The Republic of Uganda

MINISTRY OF AGRICULTURE, ANIMAL INDUSTRY AND FISHERIES

AFLATOXIN MANAGEMENT IN UGANDA

A Handbook for Extension Workers

August 2019

FOREWORD AND ACKNOWLEDGMENTS

Agriculture is the mainstay of Uganda's economy with more than 70% of the population depending on this sector for income, food and nutrition security. However, despite an increase in production and consumption of especially major staple crops like cereals, legumes and oil seeds, quality and safety is still a major challenge. Aflatoxins, caused by the mould Aspergillus flavus are a key contributing factor to poor quality and safety of the major staples in Uganda. These toxins have caused significant health effects and economic losses in the country.

The Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) has embraced aflatoxins mitigation as part of its food safety interventions under the Agriculture Sector Strategic Plan (ASSP) for the period 2015/2016 to 2019/2020. One of the major components of the Strategic Action Plan for Prevention and Control of Aflatoxin in Uganda (SAPPCA, 2018/19 - 2023/24), that has been mainstreamed within the ASSP is creation of awareness of the problem among stakeholders involved in the agricultural value chains. This training handbook is developed to help extension workers deliver appropriate knowledge and skills to agricultural value chain actors on management of aflatoxins in the country. The Ministry of Agriculture Animal Industry and Fisheries is greatly indebted to the Uganda Aflatoxin Technical Working Group (ATWG) for their well thought out technical input in this handbook. In a special way, MAAIF would like to specifically recognize and thank USAID Feed the Future Uganda Enabling Environment for Agriculture Activity for availing financial resources and technical assistance to develop this handbook.

Finally, I appeal to extension workers to disseminate the recommended aflatoxin management strategies in this handbook widely to all the value chain actors. This will greatly contribute towards ensuring supply of safe food at household level and in the market and consequently improve food security, nutrition, export growth and overall social economic development in the country.

For God and My Country.

Hon. Vincent Bamulangaki Ssempijja (MP)

MINISTER OF AGRICULTURE, ANIMAL INDUSTRY AND FISHERIES

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LIST OF ACRONYMS

ASSP	Agriculture Sector Strategic Plan
ATWG	Aflatoxin Technical Working Group
CAN	Calcium Ammonium Nitrate
DI	Dietary Intervention
EAC	East African Commission
EU	European Union
FAO	Food and Agriculture Organization
GAP	Good Agricultural Practices
GHP	Good Hygiene Practices
GMP	Good Manufacturing Practices
GSP	Good Storage Practices
IARC	International Agency for Research on Cancer
IEC	Information Education and Communication
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MC	Moisture Content
ML	Maximum Limit
MoH	Ministry of Health
MTIC	Ministry of Trade, Industry and Cooperatives
PACA	Partnership for Aflatoxin Control in Africa
PICS	Purdue Improved Crop Storage
SACCO	Savings and Credit Cooperative Organizations
SSP	Single Super Phosphate
UMMSC	Uganda Mycotoxin Mitigation Steering Committee
UNBS	Uganda National Bureau of Standards
UV	Ultraviolet

ABOUT THE HANDBOOK

Aflatoxins are poisonous compounds produced by mould/fungus known as *Aspergillus flavus*. These toxins are produced when the moulds invade not-well-dried foods like maize, groundnuts, sorghum, soybean, millet, cassava, sweet potatoes, spices, and fish feeds as well as animal feeds if processed from contaminated raw materials like maize bran and soybean. These toxins may lead to death in both humans and animals and should be prevented from contaminating foodstuffs and animal feeds.. They are also a major contributor to economic losses as a result of rejection of aflatoxin-contaminated foods on the market. It should be particularly noted that aflatoxins, once in the food, cannot be easily eliminated through the usual cooking processes due to their tolerance to high temperatures.

Aflatoxin contamination of foods starts from the farm, may occur during crop growth (preharvest), and, continue during harvest and postharvest as the produce moves along the value chain as a result of inappropriate handling. Drought, high temperature, low soil fertility, pest infestation and other stresses that affect plant growth and vigor increase the likelihood of fungal infection as well as the levels of aflatoxins produced by the *Aspergillus* fungi. The prevailing climatic conditions in Uganda have been found to favor mould growth and multiplication hence aflatoxin production in susceptible produce. Many stakeholders are not aware of the harmful effects of aflatoxins. The agricultural sector in the country is dominated by peasant farmers who depend on traditional farming practices dominated by rudimentary technologies. Farmers leave the produce to dry in the field thus exposing them to deterioration before harvest. During open-sun drying the produce is placed on bare ground causing contamination. Furthermore, many farmers do not dry the produce to safe storage moisture content. There are also problems related to storage where the produce is not adequately packaged for protection against moisture; some farmers heap the produce on the floor or in granaries while others store bagged produce on the floor. Also, transporters, wholesalers and retailers do not have appropriate handling facilities. Processors of food and feed sometimes use poor quality materials already contaminated with aflatoxins hence their products will also contain aflatoxins. Overall, there is inadequate use of modern technologies that help to enhance production of quality and safe food.

This handbook, which is primarily intended for use by Extension Officers in Uganda, gives detailed information about improved technologies and important activities that should be put in place by all agricultural value chain actors to manage aflatoxins. Extension officers should be informed that everybody who handles food (farmers, traders, transporters, processors and consumers) contributes to this problem and therefore should adhere to the practices suggested in this handbook.

This handbook aims at imparting knowledge to the trainer on the factors that contribute to aflatoxin contamination of produce along the agricultural value chain. The handbook gives detailed information on what each of the value chain actors (farmers, transporters, food and feed processors, retailers, wholesalers as well as consumers) should do and not do in order to manage aflatoxins in this country. The handbook is categorised into eight chapters based on how the produce is handled along the value chain from the farmer through transporter, trader, processor and finally consumer. Where possible, illustrations in form of pictures have been given either to prove existence of a problem or to emphasize the suggested aflatoxin management activities.

Chapter 1 gives general information that helps the trainer to understand what aflatoxins are, the type of produce most likely to get contaminated, stages at which contamination occurs, the health and economic effects as well as the reasons why aflatoxins are common in our produce. Chapter 2 gives detailed description of good agricultural practices farmers should apply during crop production from land preparation, seed selection, planting through production to harvesting with particular emphasis put on those critical stages where mould infection becomes a problem. Chapters 3 and 4 describe on-farm activities of drying, shelling, threshing, cleaning and storage that have been reported to be the most critical stages for mould infection and aflatoxin production. Detailed information is presented on

insects and rodents as agents that promote aflatoxin contamination during storage and thus methods of control of these have been suggested. It should be particularly remembered that the moulds that produce aflatoxins invade low moisture content foods hence produce drying and storage are key in moisture content levels of the produce and if not well-catered for, aflatoxin contamination is inevitable. Chapters 5 and 6 describe the activities food and feed processors should do and avoid to manage aflatoxins. During processing to add value to agricultural produce, aflatoxin contamination is possible. Quite often, processors use raw materials which are already contaminated with aflatoxins and, since these toxins are not destroyed during processing, they end up in the products. Emphasis should be put on quality control and assurance including obtaining the Quality Mark (Qmark) from UNBS.

The chapter on animal feed processors emphasizes that aflatoxins affect all domesticated animals and have been responsible for reduced productivity and high mortality of animals. Chapter 7 gives detailed description of marketing the produce including transporters', wholesalers' and retailers' activities. During marketing, produce is handled by these categories of people and, each one has a role to play in ensuring produce quality and safety. Chapter 8 targets consumers of agricultural produce. Consumers need to maintain good hygiene and sanitation to prevent disease-causing agents. They should enhance their health by feeding on a balanced diverse diet and eating less of the staples that have been found to be highly contaminated by aflatoxins. The handbook concludes by emphasizing that aflatoxin contamination of food and feed in Uganda is real and, given the nature of our climate we cannot completely avoid it. It is therefore the responsibility of all value chain actors to put the recommended aflatoxin management practices into place to enhance the health and livelihood of the population.

