GUIDELINES FOR THE MANAGEMENT OF AFLATOXIN CONTAMINATION IN GROUNDNUTS AND MAIZE IN MALAWI

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Government of Malawi

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GUIDELINES FOR MANAGEMENT OF AFLATOXIN CONTAMINATION IN GROUNDNUTS AND MAIZE IN MALAWI

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PREFACE

This booklet has been developed to provide extension personnel, traders, farmers and consumers with knowledge about mycotoxins (particularly aflatoxins) and their implications on human and animal health as well as marketing of agricultural commodities. Aflatoxins can contaminate a wide range of food and feed substances such as cereals, nuts, spices and fruits both in the field and in storage. In this booklet maize and groundnuts have been chosen on the basis of their significant contribution to food security in Malawi.

Current consumption trends suggest that the amount of food considered as unsafe for human consumption due to contamination by hazardous agents such as aflatoxins is quite substantial. This has led to increased global concerns on food safety and security. Improvements in domestic food safety may have direct and indirect benefits, in terms of better health and higher productivity that will eventually lead to food security and enhanced welfare of citizens in the country.

It is imperative that we strive to improve food safety in the country, beginning with what we consume at household level, as well as what is offered for sale at the local and international markets. These guidelines are therefore envisaged to contribute to increased production of good quality and safe agricultural products which meet the requirements of both domestic and export markets.

A. P. Mtukuso (PhD)

Director for Agricultural Research Services
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INTRODUCTION

Mycotoxins and aflatoxins

Fungi are ubiquitous in nature, and they infest cereals, nuts, beans and many other agricultural crops including many fruit crops. They also produce a wide range of secondary metabolites called mycotoxins. Mycotoxins are chemically and biologically active secondary metabolites produced by several families of saprophytic and plant pathogenic moulds such as Fusarium, Aspergillus, Penicillium, Alternaria, and Claviceps spp. Mycotoxin contamination of agricultural commodities occurs as a result of environmental conditions in the field as well as improper harvesting, storage, and processing operations. Mycotoxins contaminate about 25% of food commodities produced worldwide annually. Currently about 400 mycotoxins have been identified but not all are regulated either due to their low toxicity or lack of sufficient toxicological evidence. Table 1 below shows some of the important mycotoxins.

Table 1: Important mycotoxins, their sources and potential toxicities

<table>
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<th>Toxins</th>
<th>Producing fungi</th>
<th>Toxicities</th>
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<td>Aflatoxin</td>
<td><em>A. flavus, A. Parasiticus</em></td>
<td>Hepatocarcinogen</td>
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<tr>
<td>Fumonisins</td>
<td><em>F. verticillioides</em></td>
<td>Brain hemorrhage (equidae)</td>
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<tr>
<td>Zearalenone</td>
<td><em>F. graminearum,</em></td>
<td>Hyper-estrogenic effect</td>
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<td>Ochratoxins</td>
<td><em>A. ochraceus</em></td>
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<td>Vomitoxin</td>
<td><em>F. graminearum</em></td>
<td>Vomiting, Feed refusal</td>
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<tr>
<td>(Deoxynivalenol)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Citreoviridin</td>
<td><em>P. viridicatum</em></td>
<td>Cardiac beri-beri</td>
</tr>
<tr>
<td>Cytochalasin E</td>
<td><em>A. clavatus</em></td>
<td>Cytotoxicity</td>
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Mycotoxins are lipid-soluble, and are easily absorbed by the intestines, airways and the skin. As such they have been implicated as chemical agents of toxic diseases in humans and animals. They pose a higher chronic dietary risk than anthropogenic contaminants, some phytotoxins, unbalanced diet, phycotoxins, food additives, pesticide residues, and other microbiological contaminants. Due to this dietary risk of mycotoxins to humans and animals many countries regulate the maximum levels that can be tolerated in foods and feeds.

**Aflatoxin**

The term aflatoxin is an acronym derived in 1960 from three words: Aspergillus, Flavus and Toxin following a poisoning outbreak that caused deaths of about 100,000 turkeys in England. Aflatoxins are potent mycotoxins mostly produced by fungal species that include *Aspergillus flavus* and *A. parasiticus* and rarely *A. nomius* on a variety of food products, including cereals and legumes, (See Figure 1). These
are crystalline substances that dissolve fairly in water. Aflatoxins are generally thermal stable even at temperatures in excess of 100 °C and therefore can not be destroyed by normal cooking. Aflatoxins are the most important mycotoxins due to their acute and chronic toxicity and prevalence. They are also the most studied and well understood of the mycotoxins.

