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Farmers' Guide to Management of Aflatoxins in Maize and Groundnuts in Africa

J. Atehnkeng, J. Augusto, L.A. Senghor,
A. Akande, J. Akello, C. Mutegi,
A. Ortega-Beltran, P.J. Cotty,
and R. Bandyopadhyay



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Joseph Atehnkeng
Joao Augusto
Lamine A. Senghor
Adebowale Akande
Juliet Akello
Charity Mutegi
Alejandro Ortega-Beltran
Peter J. Cotty
Ranjit Bandyopadhyay

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PMB 5320 Oyo Road
Ibadan, Oyo State

International mailing address:
Grosvenor House, 7th Floor, 125 High
Street, Croydon CR0 9XP, UK

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Foreword

Aflatoxins are chemical poisons produced by fungi belonging to *Aspergillus* section *Flavi*, primarily *Aspergillus flavus*. Those poisons cannot be seen with naked eyes and do not have a particular taste or odour. Hence, it is difficult to convince farmers and consumers about their presence in foods and feeds. The majority of farmers, traders and consumers in Africa are not aware of aflatoxin contamination of food and feed and its implications on trade and both human and livestock health. Aflatoxin contamination begins in the field, and increases during storage and transportation. Factors influencing aflatoxin contamination include cultural crop handling practices, weather conditions during crop growth, plant susceptibility, and storage conditions.

Maize and groundnut, staple crops for millions across West Africa, are the most susceptible crops to aflatoxin contamination. Awareness and sensitization on aflatoxins to farmers and all the stakeholders are therefore an important part of any intervention strategy to manage the problem. Increased awareness will help enhance the adoption of aflatoxin biocontrol technology “aflasafe” and other management practices available to minimize aflatoxin contamination.

Development and distribution of training manuals, flyers and brochures in major languages, conducting training, workshops, and use of media are major sources of information dissemination. A more effective method of controlling aflatoxins requires a combination of technologies and improvement on existing cultural practices by subsistence farmers.

In order to monitor aflatoxin contamination in Nigeria, local personnel need to be trained to control factors that induce aflatoxin contamination. Documentation of farmers' current practices and training them on the code of practice of maize and groundnut production will improve crop quality. This requires monitoring and adoption of Good Management Practices (GMP) from pre-harvest to post harvest measures that improve food quality both at household and market levels should be encouraged and implemented by stakeholders especially the policy makers.

It is recommended that resources be directed to emphasizing the Good Agricultural Practices (GAPs) at the pre-harvest level and during drying and storage and Good Manufacturing Practices (GMPs) during the processing and distribution of various products. The implementation of the guidelines contained in this manual will minimize aflatoxin contamination of maize and groundnuts through adoption of biocontrol technologies and other preventive or control measures in the production, handling, storage and processing of the crops.

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Introduction

What are aflatoxins?

- Aflatoxins are poisons produced by the fungus (mould) *Aspergillus flavus* and closely related moulds.
- *A. flavus* resides in soils and both dead and decaying organic matter.
- Aflatoxins contaminate 25%+ of maize and groundnut produced in Sub-Saharan Africa.
- Other affected crops include chillies, cassava, sorghum, and rice.
- Aflatoxins pose health risks to both humans and animals even at low concentrations.



Green growth of *Aspergillus* fungi on maize (left) and groundnut (right).

How do aflatoxins harm us?

- Aflatoxins cause liver cancer, suppress the immune system, retard growth and development of children, among other health problems.
- Consumption of aflatoxin-contaminated food and feed decreases productivity in humans and animals; sometimes it is fatal.
- Aflatoxin-contaminated crops typically are forced into low-value markets.
- Aflatoxins damage our health and reduce both crop value and business opportunities.



Can we see aflatoxins?

- Aflatoxins are colourless chemicals and cannot be seen.
- Colour of *Aspergillus flavus* is yellow/green.
- Grains without visible signs of *A. flavus* may contain high amounts of aflatoxins.
- Aflatoxin concentrations are determined with laboratory tests.

Where and how are aflatoxins produced?

- *Aspergillus* moulds produce aflatoxins when infect grains before and/or after harvest.
- Insect damage increases fungal growth and aflatoxin contamination.
- Drought and high temperatures increase aflatoxin production as do improper pre-harvest, post-harvest, and storage practices.

Can we reduce aflatoxin contamination?