CHAPTER 1.

1.0 UNDERSTANDING AFLATOXINS

This chapter provides background information on aflatoxins as the most studied mycotoxin, the type of produce aflatoxin commonly contaminate, the stages where contamination occurs along the food chain and the health and economic effects that warrant management of these toxins. The chapter ends by highlighting reasons why aflatoxin contamination is common in our produce.

1.1. What are aflatoxins?

Fungi, when they infect food, cause spoilage but may sometimes produce chemicals (toxins) which are toxic to consumers, known as mycotoxins (Myco=Fungi). Since there is a wide range of fungi in the environment, even the mycotoxins are many and the extent to which they affect consumers also varies. One of the most common and widely studied mycotoxins are aflatoxins. Aflatoxins are poisonous/toxic chemicals produced by the fungi *Aspergillus flavus* and *Aspergillus parasiticus* on a variety of food products in tropical and subtropical regions of the world, including Uganda. The name aflatoxins is short for *Aspergillus flavus* toxins. There are four major types of 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 on aflatoxin contaminated rations; hence, the M designation. The B designation of aflatoxin B_1 and B_2 results 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. Aflatoxin B1 is the most lethal and common type of aflatoxin that occurs in foods. Aflatoxin M1 is a derivative of aflatoxin B1. Once in the food, aflatoxins are not easy to eliminate by cooking methods including roasting, boiling and steaming among others because, their melting point (temperature at which they get destroyed) is 400^{o}C and above.

1.2. Which produce are most contaminated?

The moulds that produce aflatoxins (*Aspergillus flavus*) invade not-well-dried produce because they thrive well under low moisture content conditions. The following categories of foods are commonly contaminated by aflatoxins:

- Cereals: maize, sorghum, rice and millet
- Legumes: groundnuts, soyabean
- Oil crops: sunflower and simsim/sesame
- Dry spices like chili, ginger, turmeric
- Dried roots & tubers: cassava, sweet potato *(Amukeke)*
- Dried fish (mainly silver fish/*mukene*)

Thus, from the above, it can be observed that aflatoxins are mainly found in foods which are not properly dried by farmers. In addition, animal feeds if processed from aflatoxin-contaminated raw materials like maize and soybean may also contain aflatoxins. When animals eat aflatoxin-contaminated feeds, these toxins can end up in milk, eggs and meat as aflatoxin M1. In addition, if a lactating mother eats aflatoxin-containing foods, these toxins end up in breast milk as aflatoxin M1 and will poison the baby. In Uganda, aflatoxin contamination in the key food crops of maize, groundnuts, cassava and sorghum is high and widespread.


Moulded maize and cassava creates high chances of aflatoxin contamination

1.3. At what stages of the food chain does aflatoxin contamination occur?

Aflatoxin contamination of foods starts from the farm, during crop growth (preharvest), and, continues during harvest and postharvest as the produce moves along the value chain as a result of inappropriate handling. Drought, high temperature, low soil fertility, pest infestation and other stresses that affect plant growth and vigor increase the likelihood of fungal infection as well as the levels of aflatoxins produced by the *Aspergillus* fungi. For example, aflatoxins can contaminate maize in the field if insects or birds eat/destroy part of the cob or grains, creating avenues, which allow moulds to enter and produce aflatoxins; or if farmers damage groundnut pods during harvesting which allows moulds to invade the kernels. Aflatoxin contamination can thus be prevented by application of good agricultural practices in crop cultivation and good management practices in postharvest food handling.


Maize destroyed by moulds, insects and birds in the field increases chances of aflatoxin contamination

1.4. Why care about aflatoxins?

These toxins should be prevented from contaminating foodstuffs and animal feeds because of their impact on trade and the health of both humans and animals (all domestic animals including cattle, goat, sheep, pigs, rabbits, pets and fish). The health effects of aflatoxins can be categorized into two general forms: acute and chronic toxicity. Acute toxicity results from ingestion of food containing moderate to high levels of aflatoxins and is characterized by a rapid and obvious onset of toxic responses, including hemorrhaging, acute liver damage, edema (swelling), digestive difficulties, and possibly death, usually within a week of exposure. For example, in Kenya, in 2004, over 200 people died while in Tanzania, in 2016, 14 people died as a result of consuming mouldy maize contaminated with aflatoxins.

Chronic toxicity is experienced when individuals ingest low levels of aflatoxins in food over a long period. The biggest and best known chronic health effect of aflatoxin is liver cancer. In fact, the International Agency for Research on Cancer (IARC) ranks aflatoxins as Group 1 Carcinogenic Compounds. In children, aflatoxins reduce growth, leading to stunting and kwashiorkor. Generally, continuous exposure to these toxins weakens body immune system escalating the effects of other illnesses like HIV/AIDS and malaria. Aflatoxins contribute 40% to daily disease burdens in Africa. In animals, they reduce productivity like egg production and growth.

Aflatoxins negatively affect trade thus our social and economic status because we lose money as we cannot effectively sell produce contaminated by this poison in the international markets. The Food and Agriculture Organization (FAO) of the United Nations estimates that 25% of the food produced worldwide is contaminated with aflatoxins. Due to the increasing recognition of the impact of aflatoxins on human health, food regulatory authorities have set and enforced limits for aflatoxins in traded food. For example, stringent limits of 2 parts per billion (ppb) for aflatoxin B1 and 4 parts per billion (ppb) for total aflatoxins in foods are enforced in the European Union (EU).

In countries that fail to meet aflatoxin standards, foreign income from aflatoxin prone foods falls as exporters cannot access strategically important international markets. Africa is reported to lose more than US$ 670 million in export earnings due to the presence of aflatoxins in farm produce per year. If a country does not have or enforce aflatoxin regulations, contaminated foods which do not meet export standards will be sold in the domestic market or used for household consumption, increasing the health risks associated with aflatoxin exposure in local communities.

A child suspected to have liver-aflatoxin associated symptoms

1.5. Why are aflatoxins common in produce?

The following major factors have been reported to enhance aflatoxin contamination of produce

1.5.1. Climate effects

Aflatoxin susceptible countries are those that lie between 40°N and South of the equator, Uganda inclusive, where the environment is suitable for growth and multiplication of the moulds that produce aflatoxins. Uganda experiences a warm-wet climate with most parts of the country having two rainy seasons. Sometimes rain comes even during the dry season, thus rewetting produce dried by farmers or completely hampering the drying process. This kind of environment is suitable for *Aspergillus* moulds to grow and produce aflatoxins. There is need to adopt practices which prevent growth of moulds under these conditions.

1.5.2. Field contamination

Field contamination: Mainly as a result of failure by farmers to observe good agricultural practices right from seed selection through land preparation, planting, management of all stress-causing agents to harvesting. Many farmers do not harvest crops like maize right away, leaving it to dry partially in the field. All these factors have a direct influence on the ability for aflatoxins to contaminate the produce while in the field.

Drying of maize in the field should be avoided

1.5.3. Inappropriate handling of produce

This involves drying produce on bare ground, shelling and threshing through beating, improper transportation and storage.

Drying produce on bare ground predisposes produce to moulds and affects quality

Dropping cassava chips on ground during packaging reduces quality

Heaping produce during storage encourages insect and rodent infestation and moulding

Improper storage of maize increases moisture content, chances of germination and moulding

Inadequate packaging of maize leads to spillage and chances of contamination with dust

1.5.4. Low level of awareness

Low level of awareness of aflatoxins, their health and economic impacts and management practices by value chain stakeholders including consumers is a problem. If stakeholders are aware of these, measures to prevent and manage aflatoxins can be put in place.