Figure 1: Groundnut kernels and pods colonised by fungi

HEALTH IMPLICATIONS OF AFLATOXINS

Human consumption of foods prepared from aflatoxin contaminated crops or livestock result in numerous health problems. Aflatoxins are known to be carcinogenic, producing tumours, liver cancer and other unpredictable disorders in humans and animals. Aflatoxin B1 is the most natural potent hepatocarcinogen known in mammals classified by the International Agency of Research on Cancer (IARC) as group 1. Once consumed aflatoxins are subsequently expressed into other more toxic forms. These forms may be passed on from mothers to babies through milk.
Toxic effects may vary depending on a number of factors such as intake levels, duration of exposure, mechanisms of action, toxin species, metabolism, as well as each animal or person’s immune system. Exposure to aflatoxins may either be acute (short-term) or chronic (long-term).

- Acute exposure may result into fever, oedema, lethargy (sluggishness), vomiting, abdominal pain, fatal liver failure and fatality of up to 25% (of the exposed population).
- Chronic exposure may lead to:
  i. Immune suppression
  ii. Loss of appetite
  iii. Reduced growth rate
  iv. Reproductive disorders such as reduced egg production, abortion, impotence and teratogenicity
  v. Decreased milk or egg yield
  vi. Death

**ECONOMIC IMPLICATIONS OF AFLATOXINS**

Since the discovery of aflatoxins, many countries have established regulations in food and feed to safeguard the health of humans and animals, and also to protect the economic interests of producers and traders. Most developed countries have set low maximum tolerable limits (MTLs) for the aflatoxin in human and animal feed, and have instituted efficient regulatory and monitoring systems. For most developing countries regulatory systems are not well developed and as such it has remained difficult for these countries to export their food produce to high value markets. Further, critical population dietary exposure to aflatoxins leads to increased cost of health care.
IMPORTANCE OF AFLATOXINS IN GROUNDNUTS AND MAIZE

In Malawi, maize and groundnuts are of great importance. Maize is Malawi’s main staple which is generally consumed in large quantities. It represents a staple food for more than 80% of the population, with per capita consumption of about 180 kg per year, considered the highest in the world. Groundnut is another major dietary component and a relatively cheap source of protein and vegetable oil for many people in Malawi. If these commodities are contaminated with aflatoxins, dietary exposure and impact on the population are also likely to be high.

MANAGEMENT OF GROUNDNUTS TO REDUCE AFLATOXIN CONTAMINATION

Aflatoxin contamination may occur at any stage in the value chain, including during pre-harvest, harvesting and post-harvest handling of the crop. Pre-harvest contamination is severe during periods of drought. Contamination occurs during harvesting due to poor harvesting procedures. Post-harvest contamination results mostly from poor drying procedures, remoistening of pods at shelling, and sometimes poor handling and damage occurring during transportation.

In the Field

Prevention through pre-harvest control is the first step to ensure a safe final product. This can be achieved through the following:

- Avoid continuous mono-cropping of groundnuts as this may lead to a build-up of high populations of Aspergillus in the soil, which will increase the probability of infection and
aflatoxin contamination. At least a 3-year rotation with a cereal crop is recommended.

- Plant early to reduce risk of exposure to aflatoxin contamination by ensuring a vigorous crop stand. An early planted crop matures when there is still moisture in the ground thereby escaping end of season drought. Early planting also avoids build up of soil pests that predispose plants to fungal infestation.

- Apply fertilizer and/or other soil amendments to ensure adequate plant nutrition to avoid plant nutrient stress, especially during seed development, which increases susceptibility of groundnuts to fungal infestation. In groundnuts, resistance to aflatoxin is classified into: pod resistance, seed coat resistance and resistance to aflatoxin production. The first two can be enhanced through improved plant nutrition.

- Maintain optimum plant population by adhering to the recommended inter- and intra-row spacing for the varieties grown to avoid moisture and nutrient stress.

- Use tied ridges (box ridges) to conserve soil moisture during drought periods. Adequate soil moisture minimizes pod cracking and pod scarification by termites thereby also reducing the chance for fungal entry into the kernels.