Yes, by using aflasafe, a highly cost-effective, environmentally safe biocontrol product developed by IITA and partners. aflasafe products should be used along with other management practices.

Occurrence of aflatoxins

About 25% of maize and groundnut become contaminated with aflatoxins. Over 2.5 billion people are regularly exposed to dangerous aflatoxin concentrations.

Effect of aflatoxins on health

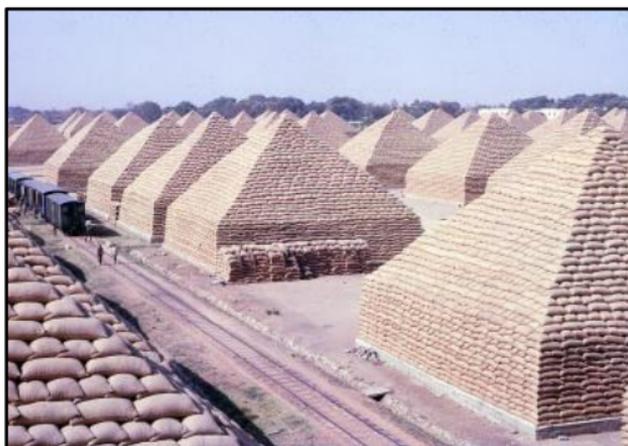
- Aflatoxins are linked to: cancer (especially of the liver), immune-system suppression, child stunting, impaired food conversion, kidney toxicity, and when consumed in large quantities, can cause death.
- Exposure to aflatoxins may start before birth; mothers can pass aflatoxins to the fetus through the umbilical cord.



Broilers fed with: good quality, aflatoxin-safe feed (left) and aflatoxin-contaminated feed (right).

Effect of aflatoxins on trade

- Because of dangerous effects on human and animal health aflatoxins are strictly monitored in crops sought by domestic and international premium markets.
- When containing aflatoxins above tolerance limits crops have reduced commercial value and should be destroyed.
- European nations have set a limit of 4 parts per billion (ppb) for crops destined for food. The limit in the US is 20 ppb. Across Africa it varies from 10 to 20 ppb.
- Trade and income of farmers is affected as a result of rejection of contaminated crops.



In Nigeria, groundnut export market has been lost as a result of failing to meet safe, premium standards.



Awareness and sensitization

Awareness campaigns through meetings and simple communication messages provide valuable aflatoxin management related information to stakeholders in the maize and groundnut value chains (consumers, farmer groups, extension services, marketers, and food/feed industries), governmental and large non-governmental stakeholders (e.g. policy makers, quarantine officials, among others).



Awareness campaigns in farmer's fields across African nations.



Awareness in the field with regulators (left) and farmers (right).

Aflasafe

IITA, the Agricultural Research Service of the U.S. Department of Agriculture and partners have developed several biocontrol products under the trade name aflasafe. Use of aflasafe products results in 80 to 99% less aflatoxin levels in maize and groundnut in comparison to untreated crops.

What is aflasafe and how does it work?

- Aflasafe products contain four atoxigenic *A. flavus* strains native to the target nation.
- Roasted, sterile sorghum grains serve as carrier and nutritive source for the atoxigenic strains.
- Spores of the strains are coated onto sorghum using a polymer sticker. A blue food dye is used to distinguish aflasafe from regular sorghum.
- Aflasafe is broadcasted on fields at a rate of 10 kg/ha. In maize, aflasafe is applied 3 weeks before flowering. Groundnut fields are treated 30-45 days after planting.
- Within 2-3 days, atoxigenic strains sporulate on sorghum and displace aflatoxin-producing fungi.



Maize farmer broadcasting aflasafe across her field. Treated crops have significantly less aflatoxins than untreated crops; aflatoxin-safe crops have higher chances to be commercialized in premium markets.



Maize, pre-harvest recommendations for aflatoxin management

Use improved varieties

Contact extension agents to know which varieties perform better in your area.



Plant maize varieties recommended in your area.



Contact extension agents for advice.

Sources of seeds

Resistant or adaptable varieties. Obtain seeds for planting and other inputs from a reliable source, such as an agro-dealer. Follow good agronomic practices to grow the crop.



Farmers must buy high quality seeds from reliable companies (left). High quality chemicals must be used (right).

During crop growth

Time of planting:

- Plant at the right time to enable crop disease escape, and have enough rain for growth and maturity towards the end of the season.
- Do not plant too early to avoid crops maturing during the rains.
- Planting on time and timely application of inputs will enable maize to grow healthy and resist pest and diseases.