1.5.5. Low education level

Generally, an educated population is easy to deal with in terms of appreciation and dissemination of information on the aflatoxin menace compared to people who are illiterate. Majority of Ugandan rural farmers' education level is low thus it takes them time to appreciate the aflatoxin problem.

1.5.6. Cultural habits and socio-economic status

Majority of the value chain stakeholders are stuck to their poor cultural practices while others are of bad economic status hence limited access to appropriate postharvest technologies to improve quality and value of produce. For this reason, value chain actors rely on inappropriate traditional handling and storage technologies that encourage mould and aflatoxin contamination of the produce. Stakeholders need to use improved technologies that allow production and handling of good quality produce.

1.5.7. Inadequate policy and law

Lack of enabling policy and law on enforcement of aflatoxin standards despite presence of these standards as established by UNBS in the country. Thus, produce handlers at all levels are not bothered to put in place the quality standards that can enable management of mould and aflatoxin contamination of the produce.

1.5.8. Lack of direct budget support

Uganda has no direct budget for control of aflatoxins. Rather, funds are embedded within sectors for example, in MAAIF, MTIC and MoH which may not be adequate depending on the sector priorities.

1.5.9. Limited coordination

There is limited coordination among the key value chain stakeholders coupled with many stages and produce handlers along value chains. For example, farmers may put in all the necessary measures to control aflatoxin contamination but transporters or traders could mishandle the produce during transportation and storage enabling mould growth and aflatoxin production.

1.5.10. Limited aflatoxin information and data

There is inadequate information/data available on aflatoxin exposure to both humans and animals in the country. Besides, data on volumes of produce rejected for the export market is also scanty. Lack of data or information limits studies on health and economic impacts of aflatoxin in a country.

CHAPTER 2.

2.0 PRE-PLANTING, PRODUCTION AND HARVESTING ACTIVITIES

This chapter covers recommended Good Agricultural Practices (GAP) intended to prevent aflatoxin contamination of the crop while in the field. These include land preparation before planting (pre-planting), planting, production and harvesting activities.
GAP refer to specific methods which, when applied during farming, produce food for consumers or further processing that is safe and wholesome. The idea behind GAP as far as aflatoxin contamination is concerned is to produce a healthy crop that can resist *Aspergillus* infection. GAP also reduce stressful conditions that would otherwise predispose the produce to mould infection and subsequent aflatoxin production.

2.1. Land preparation and planting

Farmers should select land that is suitable for crop production. For example, for groundnuts, the land should be with deep, well drained sandy, sandy loam or loamy sand soils to allow the pods to develop properly. Good and timely land preparation provides suitable soil conditions for rapid and uniform germination, early weed suppression, good root penetration and growth. Land should be prepared early, before the rains start, so that sowing can take place early in the rains. All previous crop residues and weeds should be completely removed or buried, and seed beds should be smooth to provide good soil-to-seed contact after sowing.

Planting should be done in rows with recommended spacing for the following reasons:

i. Low seed rate is used than with broadcasting;
ii. It ensures uniform germination of seeds.
iii. It reduces competition for water, nutrients and space
iv. It reduces disease incidents for example groundnut rosette
v. Light exposure is maximized thus, excessive shading effect of other plants is minimized which favors more efficient photosynthesis and improved crop yield;
vi. Movement within the crop area is more convenient and allows close inspection of individual plants, weeding, pest and disease control and other farm operations including field mechanization
vii. It is easy to calculate or count the plant population in a given farm area.

Groundnuts planted in rows are easy to weed ensuring very good and clean garden

Groundnuts not planted in rows are not easy to weed hence with weeds, can easily be attacked with several pests and diseases

2.2. Timely application of recommended fertilizers

Application of recommended fertilizers ensures enrichment of the soil with the required nutrients for the crop to grow healthily and vigorously with good resistance against pests and diseases. In order to know whether there is the need to apply fertilizers, and the type to apply, test the soil. There are two types of fertilizers; organic and inorganic. Organic fertilizers are the natural ones, for example, cow dung, coffee husks and crop residues and supply a wide range of nutrients while inorganic are the artificial ones (chemical) manufactured in the industry for example, Single Super Phosphate (SSP), Calcium Ammonium Nitrate (CAN),, and Urea. These supply specific nutrients.

Different crops require different types of fertilizers. Thus, always, read crop manuals to understand the appropriate/recommended fertilizers. For example, Groundnut requires adequate levels of phosphorus, potassium, magnesium and particularly calcium, which are required for maximizing yield and good quality seed. Some fertilizers are applied before planting while others during the course of crop growth. It is important to follow manufacturers' recommendations to avoid application of excess or low doses of the fertilizers. Excess doses are wasteful, can sometimes scotch the crop while low dozes do not supply the required nutrients.

Groundnuts growing on infertile soil and those on fertile soil: Note difference in green colour.

2.3. Good water management

All crops need adequate soil water for them to grow because it is needed for the uptake of nutrients and during manufacture of their food. This is always a problem during drought because majority of the farmers depend on rain-fed agriculture. Stress resulting from drought has been reported as one of the major contributors of aflatoxin contamination of crops while in the field. For example, people who died in Kenya in 2004 were from the drought-prone districts of Makueni, Kitui, Mwingi and Machakos whose maize was stressed and highly contaminated with aflatoxins. Good water management practices include the following

2.3.1. Irrigation

Irrigation, which is the application of controlled amounts of water to plants at needed intervals, is one of the best methods of ensuring that water is always present in the soil. Several simple and modern irrigation techniques are available and these include among others;

- Surface irrigation. Water is distributed over and across land by gravity, no mechanical pump involved. Example is Mubuku irrigation Scheme
- Bucket irrigation (sometimes referred to as manual irrigation)
- Drip irrigation, sometimes known as fertigation when fertilizers are mixed with irrigation water. This is common and can be as simple as using plastic bottles with small holes
- Sprinkler irrigation involving pumping of water.

2.3.2. Mulching

Mulching is a simple process of using garden leftovers such as leaves, straws, grass and shredded trees to cover any bare soil in the garden. In addition to conserving moisture in the soil, m*ulching* returns organic materials and nutrients to the soil and it has the added benefit of preventing weeds or unwanted grass growth. The disadvantage of mulching is that use of plant materials to mulch, such as maize stover may sometimes be discouraged as they may carry over fungal innocula including *Aspergillus* thus contaminating crop of the next season.

Mulched gardens using dry grass controls weeds and conserves moisture.

2.3.3. Use of cover crops

A *cover crop* is a *crop* of a specific plant that is grown primarily for the benefit of the soil rather than the *crop* yield. *Cover crops* are commonly used to conserve soil moisture, suppress weeds, manage soil erosion, help build and improve soil fertility and quality, control diseases and pests, and promote biodiversity. These include crops in the categories of grasses (e.g. rye), legumes (e.g. peas, soybean), cabbage family, sweet potato and pumpkin.

2.3.4. Crop rotation

Crop rotation: is the practice of growing a series of different types of *crops* in the same area in sequenced seasons. For example, if maize which is a heavy nitrogen using plant is planted in season I, season II could be soybean which is a good nitrogen fixing plant, then season III one can plant a cover crop; this will help to maintain soil nutrients as well as moisture. Crop rotation is done so that the soil on farms is not used for only one set of nutrients. In addition to water conservation, crop rotation controls pests and diseases (including moulds that produce aflatoxins), helps in reducing soil erosion and increases soil fertility and *crop* yield.

2.3.5. Use of manure

This is mainly farmyard manure like cow dung; chicken, goat and rabbit droppings among others. These improve soil structure thus enabling it to hold moisture very well in addition to other benefits especially improving soil fertility and crop yield. A healthy crop will resist mould infection and aflatoxin contamination.