- Use varieties that are well adapted to the prevalent length of growing season. Suitable cultivars are those that mature at the end of the rainy season so that post-harvest field drying can be done under favourable conditions. On the other hand earlier maturing varieties are ideal for escaping severe terminal drought stress thereby substantially reducing aflatoxin incidence.

- Employ recommended cultural practices that reduce weed growth, lower the incidence of soil insects, mites, and nematodes thereby reducing aflatoxin contamination by ensuring a more resilient crop.
Harvesting

- Harvest the groundnuts at full physiological maturity. Groundnuts attain full maturity when over 70% of the pods have dark markings inside the shell, and seeds are plump and of the correct colour for that variety. Delays in harvesting may increase risk of aflatoxin contamination. However, if terminal drought has set in while the crop is not fully mature, but has started to show signs of wilting without further prospects for a rainfall event, then the crop should be harvested to avoid further predisposition.

- Shake the groundnut plant after lifting to remove excess soil from the pods. Soil stuck to the pods will lengthen drying time thereby increasing the risk of fungal growth and aflatoxin contamination.

- Handle groundnut plants gently using recommended harvesting procedures to minimize any mechanical and physical damage to pods at all stages of harvesting.

- Remove and destroy all dead plants. Do not mix immature pods and damaged gleanings with main produce.

- Thoroughly dry harvested pods to moisture levels of 6-8% (dried pods produce a metallic rattling sound when shaken). Effective and efficient drying methods should embrace slow drying in a well ventilated environment. Common methods include: drying unstripped pods on straws in windrows, ventilated drying of unstripped pods using Mandela cock (ventilated stack) or the A-frame, and drying stripped pods on clean soil surface or mats.

- Use clean and dry containers for transporting produce from either the field to storage or from storage to markets to avoid contamination.
Mandela cocks

- Groundnut straws are stacked in a circular fashion (1.0 m diameter) with pods facing upwards on a raised surface to form a base or platform of the Mandela cock that will divert surface runoff and drain off any rain water (Figure 2).

![Figure 2: Base of a Mandela cock](image)

- More straws are added on the platform from the outside of the circle with pods facing inwards whilst leaving a chimney in the middle to facilitate drying through airflow.

- Chimney diameter is reduced in subsequent layers, eventually creating a conical structure.

- Finally the stack is closed with 1 or 2 straws at a height of about 1.5 m (Figure 3).

- Within 2-4 weeks after lifting, the Mandela cocks are ready for stripping depending on weather conditions.
Figure 2: A completed Mandela cock

In storage

- Store groundnuts in-shell (pods) as this minimizes levels of insect and fungal attack in storage facilities.
- Do not bag groundnuts that are not adequately dry for storage. Groundnuts should be stored in a dry, properly ventilated storage facility with a good roof, well protected from insects, rodents, and birds, and with minimum temperature fluctuations.
- Use clean and dry bags and stack them on pallets or poles. Make sure stacks of good sizes are made i.e. up to 10 bags high to facilitate adequate air circulation and reduce possibility of building up a humid environment (Figure 4). Gunny bags are recommended. Do not use polythene or
polypropylene bags as these restrict air flow and increase the risk of fungal growth and aflatoxin contamination.

Figure 3: An example of stacking bags with stored groundnuts

- Periodically check stored groundnuts for mould growth and insect infestation. If no external mould is visible, randomly sample and split the kernels to disclose possible hidden mould growth.
- Groundnut pods and kernels should be carefully sorted and graded, separating the apparently under developed and infected portions from sound produce, and send samples for analysis of aflatoxins if possible.
- Defective (mouldy, discoloured, rancid, decayed, shrivelled and insect damaged) kernels should be screened and discarded and only well matured produce should be used for direct consumption by humans and livestock, or offered for sale to other consumers and end-users.
- Avoid sprinkling water on pods and nuts during shelling as this is one of the major conditions that encourage fungal growth.

**MANAGEMENT OF MAIZE TO REDUCE AFLATOXIN CONTAMINATION**

The fungi that produce aflatoxin favour hot and sunny conditions during the day and warm-wet conditions at night. Maize is prone to fungal attack at silking and grain-filling stage under water stress conditions. Insect, bird, and mechanically damaged grains, as well as exposed ear tips, are particularly prone to fungal colonization and aflatoxin contamination (Figure 5). Storing of inadequately dried grain, storage of grain under damp conditions and pest damage predisposes grain to aflatoxin contamination.