Maize with correct inputs applied (left). Maize with low quality inputs and delayed weeding (right).

Apply fertilizer and other inputs

Crops grown under stress are more susceptible to infestation by the aflatoxin-producing fungi that cause contamination. Applying fertilizer and other key inputs reduces crop stress.



Farmer applying fertilizer on his maize field (left). Maize where no fertilizer was applied (right).

Insect damage

- Control insects, particularly stem borer, during crop growth.
- Insects create wounds on the crop that lead to invasion by fungi. Sometimes insect attack may completely damage the crop.



Maize plants with insect damage.

Weeding

- Undertake timely control of weeds to avoid them competing with the crop.
- Weed control can be done manually with a hoe, bull, tractor, or herbicide.



Weed fields on time with hoe (left) or bull (right) to avoid weeds competing with the crop. If available, use herbicides or tractor.

Before aflasafe application

Before aflasafe application ensure that all agronomic practices (weeding, last dose of fertilized applied, etc.) have been completed.



Weed fields on time before aflasafe application.



Ensure that the crop is at the right stage before aflasafe application.



Right stage of the crop for aflasafe application.

aflasafe application

Apply aflasafe in maize fields at 2–3 weeks before flowering. Broadcast at the rate of 10 kg/ha.



Ensure that aflasafe is distributed uniformly in the field during application.

The beneficial strains of aflasafe require moisture to grow, therefore apply aflasafe after rains, when rains are expected or when the soil is wet. When there is adequate moisture in the soil, aflasafe atoxigenic strains grow rapidly on the sorghum grain carrier which serves as their food.



The atoxigenic strains of aflasafe produce spores on sorghum grains 2-3 days after application.

After the initial reproduction cycle, the atoxigenic strains will colonize organic matter in the field before moving to the target crops. This will prevent toxigenic fungi to become associated with the treated maize.

Application of aflasafe has carryover effects and is beneficial for maize and groundnut intercrop. The atoxigenic *A. flavus* strains of aflasafe do not have negative effects on other crops.



Application of aflasafe in mixed cropping.

Wrong stage of aflasafe application



Maize plants already flowered; application of aflasafe at this stage will not be effective in reducing aflatoxin accumulation.



Delayed weeding is not proper for aflasafe application.

USE PRECAUTIONS

Do not apply with fertilizers, insecticides, or fungicides. Apply **aflasafe** only when the possibility for drift to potential sensitive areas (e.g., residential areas, water bodies, known habitat for threatened or endangered species) is minimal.

STORAGE AND DISPOSAL

DO NOT CONTAMINATE WATER, FOOD, OR FEED BY STORAGE AND DISPOSAL

aflasafe STORAGE: Store dry. Do not expose to relative humidity greater than 80% prior to use. This product contains a living organism that must be alive to work. Do not store under extreme conditions. Do not expose to temperatures above 50°C.

aflasafe DISPOSAL: Use all product of this package by applying according to directions. Offer remaining product to a waste disposal facility or pesticide disposal program (such programs are run by Regional or local Governments or by industry).

CONTAINER HANDLING: Do not reuse or refill container. Offer bags for recycling if available or dispose empty bag in a sanitary landfill or by incineration or, if allowed by state or local authorities, by burning. If burned, stay out of smoke.

ENVIRONMENTAL HAZARDS

Do not apply directly to water, or to areas where surface water is present. Do not contaminate water when disposing of equipment wash water or rinsate.



Maize, harvest and post-harvest recommendations for aflatoxin management

Harvesting

Timely harvest of crops limits aflatoxin contamination.

Harvest immediately after the crop is mature. Pluck the cobs off the plant and dry to less than 13% moisture content without delay.



Harvest maize ears while the plants are still standing.



Delayed harvesting may lead to infestation by dangerous moulds.



Lodging

Maize plants that are fallen on the ground should be lifted up and tied together.



Plants should remain erect during harvesting (left); plants lying on the ground should be lifted and tied in groups (right).

Sorting of damaged cobs

During harvesting, remove cobs damaged by birds or rodents. Damaged crops may have been infected by aflatoxin-producing fungi and may contain high aflatoxin concentrations.



Heaping

Farmers often heap the maize plants in the field and allow for drying.



The heaps should remain erect in the form of a cone.



Heaps that are too big or fall on the ground are likely to accumulate moisture at its center.