2.4. Harvesting

Harvesting is the separation of a foodstuff from its growth medium and gathering the harvested stuff. It is the stage that begins the postharvest life of produce. The separation may be done manually by cutting, breaking, digging or by machines. Before harvesting, the crop part must be mature depending on the intended use. Thus, use of maturity indices is very important to ensure timely harvesting of the crop. In order to prevent aflatoxin contamination, the following harvest practices are recommended

2.4.1. Timely harvesting

As soon as the crop has reached physiological maturity, it should be harvested. One of the practices predisposing crops like maize and groundnuts to aflatoxin contamination is late harvesting. Farmers usually leave maize to dry in the field for several weeks after attaining physiological maturity, before harvesting. Some farmers harvest groundnuts and, due to some reasons, leave them to dry in the field. Late harvesting of groundnuts may lead to germination which opens the pods allowing moulds to enter. Late harvesting and drying produce in the field has been reported to enhance aflatoxin contamination in Uganda. The longer the produce stays in the field, the higher the chances of mould infection and infestation by field pests especially insects that can predispose it to mould contamination. There is also a possibility of rewetting if rain comes while the produce is still in the field leading to rotting and sprouting. Chances of crop lodging and splitting of pods are enhanced. Lodged crops and fallen cobs will rot or be attacked by termites. Thus, timely harvesting enables the crop to be removed from the field and survive all these loss agents.

2.4.2. During harvesting

Harvesting should be done carefully. Place harvested crop on a tarpaulin, or plastic sheets, avoiding contact with the ground. It is common practice for farmers to harvest maize and place it on bare ground. This practice predisposes the crop to aflatoxin contamination because the moulds that produce aflatoxins are soil-borne. In this way, they will get a chance to enter the maize.

Be careful while harvesting groundnuts manually with hand hoes as damage may be inflicted on the pods. This creates avenues in the pods for moulds to enter, grow and produce aflatoxins. This damage should be avoided. Harvesting by pulling is the best to avoid pod damage.

Harvesting immature groundnuts should be avoided.

Late harvesting of groundnuts leads to germination in the field predisposing them to moulds

CHAPTER 3.

3.0 DRYING, SHELLING AND THRESHING ACTIVITIES

This chapter presents the primary processing activities which take place on the farm. These operations do not involve product development but are very important in quality management and extension of the shelf life of the produce. In other words, if not well done, the quality of the produce can easily be compromised. All these activities are key in management of aflatoxins. The chapter presents the stages where most of the on-farm contamination of produce by these toxins takes place.

3.1. Drying produce

Drying is the systematic reduction in the moisture content of produce to safe storage levels (9-14% depending on the produce) and it is the most critical stage as far as mould and aflatoxin contamination of produce are concerned. Once produce has been dried to safe storage moisture content, it can last for a longtime during storage with minimum mould infection and insect infestation. Thus, drying is a preservation method.
There are 2 categories of drying: traditional drying (local and improved) and modern drying.

3.1.1. Traditional drying

3.1.1.1. Local drying

Traditional drying is common and employs use of sun-drying method.

Disadvantages of traditional drying

Traditional drying has the following disadvantages which are related to mould and aflatoxin contamination

i. Traditional drying depends on weather, which farmers have no control over. Sometimes there is adequate sunshine during the day to dry the produce, sometimes the day may be rainy or dull in which case the produce will not dry. Thus, the period the produce takes to dry will very much depend on availability of sunshine
ii. Drying traditionally may lead to under-drying of the crop because the drying process is not controlled compared to use of mechanical dryers
iii. Rewetting of the drying crop often occurs directly from the rain or soil moisture .In Uganda, sometimes rain comes during the drying/harvesting season of cereals, legumes and oil seeds which require a lot of sunshine to adequately dry, wetting the drying produce.

Drying on bare ground is the most common traditional drying method at village level.

Disadvantages of drying produce on bare ground

i. The process is slow, the produce takes a long time to dry andinvolves lots of crop movements leading to high quantitative and quality losses. The longer the produce takes to dry the higher the chances of moulding and aflatoxin production.
ii. There are high chances of rewetting produce since often, it continues to rain during drying seasons. This enhances rotting/decay due to mould development, as well as aflatoxin contamination.

iii. Encourages produce contamination with moulds, soil and other foreign matter which are important quality parameters. Such produce is always contaminated with high levels of aflatoxins
iv. There are high chances of produce discolouration which greatly reduces produce quality
v. Domestic animals for example chickens, ducks and goats get a chance of eating and contaminating the drying produce. Domestic animal fecal matter for example cow dung, and goat and chicken droppings can be associated with dangerous microorganisms such as E.coli and Salmonella which can be very deadly to humans..
vi. There are high chances of leaving some of the grains on the ground as a result of mixing with soil hence quantitative losses. In addition, when soil/sand mixes with the drying produce, it is a big physical hazard that can easily injure the consumer.

Drying maize on bare ground causes soil contamination

Drying millet on bare ground. Chicken eating grains leads to losses

3.1.1.2. Improved drying

In order to enhance the quality of the produce during traditional drying, use of improved drying methods is recommended. These are simple and better than local drying methods especially in addressing aflatoxin problem. This is because, improvements on traditional methods do consider the following:

- Making the drying process faster so that the moulds are not given chance to develop
- Facilitate attainment of right produce/product moisture levels for safe storage thus prolonging the shelf life of a produce
- Retain maximum quality of the produce since there is minimum contamination with soil and domestic animals
- Give desirable added value to the crop

Some useful improved drying methods recommended for on-farm use to manage mould and aflatoxin contamination include:

(a) Drying on mats

Simple mats made of natural leaves or papyrus for open sun drying are laid on bare ground. Contamination and moisture diffusion absorption is eliminated, the quality of the drying crop is improved, mats are easy to use and often affordable.

(b) Drying on plastic sheets/tarpaulin

This method is suitable for cereals, legume grains, and semi-perishable crops. Commercial plastic sheets, heavy-gauge polythene sheets, tarpaulins or cut opened-plastic bags can be used.

Drying crop is protected from ground dampness. It eliminates microbial (including moulds) and soil contamination. Black colour plastic sheeting should be used and not any sheet of other colours (e.g. blue, orange, yellow, white/silver) because black readily absorbs solar heat with increased drying rate.

Drying cassava chips on black plastic sheet is a good practice. The drying process is faster due to black colour that absorbs heat.

Drying groundnuts on white plastic protects produce but prolongs the drying process due to the white colour.

(c) Drying on wood/bamboo/reed/coffee wire-mesh trays/racks

The crop can efficiently be dried on simple wire/bamboo or reed-mesh tray mounted either horizontally or inclined on wooden or brickwork racks. Crop held on the tray is dried under the influence of both the sun and the ambient air. Design is simple and the structure is easy to make. It is raised at least 90-cm above the ground. Product quality is high since contamination is avoidable. Loading rate 20-25kg/m^2 and a 4-cm deep batch size in good weather can be achieved. It takes 1-2 bright sunny days to dry for example well-grated/sliced cassava to safe storage moisture content.

Drying produce on wooden racks: Efficient drying leading to good quality produce

Drying cassava chips on wire mesh. The same can dry small grains like millet

(d) Drying in improved natural ventilated structures

A natural ventilated structure becomes a positive smallholder option specifically when more than one ton of timely harvested cob maize is to be handled on-farm. Rectangular cribs can have walls made of reed or bamboo splits, woven panels from a variety of materials and build by local artisans. A more appropriate structure is with vertical walls and base made of parallel strips or slats of timber; bamboo; or any local pole tolerant/resistant to insect attacks. The roof may be of corrugate iron sheets or grass thatched.

The drying process is achieved by the moving dry air that blows through the structure walls and through the crop; thereby removing the moisture.

