below:

3.1 How crops get contaminated

3.1.1 Preharvest contamination

Preharvest contamination can occur in the growing plant due to:

1. **Damage to the cobs:** Preharvest contamination in cereals like maize mostly occurs when there is a crack in growing cobs and damage due to pest attack.

2. **Airborne spores:** Air dispersal of fungus is associated with infection of above ground crops like maize. Fungal infection can occur through airborne spores in the field during grain filling or during storage and handling. The fungus usually colonizes the silk and kernels when the silk is cut or the cob is damaged due to excessive drought (Saori and Nancy 2011).

Insect damaged maize cob a common source of field infection by Aspergillus.

3.1.2 Contamination during harvest

Fungal attack occurs during harvest mostly because of drying cobs on bare ground, allowing easy pick up of the fungus from the soil to storage facilities.

3.1.3 Postharvest contamination

1. **Improper drying:** Improper drying of cobs easily leads to retention of moisture. Cobs drying on the roof absorb more moisture while those drying on bare soil also encourage growth of the fungus which leads to aflatoxin contamination.


Maize cobs drying on the roof.


Maize cobs drying on the ground.

Maize cob contaminated with Aspergillus flavus.

2. **Damaged cobs:** Drying infected and damaged cobs with the healthy cobs can lead to spread of the fungus. Hence, grading is important to avoid contamination.
3. **Improper storage:** Storage of poorly dried cobs exposes them to excessive moisture and humidity and these are preconditions that support fungal infection.

3.2 How to reduce aflatoxin contamination

3.2.1 Preharvest management

- **Pest management techniques:** Using appropriate insect management techniques will reduce formation of holes and damage to the cobs which, in turn, will reduce the entry points for the fungus.
- **Biocontrol:** Application of biocontrol agents to the crop such as Aflasafe is based on the competition between two species of Aspergillus, i.e. the non-toxigenic and toxigenic forms. This biocontrol technology makes use of carefully selected non-toxigenic strains that can safely outcompete and virtually eliminate their toxic relative effectively reducing contamination of the maize grain in fields. A single application of Aflasafe two to three weeks before maize flowering can prevent aflatoxin contamination throughout, even when grains are stored (Achia 2011).

3.2.2 During harvest

- **Proper harvesting:** After harvesting, cobs should not be left to dry in the field on bare soil, where they can easily pick up soilborne fungus. It is advised that cobs should be dried on polyethylene sheets laid on the ground instead of directly drying them on the ground.
- **Grading cobs**: Damaged cobs should not be mixed with healthy ones to reduce spread of spores and subsequent infection. Sorting insect-damaged cobs and cobs having poor husk covering can reduce aflatoxin contamination. Apart from this, winnowing, washing before cooking, and dehulling of maize grains are effective in achieving significant aflatoxin and other mycotoxins removal (Bankole and Adebanjo 2003).

3.2.3 Postharvest management

- **Sanitation:** Clearing the remains of previous harvests and destroying infected crop residue reduces the spread of the fungal spores and aflatoxin contamination. Cleaning the stores before storing the new harvest also reduces aflatoxin contamination.
- **Proper storage:** Cobs should not be heaped in stores but rather packed in a clean, sealed container to avoid exposure to excessive moisture and humidity.

Conclusion

Producing aflatoxin-free maize, groudnuts and other grains ensures food safety. The health and economic well-being of a farmer is an important investment in the agricultural sector. Since it is difficult to identify groundnuts that are contaminated, it is important to avoid consuming groundnuts that are shrievelled, broken, discolored, or show symptoms of fungal infection. As much as farmers grade groundnuts for the market, they also need to grade for consumption. Use of good crop production practices and postharvest handling techniques can effectively reduce fungal contamination and maintain the quality of the produce. Such efforts would then open up opportunities for farmers to access rewarding markets that currently have stringent quality standards.

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