Do not heap plants that have been lying on the ground for a long period and/or have signs of animal/insect damage.



Dehusking

Dehusk the cobs directly into a bag and avoid contact with the soil.



Cobs should be plucked into bags.



Do not put cobs in bare ground.

Drying

During drying, sort to remove immature cobs, infected cobs/grains, debris and broken cobs.



Sort to remove diseased or infested cobs during drying.



Dry grains on polyethylene sheets or tarpaulin.



Dry maize in elevated platforms.



Cover with polyethylene sheets if rain is about falling.



Do not dry grains on bare ground either in the field or at home.



Avoid contact with soil during drying.



Avoid crops to become in contact with water during drying.



Sorting during drying

Do not dry grains with symptoms of infection or diseased along with healthy ones. Separate the healthy cobs from immature, insect damaged or diseased cobs.



Healthy, good looking maize cobs.



Unhealthy, infested cobs should be separated from healthy cobs.



Determining safe moisture content

Use a moisture meter to know moisture content of your maize. Alternatively, farmers can test for properly dried maize by cracking kernels between the teeth. If it shatters then kernels are dry. If it is sticky then kernels are not dry. Also, farmers can throw maize up and down their palms, or inside a bottle. Dry maize will produce a rattling noise, compared to maize that is not well dried.



Use a standard moisture meter to read moisture content of your maize.



If the grain shatters then the moisture content is safe but if it is sticky then it is not safe to store.



Threshing

Use well calibrated threshers in order to maintain good grain quality in maize.



Calibrate machine before threshing.



Thresh on tarpaulin and maintain good hygiene during threshing and bagging of maize.



Whole grains of good quality after threshing.



Poorly calibrated threshers damage kernels (see inset).



Do not thresh maize by beating with sticks; this may increase proportions of broken kernels (see inset).



Do not thresh maize on bare ground.



Storage

- Clean, repair and disinfect the storage structure before bringing in new harvest.
- Fumigate the storage structure to control insects and rodents.
- Storage structure should have well-built wall and roof to prevent rain seepage and excess moisture.
- The structure should be well ventilated, with low relative humidity.
- Do not mix new crops with old crops.



Good sanitation in the storage.



Good looking storage structure.



Poor storage structure.



Poor sanitation practices in the store.



Training

Organize farmers' field days for demonstration.



When to apply aflasafe.



How to apply aflasafe.



How to identify diseased cobs.

Groundnut, pre-harvest recommendations for aflatoxin management

Use improved varieties

Contact extension agents to know which varieties perform better in your area.



Plant groundnut varieties recommended in your area.



Contact extension agents for advice.

Sources of seeds

Resistant or adaptable varieties. Obtain seeds for planting and other inputs from a reliable source, such as an agro-dealer. Follow good agronomic practices to grow the crop.



Farmers must buy high quality seeds from reliable companies (left). High quality chemicals must be used (right).

During crop growth

Time of planting:

- Plant at the right time to enable crop disease escape, and have enough rain for growth and maturity towards the end of the season.
- Do not plant too early to avoid crops maturing during the rains.
- Planting on time and timely application of inputs will enable groundnut to grow healthy and resist pest and diseases.



Groundnut with correct inputs applied (left). Groundnut with low quality inputs and delayed weeding (right).

Apply fertilizer and other inputs

Crops grown under stress are more susceptible to infestation by the aflatoxin-producing fungi that cause contamination. Applying fertilizer and other key inputs reduces crop stress.

Insect damage

- Control insects during crop growth.
- Insects create wounds on the crop that lead to invasion by fungi. Sometimes insect attack may completely damage the crop.



Groundnut plants with insect damage; both photographs from mississippi-crops.com.

Weeding

- Undertake timely control of weeds to avoid them competing with the crop.
- Weed control can be done manually with a hoe, bull, tractor, or herbicide.



Weed fields on time with hoe or bull to avoid weeds competing with the crop. If available, use herbicides or tractor.

Before aflasafe application

Before aflasafe application ensure that all agronomic practices (weeding, last dose of fertilized applied, etc.) have been completed.



Weed fields on time before aflasafe application.



Ensure that the crop is at the right stage before aflasafe application, as shown in the picture.



Use of tied ridges (left) and mulching practices help to conserve moisture and reduce stress in the plant. Both practices aid in reducing aflatoxin contamination. Photographs from Dr. Sam Ngoroje, ICRISAT.

aflasafe application

Apply aflasafe in groundnut fields 30 to 45 days after planting. Broadcast at the rate of 10 kg/ha.