In order to achieve a fast and uniform drying the following design characteristics in a crib should be taken into consideration:

- The crib width should not exceed 1.5-m.
- The narrower the structure, the more uniform the drying rate, giving less chance for moulding.
- The wall of the structure must ensure a minimum of 50 percent wall opening. This allows effective passage for drying air. The constant ventilation keeps for example, the maize cobs cool, and thus limit the rapid infestation by insects. Up to 28 metric ton capacity of freshly harvested cob-maize per loading per single crib is achievable with a loading rate of 560 kg/m^3. Lengths of one section not greater than 1.6 m and crop loading height about 1.5 m from platform are acceptable. However, the crib capacity can be extended with the extension of the length to accommodate the required volume. It takes 9-37 days in this crib to get moisture level from 37% down to 20-19% wet basis depending on initial moisture and on ambient weather conditions.
- One of the longest sides (facades) must face the direction of the wind
- The site for the crib must be at least 20-m away from other farm buildings, trees and bushes to ensure maximum wind effects without obstruction.
- Roof with large overhang is necessary to protect drying cob from sporadic rains
- The crib must be erected at a site as far as possible from maize field to reduce chance of cross-infestation.
- After cobs are dried, they must be removed for shelling, cleaning, and pre-storage treatment applied as may be required to protect the grain from damage by insect pests.

Remark: For better stability the height of the crib container/body as part of the crib should not exceed 1.7 m.

Drying maize in an improved crib helps maintain quality.

(e) Stabilised/concrete drying yard (multipurpose)

The yard is made of concrete-cement floor with a gentle slope to enable water flow/run-off in case of rain. Contamination due to soil, sand and microorganisms etc. is eliminated. It is simple and easy to build, and versatile since many products can be dried on it. It is also environmentally adequate because it only uses solar energy for drying. For example. on a typical yard of 5x5 m, it is possible to dry one tone of maize grain in 8 hours on a sunny day.

Typical concrete-cemented drying yards

(f) Biomass heated dryer.

It is suitable for drying of grains, cassava and sweet potato chips. It is a natural air convection dryer using energy from burnt plant waste or charcoal in a stove. The dryer is a simple and easy to construct structure. It can be built with bricks, sand, earth and cement or cassava flour. The drying platform/ bed is made of wire mesh tray. The firing unit is composed of a hanging "radiator" made of split tin drum. Below the radiator, charcoal stove or empty maize center cobs that are glowing can be used as the source of energy. A roof is then built over the structure to prevent rains from re-wetting the drying produce. The loading capacity e.g. of cob maize is about 3-4 bags. Drying takes between 5-6 hours to reduce cob maize moisture from 28-26% down to 16-14% that is suitable for safe shelling. The dryer can be used all year round. Grain if properly dried using this technology is good for seed.

(g) Solar natural dryers

These are suitable for drying high value crops and fish. These dryers are faster and ensure product safety and are out of reach of domestic animals. Product quality is improved, no soil and mould contamination; nutrients are retained and loss during drying reduced: dust and pollution-free. There are several types of solar dryers: The cabinet and tunnel dryers are most common. The latter can dry large volumes of the produce while the former can dry smaller quantities.

Different types of solar dryers

3.1.2. Modern drying technologies

Modern drying employs use of mechanical dryers, whose temperatures are controlled/computerised depending on the produce being dried. Thus, they are faster and dry produce to required safe storage moisture content. The technologies are intended for large scale farmers handling large volumes of the produce. They are suitable for farmers who have access to electricity.

Mechanical dryer for drying maize

3.1.3. Determination of produce dryness

It is important that farmers determine whether the crop has dried properly to the required safe storage moisture content or not. The safe storage moisture content for grains should be below 14% (EAC standard for grains is 13.5%). This is the moisture content that will not allow moulds to grow and produce aflatoxins. There are two methods of determining crop dryness: Indigenous/traditional and modern methods.

3.1.3.1. Indigenous/traditional methods

Farmers in different localities over the years have developed practical techniques for fast assessment of the degree of dryness of a crop. However, these methods are subjective (cannot give the exact moisture content) and depend on estimations and personal experience. These methods include:

- Shaking a handful of pods and listening to the sound of seed inside the pods; if a sharp sound is give, the produce is suspected to be dry. Example, shaking groundnut pods
- Bite between teeth – dry grain split once (snap). This method is commonly used for maize
- Rattling grain inside a tin/can or ground and judging from the sound made. A dull sound implies produce is not yet dry while a sharp/high sound implies dryness. This method is also used for maize
- Shelling the actual pods and noting the ease with which the pods shell and the snap sound made. Well-dried pods shell easily giving a sharp snap sound. Or, shelling maize from the cob and

noting the ease with which the grains get off from the cob. Wet maize sticks on the cob while dried maize will easily get off from the cob.

- Plunging the hand with fingers extended into a heap of grain: wet grain offers more resistance to penetration than dry grain.
- As can be seen, none of the above methods clearly gives the exact moisture content of the produce. Thus, modern methods which are objective (give exact values of moisture content), are strongly recommended.

3.1.3.2. Modern methods

Modern methods of determining produce dryness are more improved and give accurate figures of crop moisture content either on a wet or dry basis. Wet basis involves determination of moisture content based on the weight of the whole material as presented while dry basis moisture content is based on the dry matter of the produce.
Modern methods of determining moisture content are the following:

(a) Salt test

A small sample of grain is vigorously shaken mixed with dry common salt in a clean dry glass jar or clear plastic bottle for several minutes and the sample is allowed to settle. If damp salt is seen to stick on the walls to jar/bottle, this implies grain hasn't dried and its moisture content is above 15% M.C. and therefore not suitable for storage. If the salt does not stick to the walls of the jar/bottle, and these look dry, then the moisture of the grains is less than 15% which is a little better for storage.

(b) Use of moisture meter

Moisture meters are the class of instruments that are able to measure and quantify (%) the amounts of water in a given material/foodstuff. Use of moisture meters as measuring equipment by extension agents, grain traders and processors, and co-operative societies is strongly recommended. However, moisture meters are sometimes, expensive and, therefore, individual farmers may not afford them. Under such circumstances, we encourage farmers to form groups, SACCOs, and cooperatives, so that they can purchase and use them. Moisture meters can be made to measure moisture of selected foodstuffs or can just be calibrated to measure moisture in a wide range of foods. This equipment is very sensitive such that it should be stored well, in dry places, protected from dust.

Different types of moisture meters

(c) Oven method

This is a Laboratory method. Here a known quantity (for example, a) of the food material is oven-dried at a particular temperature to constant weight (for example, b). Percentage (%) M.C. is determined from the formula: (a – b/a) x 100. This method is quite accurate and objective giving the exact M.C. of the produce.

3.1.4. Summary of important points to remember about drying to minimise aflatoxins

- Do not dry produce on bare ground
- Do not dry produce on the roadside or tarmac to avoid contamination with dust or vehicle fuel and oils
- Always dry produce as soon as possible
- Do not dry good grain together with bad grain
- Do not allow produce to be wetted and soaked by rain
- Always check crop dryness using salt method or moisture meter

3.2. Shelling

Shelling is the removal of maize from the cob or groundnuts from the pods. Shelling is done traditionally by hand prising (mainly by women and children) or packing the produce in bags or heaps and beating it with a stick or trampling on it. Beating or trampling are tedious, inefficient and cause grain damage and spillage losses and these should not be avoided. Once the grain is damaged, moulds can easily enter and produce aflatoxins.

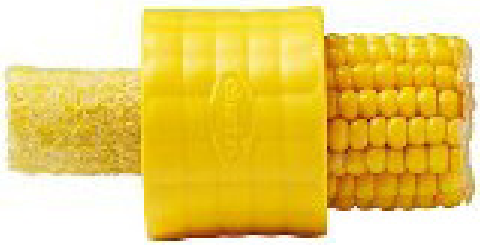
Shelling maize with hands (prising) is a good practice.