![Figure 4: Aspergillus growing on maize](image-url)
In the field

- Plant with first planting rains.
- Use well adapted varieties.
- Improve plant nutrition.
- Follow recommended plant spacing.
- Weed timely.
- Use box ridges to conserve soil moisture.
- Control pests such as insects and birds.
- Remove diseased and pest damaged maize plants in the field (Figure 6a and 6b).

Figure 5: (a) Maize cob damaged by birds
(b) Maize attacked by stalk borer
**Harvesting**

- Consider harvesting maize soon after kernel black layer has developed. The longer maize stands in the field, the greater the risk of insect attack and the more time ear moulds have to produce toxic by-products such as aflatoxins.
- Burn all the mouldy cobs and those attacked by pests in the fields. Do not transport such cobs to the homestead (Figure 7). Mouldy maize acts as a source of *Aspergillus* inoculum.

Figure 6: Mouldy maize likely to contain several types of fungi and mycotoxins

- Do not heap maize that is not thoroughly dried.
- Do not heap or dry maize on a bare floor as shown in Figure 8.
Storage

- Always sanitize grain storage containers and rooms.
- Control storage pests by applying recommended storage pesticides and use of rat guards.
- Avoid grain damage during shelling. Do not shell by beating.
- Do not store maize in damp conditions. Periodically check stored grain for mould development. Moisture levels of long-term stored grain should be maintained below 13%.
- Sort and destroy all mouldy grains. Mouldy maize should not be fed to animals as aflatoxins affect animal productivity. Aflatoxin excreted in the milk may subsequently contaminate dairy products made from such milk. Human beings may also take aflatoxin through consumption of the aflatoxin contaminated dairy products.
Figure 8: Fungal colonisation on maize after weevil damage

REGULATORY CONTROL OF AFLATOXIN

Regulatory limits are governed by law, violation of which has legal consequences. Regulatory limits or standards provide a benchmark against which effectiveness of food safety programmes can be tested. Adverse health effects from the ingestion of toxins have caused regulatory agencies throughout the world to limit the amount of aflatoxins that are permitted in food or feed that is available for sale. The Common Market for Eastern and Southern Africa (COMESA) of which Malawi is a member has set the legal limits for total aflatoxin in cereals and legumes at 10μg/kg (10 parts per billion, ppb). Recommended limits for total aflatoxins in foods globally range from 4–20 ppb and Codex Committee proposed a level of 10 ppb. The US Food and Drug Administration (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. The European Union (EU) which is the potential market for groundnuts from
Malawi has a regulatory limit of 4 ppb in groundnuts meant for human consumption.

**RECOMMENDATIONS FOR TRADERS TO MANAGE AFLATOXINS IN GRAINS**

- The traders should directly purchase produce from farmers. Traders must avoid buying produce from intermediaries (*middlemen*) who sometimes bulk produce of different quality. Sometimes intermediaries deliberately moisten the produce to increase weight hoping to fetch more profits.
- Always check grain quality condition before purchase.
- Always purchase new or the current season’s produce.
- Always ensure that grain moisture at point of purchase is less than 13%. If not, the grains should be immediately dried (Moisture meters should be used to monitor moisture levels).
- Grains should be sorted to remove the following:
  1. Diseased grain,
  2. Mouldy and discoloured grain,
  3. Broken grain,
  4. Soil contaminated grain,
  5. Foreign matter and chaffs,
  6. Insects and insect damaged grain.
- Do not process poor quality grain into any food products. Processing of poor quality groundnuts into peanut cake or butter is a common practice among traders. This results into high aflatoxin content and a risk to the consumer.
- Grains purchased should not be stored for long before sale.
- The grains should be stored in new interwoven polypropylene bags stacked in a moisture and rodent proof store (no rodents and insects).
• Regular inspection of grains and the processing premises should be carried out. Where the trader has no capacity to do so, expertise should be out-sourced from competent authorities.
• Aflatoxin testing should be done regularly.
• Proper packaging of the finished products in moisture-tight containers is recommended. Wherever possible vacuum packaging should be considered and encouraged.
• Before engaging in export of produce traders should consult competent authorities such as the Department of Agricultural Research Services for technical advice. The legal requirement of the importing country or company should be thoroughly studied. Grains should be tested for mycotoxin by a reliable testing facility. A Mycotoxin laboratory at Chitedze Agricultural Research Station of the Department of Agricultural Research Services offers reliable HPLC mycotoxin testing (See Figure 10 below).
HANDLING MOULDY AND AFLATOXIN CONTAMINATED GRAINS