Ensure that aflasafe is distributed uniformly in the field during application.

The beneficial strains of aflasafe require moisture to grow, therefore apply aflasafe after rains, when rains are expected or when the soil is wet. When there is adequate moisture in the soil, aflasafe atoxigenic strains grow rapidly on the sorghum grain carrier which serves as their food.



The atoxigenic strains of aflasafe produce spores on sorghum grains 2-3 days after application.

After the initial reproduction cycle, the atoxigenic strains will colonize organic matter in the field before moving to the target crops. This will prevent toxigenic fungi to become associated with the treated groundnut.

Application of aflasafe has carryover effects and is beneficial for groundnut and maize intercrop. The atoxigenic *A. flavus* strains of aflasafe do not have negative effects on other crops.



Application of aflasafe in mixed cropping.

Wrong stage of aflasafe application



Groundnut plants already flowered; application of aflasafe at this stage will not be effective in reducing aflatoxin accumulation. Photograph from jardinage.ooreka.fr.



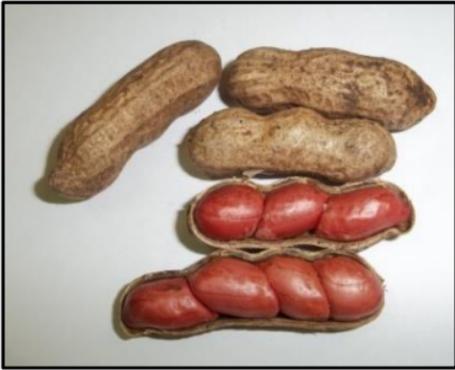
Delayed weeding is not proper for aflasafe application.



Groundnut, harvest and post-harvest recommendations for aflatoxin management

Harvesting

Avoid delayed harvesting; harvest groundnut immediately after it have reached maturity.



Timely harvest prevents fungal infection.



Good quality groundnut pods at maturity.



Delayed harvesting promotes fungal infection and subsequent aflatoxin production.



If left on the field longer than necessary, some groundnut varieties can germinate especially if it is still raining. Pods break and allow moulds to infect the grains.



Avoid mechanical injury on pods during harvesting. Harvest with care.



Pick the pods into a container.



Damaged groundnut pods allow infection of bad moulds.

Drying

Tie a few groundnut plants together and place on the ground with the pods facing upward for fast drying.



Let the pods be facing upward for fast drying.



Do not dry groundnut in a heap. The surface may look dry but the center may accumulate moisture.



Separate healthy pods from immature, insect damaged or diseased pods.



Dry groundnut on polyethylene sheets.



Do not dry groundnuts on bare ground (left); do not heap groundnut pods on the floor inside storage structures (right).



Sanitation

Maintain good hygienic conditions during threshing to avoid further contact with soil or contamination by livestock.



Threshing must be done on tarpaulin.



After threshing sort groundnut to remove contaminated grains before cooking or storage.



Threshing on the bare ground must be avoided.



Poor sanitation during threshing must be avoided.

Storage

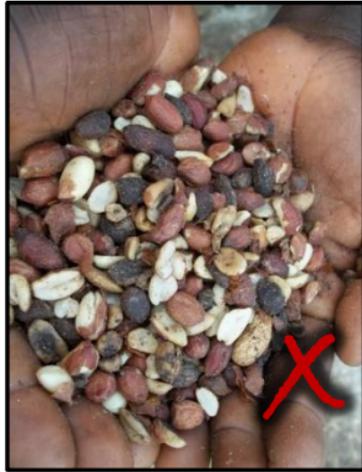
- Clean, repair and disinfect the storage structure before bringing in new harvest.
- Fumigate the storage structure to control insects and rodents.
- Storage structure should have well-built wall and roof to prevent rain seepage and excess moisture.
- The structure should be well ventilated, with low relative humidity.
- Do not mix new crops with old crops.



Store threshed groundnut in bags and on pallets.



Groundnut bags should not be put on the ground nor touching walls (left); storage of bags should not be done in a disorganized way (right).



Do not store groundnut beyond the production season. Prolonged storage results in groundnut deterioration and increased aflatoxin content (left and right).



Transport



Transport maize and groundnut in water-proof vehicles to avoid re-wetting.



If rains occur, this type of transport would allow re-wetting of the crop and fungal infection and aflatoxin contamination will probably occur.