Shelling tools and equipment that can reduce high and tedious labour requirement for maize and groundnut shelling are available and highly recommended for use by farmers. These include hand-held devices such as the Decker, rotary-bench-hand operated Sheller, free standing-manual operated groundnut sheller and motorized shellers of various designs and output. It is a common practice these days for farmers to use motorized maize shellers to shell maize while in the field and thereafter, transport it directly to the market or store it without further drying. This is a mistake and should not be done. Such shelled maize grains should be dried first to the required safe storage moisture content prior to marketing and storage. Selling and storage of wet maize promotes mould growth and aflatoxin contamination.

The choice of sheller type will depend on several factors such as the socioeconomic level of the community, level of agricultural production, sheller type availability and its capacity/effectiveness, and affordability among small and medium farmers. In any case, the sheller selected and used, should not damage the produce.

The hand-held maize sheller (Decker) is a simple low-cost device that can easily and locally be fabricated from aluminium scrap. Using the Decker, cob maize is held in one hand and the device in the other. The cob maize is inserted into the centre of the biggest hole of the device.

The cob is then twisted against the ridges/ribs that are designed in the hole for them to entangle and remove the grain from the cob. The ease and level of grain damage varies with degree of dryness of the cob. Its productivity varies between 20-28 kg/hour at optimum grain moisture between 16-14%.



Hand-held maize sheller (Decker)

The hand operated groundnut sheller is simple, easily and locally fabricated. Its productivity varies between 3-4 bags/hour. This is very common especially at bulking centres. However, some shellers have limitations in that some of them cause considerable damage to grains/kernels if not well-calibrated/set. The damaged grains/kernels have been found to be highly contaminated with moulds and aflatoxins. Some are very costly, thus unaffordable by local/rural farmers while others use electricity which may not be available especially in rural areas.

Manual groundnut sheller: should not damage kernels

Motorized maize sheller


Motorized groundnut shellers: They can shell groundnuts very fast but may cause considerable damage to the kernels if not well adjusted

3.3. Winnowing

After the produce has been shelled or threshed, it is important that cleaning/sorting/grading takes place before storage. Winnowing is one way of doing this and, it is the process of cleaning by separating the grain from chaff. Cleaning of produce is useful in order to increase purity and market value of the product, it reduces mould and insect development, controls aflatoxin contamination and thus longer shelf life; it prevents the propagation of weed seeds in grain and, maintains storage capacity and reduce storage costs. Winnowing is a simple method that consists of letting to drop grains from certain height (up to 2-m) and the natural wind eliminates the impurities. However, this method is tedious, inefficient, causes air-dust pollution and grain losses. In addition, the mistake some people make is to winnow the produce on bare ground! This, leads to tremendous loss of small grain in soil, there is also enhanced contamination with soil, moulds and thus increased aflatoxin contamination. This should be avoided by using a tarpaulin or plastic sheet or winnowing on a clean, cemented floor.


Winnowing and cleaning produce: Should not be done on bare ground

There are different technologies available that can reduce much of the current high product losses and high and tedious cleaning/sorting/grading labour requirements for produce. One way is to use locally fabricated wire mesh sieves. Some of these are made of two sieves of different eye opening sizes, one coarse and a fine one. Impurities such as stones, pieces of straw, parts of say maize cob etc. are sieved out by the coarse sieve whereas impurities such as sand, dust, insects, broken grains, etc. will pass through the fine sieve

Cleaning produce using wire mesh sieve

CHAPTER 4.

4.0 ON-FARM STORAGE ACTIVITIES

On-farm storage of produce can be indoor or outdoor. Indoor storage involves use of farmers' houses while outdoor storage involves use of traditional structures like granaries and silos.

4.1. Cleaning, disinfection and repair of the store

Cleaning, disinfection and repair of the store are performed on farm before storage of produce and are a major component of hygiene and sanitation. The main purpose is to "prevent" mould contamination of the clean produce which is supposed to be put in that store by eliminating all sources of contaminants. Cleaning activities include sweeping the store, removing dust from walls, clearing/decongesting ventilators and all parts of the store to remove all unwanted foreign materials.

Disinfection is the process of decontamination of the store using recommended chemicals like fumigants. The main aim is to kill stored pests especially insects and rodents. Common methods of disinfection include fumigation and spraying. Since some chemicals can be dangerous to humans and domestic animals, one should take the necessary precautions while using chemicals to disinfect the store, including use of experts in chemical handling; or should strictly follow the manufacturer's specifications. It is important to repair the store in order to exclude the external environmental influence. Old structures/materials may be removed and new ones replaced and, holes/cracks/crevices should be sealed to avoid pest infestation/hiding as well as entry of moisture.

Granary that needs repair: Not suitable for storage

4.2. Storage of dried produce

During storage, proper packaging of produce is very important. Before packaging, ensure that the produce is dried to safe storage moisture content. Package the produce in clean food grade containers such as gunny, plastic or hermetic bags. Other containers include the hermetic plastic drums. These packages should not be torn or damaged in any way to prevent moisture pick-up, spillage and if possible, contamination by insects and rodents. Farmers should avoid storage of unpackaged produce by heaping on the floor/ground inside house or inside a granary/silo because the produce can easily pick moisture from the ground and surrounding environment and grow moulds. In addition, storage pests can easily attack the produce making it susceptible to moulds or the produce may get directly contaminated by moulds if the floor is not cemented.

Plastic bag (polypropylene) for storage of grains

Gunny bag for storage of produce

Hermetic bags for efficient storage of grains

Produce heaped on the floor during storage should be avoided

4.3. Storage of bagged produce

Bagged produce should be stored on pallets. A pallet is a flat structure, which stably supports goods during storage, transportation or lifting by a forklift. They help to store produce off the ground. If pallets are not available, farmers could improvise and place bags on dry pieces of clean logs or stones. Either way, the bags should be away from walls. Farmers should never place bagged produce directly on the floor or ground as the produce will pick moisture from the floor/ground. In addition, farmers should not pile bags in a store without good aeration. This leads to heat build-up which may encourage moulds and insects to grow and accelerate aflatoxin production.

During storage in granaries or silos, pallets/stones/logs should be placed on the floor first then the bagged produce properly stacked on top of them.

Care should be taken not to mix new and old stock produce. The latter may be contaminated with moulds and aflatoxins and thus may contaminate the new produce.

Bagged produce stored on the floor

Bagged produce stored on the pallets

Millet stored (heaped) in a granary: See mouldness

Groundnuts stored (heaped) in a granary

4.4. Pest control

A pest is any animal or plant which has a harmful effect on humans, their food or their living conditions. During storage, a number of pests infest produce and cause substantial quantitative and qualitative losses. There are 2 main categories of pests that cause substantial losses to dried produce during storage; insects and rodents.

4.4.1. Insect pests

Storage insect pests may be divided into two categories; primary and secondary pests.

4.4.1.1. Primary insect pests

Primary storage insect pests have the ability to attack whole, unbroken/undamaged produce and start feeding on them causing considerable damage and loss.

4.4.1.2. Secondary insect pests

Secondary insect pests attack only damaged produce, dust and milled products.