Although prevention is the best control strategy, aflatoxin contamination will eventually occur. Therefore, post-harvest control and decontamination procedures represent an important measure to avoid consumer exposure. However decontamination techniques should be used with caution as the effectiveness of each processing method should be evaluated for the specific commodity and toxin present in the system.

Specific criteria for the evaluation and acceptance of given mycotoxin reduction or decontamination procedures include:

i. Inactivate, destroy, or remove the toxin
ii. Inhibit production or leave toxic residues in the food or feed
iii. Retain nutritive value and food or feed acceptability of the product
iv. Not alter significantly the technological properties of the product
v. If possible, destroy fungal spores

Some of the decontamination strategies include the following:

i) Removal of mouldy grains

Aflatoxins in contaminated commodities usually reside in relatively small number of seeds or kernels. Those grains can be removed through cleaning and segregation. As this does not significantly alter the product, it is considered as one of the best techniques to reduce aflatoxin presence in final products. For example, when peanuts are processed, a significant amount of aflatoxins can be removed by electronic sorting and hand-picking. Separation of maize screenings can significantly reduce aflatoxin concentration. The principle of this method is based on the identification of damaged kernels in the seed
lots because of variations in size, shape, colour and also visible mould growth. Aflatoxin contaminated kernels are usually damaged, shrivelled or discoloured, and can be removed by electronic sorting and hand picking. However, complete removal of all contaminated particles or aflatoxin cannot be expected with physical methods of separation. Since the toxin can diffuse into the interior of the kernel, residual contamination may be present at very low levels in the final product. If there is a high level of residual contamination, other procedures must be used to manage the residual contamination in the final product.

Another approach is through floating and density segregation. It has been observed that most of the aflatoxin contaminated grains float in tap or natural water. Although there will still be traces of aflatoxin residues following separation, the technique has shown to significantly reduce aflatoxin contamination and thereby being considered as an effective first line of defence for certain products.

Grain screening (based on size and broken kernels) usually contains several times the aflatoxin content compared to intact grains.

ii) De-hulling and Milling

De-hulling and milling of grain is an operation traditionally used for grain processing and separates the grain into different fractions. The fractions that contain higher aflatoxin levels include bran and can be diverted to less risk uses or subjected to decontamination procedures. De-hulling maize and then soaking and washing it of grit results into substantial aflatoxin reduction. In the case of groundnuts, the removal of the testa and polishing of grains also reduces aflatoxin contamination.
iii) Other industrial techniques

Other industrial techniques include: pressurised thermal inactivation, irradiation, use of granulated activated carbon, biological decontamination, nixtamalization and ammoniation processes. However, these techniques are impractical to an ordinary consumer or farmer in that they are too expensive and/or potentially unsafe due to generation of toxic by products and significant alteration of product quality.

iv) Current research efforts in controlling aflatoxins

Despite considerable research efforts around the world, widespread genetic resistance or tolerance to aflatoxin contamination has not been identified. This is not surprising considering the complex 'plant-soil-environment' interactions required for Aspergillus flavus growth and aflatoxin production. It is believed that better physiological understanding of the complex interactions will enhance the search for traits conferring resistance or tolerance to aflatoxin contamination as suitable selection criteria become available in breeding programs.
CONCLUSION

Complete elimination of aflatoxin contamination seems to be practically impossible. However, risks associated with aflatoxin contaminated commodities can be reduced by following an integrated aflatoxin prevention and management system. Recommended preharvest and postharvest practices can significantly reduce aflatoxin contamination. The most effective and practical procedures include good cultural practices and physical removal of damaged or shrivelled kernels.
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This booklet provides the recommendations for managing aflatoxin contamination in maize and groundnuts in Malawi. It highlights the health and economic implications of aflatoxin contamination as well as the regulatory measures for controlling aflatoxin enforced in Malawi and the entire globe. The information provided in this booklet targets the consumer, farmers, traders and extension workers.

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