Examples of common insect pests of stored grains

Primary insect pests	Secondary insect pests
Bean weevil Acanthoscelides obtectus	Rust-red flour beetle Tribolium castaneum
Maize weevil Sitophiluszeamayidis	Confused flour beetle Tribolium confusum
Cowpea weevil (Callosobruchus. maculatus)	Saw-toothed grain beetle Oryzaephilus surinamensis
Moths: Sitotrogacerealella	Warehouse moth Ephestia spp
Lesser grain borer Rhyzoperthadominica	Indian meal moth (Plodia interpunctella)
Larger grain borer Prostephanus truncates	Mites
Termites	Red small ants

Bean weevil

Red flour beetles (secondary insects)

Grain moth (Larva)

4.4.2. How insect infestation takes place; A case for weevils

Weevils (e.g. maize weevil, bean weevil, cowpea weevil etc.) are the principal pests in countries of the tropics like Uganda, causing great damage and loss to grains. In a number of cases infestation starts in the field as in the case of the bean weevil which lays eggs on relatively dry bean pods in the field. In most cases the infestation that starts in the field rapidly intensifies and becomes a liability in storage especially if the grains are not properly dried.

The weevils pass through several stages of development:

- The adult lays eggs from which larvae hatch. A single grain seed may simultaneously support several larvae.
- The larvae cause the most damage as a result of their intensive and greedy feeding inside the grain.
- The larvae develop into pupae, non-feeding, dormant and immobile stages.
- Prior to pupation however, each larva prepares the point of eventual emergency by outwardly chewing away the cotyledon to leave a thin layer of the testa known as a "window" through which the adult will eventually push its way out.
- The pupae eventually develop into adults which push their way out of the grain (or out of the cocoon) leaving "emergence holes" on the grain.
- Adult weevils are normally short-lived and do not feed on stored produce.

4.4.3. Why should we be worried about insect pests of stored grains?

Of all macro pests of the food chain (rodents, birds, insects), insects form the greatest danger. This is because they:

- Consume food making direct quantitative (weight) and nutritional losses. Many grain pests preferentially eat out grain embryos, thereby reducing the protein, fat, vitamins and mineral content of food grain.
- Contaminate food making qualitative losses especially through their webbing. Their excreta and body parts induce offensive smells and flavours and cause discolouration of produce
- Create conditions favourable for microorganisms especially when they damage and create avenues (holes/windows) in the produce. In addition, hey also carry along with them spores of microorganisms thus spreading them and enhancing their growth and multiplication.

- Lower milling quality: They can turn grains into powder. Grain whose moisture has increased because of insect infestation does not mill well. Also, grain which is discoloured does not produce good quality milled products.
- Lower seed germination: They always aim at the most nutritious part of the grain which is the germ/embryo. By destroying the germ/embryo, insects reduce seed viability
- Insects when present in the stored grain, produce additional moisture and heat into the environment through respiration. This in turn results in:
  - rapid multiplication of insect pests in the grain,
  - increased respiration and heating of the grain,
  - rapid growth of fungi/moulds which spoil the grain and also produce aflatoxins
- Destroy structures (storage and packaging materials)
- Transmit diseases (vectors) or cause diseases to humans by transmitting spores of pathogenic microorganisms.
- Economic losses accruing from the need to control and also to follow regulatory standards as well as the qualitative and quantitative losses they cause.

4.4.4. Sources of insect infestation

There are many sources of infestation since insects can be found everywhere.

- Farm-field infestation: many infestations start when crop is in the field. This, for example, is the case for maize and bean weevils as indicated already.
- Harvesting equipment: Some insects hide in equipment and go along with them to stores where they multiply.
- Residues of infected crop from previous season where they hide
- Transportation vehicles e.g. trucks, rail tucks etc.
- In the store, from grain to grain, or they may hide in crevices. Some insects, after their pupa stage, turn into adults and start feeding on the stored produce.
- From old storage bags especially the gunny bags and polypropylene bags where they hide.

4.4.5. Insect pest control strategies during storage

There are many techniques used to control insects during storage and, complete elimination of an infestation is required if possible. The control methods are divided into 2 areas: Non chemical and chemical.

4.4.5.1. Non chemical control methods

These are control methods that do not involve use of chemicals (insecticides). Non chemical control methods consist of 2 aspects

4.4.5.1.1 Preventive measures

Prevention is the first line of defense and, preventive measures deter insects from infesting the produce. Good store keeping, and good hygienic/sanitation conditions as well as orderliness are key in preventing insects.

Inspection: to maintain storage facilities in recommended conditions, inspection can help detect problems related to enhancing insect infestation, and should be done routinely. The person inspecting needs good knowledge of insects e.g. behaviour and appearance. Visual inspection is most common. Inspection is done on: facilities (store, packaging materials), food commodity/produce and aims at identifying live insects, dead insects, stages of insect development, signs of insect infestation (damaged grains, harborages, webbing, frass).

4.4.5.1.2 Physical and mechanical approaches

These are the oldest insect control methods and destroy insects outright or disrupt physiological and behavioural activities of insects. They may also act through modification of the environment making it unsuitable for the insects to survive. Physical/mechanical techniques include the following:

- Temperature: Involves use of heat or cold. Lethal heat of 3 hr exposure to 52 – 65^0 C is enough to kill insects. For example, in modern silos; thermal disinfestations of grains in a fluid (air) bed is possible in 150 tons/hr at 65^0C. For cold temperature, exposure for 24-36 hrs at -22^{o}C or lower, kills insects instantly. Also, cooling grain to 12^{o}C and below reduces insect reproduction, while 5^{o}C slows down insect development.
- Modified atmosphere storage: This involves modification of nitrogen, carbon dioxide and oxygen in intergranular spaces of grains stored in air-tight containers. Hermetic storage options (e.g. use of super-grain bags-PICS bags, plastic drums and cocoons) work during this method by elimination of oxygen responsible for respiration of insects making them unable to survive since all insects are aerobic.
- Humidity and moisture control: High humidity increases moisture content hence accelerating mouldy conditions and insect development. Maintaining a low relative humidity and produce moisture content, say through drying is a common and effective control measure.
- Light and radiant energy: Insects are photosensitive to UV light. Electrocute light traps (40 watts) e.g. those in restaurants and food industries, divert insects away from food establishments.
- Clean air screening: This involves use of overlapping vertical strips of heavy plastics excluding flying insects; use of filters in all air intake and exhaust vents; as well as use of barriers or screens/wire meshes on windows and doors.
- Protective packaging: Use of insect resistant packaging materials/containers is recommended. In this case, packaging success depends on material used (insect resistant), construction method of containers, tightness of closures, and attractiveness of the product. In particular, the package should be insect resistant since some insects like cockroaches have sharp teeth.
- Trapping devices: These include sticky/adhesive traps (glue) pheromone traps – chemicals mainly produced by insects to attract others. Some are produced by females only to attract males and vice versa. Other insects produce them to be able to come together or to trace their paths.

4.4.5.2. Chemical control methods

Use of chemicals is not sometimes encouraged for several reasons such as pollution to environment and, some chemicals are poisonous to man and animals. Chemicals used to kill insects are known as insecticides. Despite all disadvantages, chemical method remains the main control and main effective insect control strategy. Why? Because the results are fast and effective, majority of chemicals are manufactured with ideal characteristics which include toxicity to insects but not humans and animals (the dose that is toxic to insects is not toxic to humans and animals); no taint or odour in foodstuffs remain after application, and, no deleterious effects/residues because most degrade fast into harmless metabolites after application

Insecticides are mainly divided into three classes: Contact, Repellants and Fumigants. Contact insecticides, kill by contact when insects walk or crawl on treated surfaces. Due to safety concern, use of residual insecticides is limited to spot treatment, cracks and crevices where insects live and hide. Some insecticides are applied directly on grains intended for long storage (these have low toxicity and fast degradation). Repellents keep away/drive back the insects due to their offensive smell or off-odours. Some of the organic pesticides/local herbs like the Mexican marigold (*kawunyira*), hot peppers (pilipili), ordinary wood ash, onions and garlic, bar soap, Lantana camara, tobacco, and dung are among the repellents commonly used by farmers. Fumigants are applied in gaseous form and kill insects by suffocating. They are toxic, flammable, corrosive, need air-tight structures, may produce offensive odours, may leave harmful residues, others are phytotoxic e.g. Sulphur dioxide may bleach

the produce. Common example is the Phostoxin (Aluminum phosphide) tablet is used in Uganda. During use of chemicals, insects may develop resistance which is the ability to resist chemicals especially arising from overuse of chemicals or application not following recommendations. There are two broad categories of resistance. Behavioural (ability to avoid lethal doses by hiding, e.g. mosquitoes, cockroaches), and Physiological (insects develop ability to detoxify lethal doses and hence survive). The latter is more dangerous as many insects will survive chemicals.

There are several ways of preventing insect resistance and these include:

- Use only recommended chemicals officially approved for use to control insect pests in a given storage situation.
- Observe and adhere to the recommended dosage rates.
- Avoid any insecticide you are not sure of.
- Never use field insecticides or rodenticides to treat stored products. This is one of the major sources of chemical abuse and misuse in Eastern and Southern African countries.
- Always buy storage insecticides from a very reliable source, e.g. from approved agrochemical stores or agents to avoid counterfeits.
- Never buy insecticides from unlicensed traders or marketing agents; or from hawkers and unauthorized persons who move about selling chemicals.
- Synergists can physiologically block resistance. E.g. use of two or more chemicals mixed together.
- Rotation of insecticides is another strategy
- Genetic engineering (development of resistant varieties) is another technique

4.4.6. CONTROL OF STORAGE INSECT PESTS IN DRY GRAINS: A CASE FOR LEGUMES

4.4.6.1. Insect pest control strategy and methods

Control of insect pests on food legumes must start at harvesting or before and definitely not when the farmer sees some insect pests in his store as sadly, is often the case. The best strategy involves the following:

4.4.6.1.1 Timely harvesting

To reduce exposure time to insect pests in the field. This must be followed by proper drying, threshing and cleaning of the crop to eliminate some of the eggs and insects that came from the field on the pods.

4.4.6.1.2 Strict pre-storage hygiene

It is extremely important therefore to prepare, in advance, all storage structures and containers intended for use, making them ready and safe to receive new produce. In this regard, storage containers and structures such as metal or plastic tins, pails and drums, and earthenware pots etc., must be cleaned, disinfected with hot water and dried prior to use for storage of legumes. Jute, sisal and plastic bags previously used to store grain legumes must be washed and boiled in hot water to kill off insect pests or their eggs and larvae and dried prior to use. (or at least be exposed to sunshine for a reasonable number of hours before reuse). Previously used reed-woven indoor and out-door granaries, baskets, mud-wall bins or brick-wall silos must all be re-plastered using appropriate combinations of local material (cow dung, mud, sand wood-ash, etc.) to seal off cracks, holes and crevices which hide insect pests and their eggs. Granaries, cribs, silos and rooms previously used as stores for legumes, must be cleanly swept, repaired and where possible disinfected using appropriate storage chemicals to kill off pests.

4.4.6.1.3 Systematic storage

Newly harvested produce must never be stored together with infested residue-produce otherwise bruchids will spontaneously attack and flourish on the new roduce.

4.4.6.1.4 Continuous protection and monitoring

This should be done on the produce in storage, to ensure long storage life. This may involve redrying and repackaging.

4.4.6.1.5 Simple cultural insect control methods

There is a wide range of low-cost insect control measures which can be applied to control weevils at smallholder level. These include:

(a) Proper drying of crop to safe storage moisture content

Storing only well-dried grain and re-drying the crop in hot sun whenever infestation is detected.

(b) Use of local plants and herbs as protectants or repellents (Biorationals)

These techniques are preferred by those interested in organic food materials. A wide range of local plants and herbs have, with varying degrees of success, been used to scare off insect pests in stored pulses. These include extracts from neem tree (*Azadirachtaindica*), red peppers or chillies (*Capsicum spp*), sweet flag (*Acoruscalmus rhizomes*), fermented banana juice admixed with grain, and bark of the cailcedra tree (*Khaya senegalensis*).

(c) Use of ash or other inert dusts

Well dried inert dusts (e.g. coarse clean sand, wood ash, crushed limestone etc.) admixed with legume grains at a rate of 1-5% by weight, blocks intergranular spaces between the legume grains, restricting respiration and movement of the weevils. The inert dust also limits oviposition by the bruchids. Weevil populations decrease as the quantity of the added intergranular material increases. Abrasive ash (especially from paddy husks) admixed with grain legumes at 0.1-0.5% by weight, abrades and absorbs insects' cuticle-wax and dehydrates the insects causing death. The use of inert dusts however, contaminates and lowers the quality of the product. In pulses, this has little effects since the dust or ash can be washed off prior to preparation of the grain for consumption.

4.4.6.2. Chemical control methods

A number of cultural control methods described above offer only limited success in the management of insect pests in legumes. Where control is effective, the methods may have a number of limitations particularly when handling quantities of grain in excess of 150-200 kgs. For this reason, farmers and grain dealers have had to turn to using chemical control methods despite some of the shortcomings associated with using chemicals on edible produce. There are two main groups of chemicals used in the control of insect pests in stored LEGUMEs, and each of these must be used with caution.

4.4.6.2.1 Fumigants

Fumigants are gases or vapours taken into the body of the insect through its respiratory system, resulting in death. A common example is Phostoxin (Aluminum phosphide) tablet used in Uganda. Fumigants provide no residual effect but can penetrate through stacks or bulk of stored produce killing all stages of

insect life within. They do not protect against re-infestation of the grain by the pests and require special equipment often unaffordable and/or too complicated for application by small scale farmers. E.g. one needs a non-porous material to completely cover the grain for efficient fumigation. They are however, extremely poisonous and if mishandled, could easily cause injury or death to the applicant or consumer of the food. National regulations in most countries, strictly restrict the use of fumigants to well-trained persons who must have a license to carry out fumigation. Typical containers for on-farm fumigation, where licensed fumigators are available, include:- plastic sacks, plastic-lined jute sacks, sealable 200-litre drums modified to store produce, and grain storage bins incorporating plastic layers. Please note that the use of fumigants by untrained persons is strongly discouraged at small holder level.

4.4.6.2.2 Contact insecticides-

These are poisons able to penetrate through the insect's cuticle to the body tissue causing death. The use of contact insecticides will be either in admixture with the grain or as a surface treatment. These insecticides can confer long-term protection on the grain but are often specific in their effect upon insect species and tend to produce resistance more than the respiratory poisons. However, most of the contact insecticides are easier and safer to handle by small holder farmers than fumigants.

4.4.6.3. Grain treatment using approved contact insecticides

4.4.6.3.1 Recommended chemicals for dusting grain

Where approved storage chemicals are available at reasonable prices, food legumes should be properly dried, cleaned and chemically protected for long-term storage in seed. This practice has a number of positive advantages.

- Storing crop in shelled form (seed) simplifies storage management.
- Grain is less bulky to handle and to store and requires less labour and less storage space than the crop on the pods or cobs.
- Storing grain significantly facilitates control of insect pests and rodents in storage since grain lends itself well to uniform and more effective chemical treatment than the pods or cobs.

The contact insecticides enlisted below are recommended for admixing with the grain to protect against insect pests in storage.

4.4.6.3.2 Admixing using a shovel

This method is easy to accomplish and ensures uniformity in dusting the grain, thus better results in insect control. It is best conducted on a concrete floor (if available), otherwise a polythene or metal sheeting or tarpaulin may be used spread on the floor. Using the method, up to 180-200 kg of grain can be treated at a time, based on the following procedures:-

- Empty one or two bags of well dried and cleaned grain onto a concrete floor, polythene sheet or tarpaulin.
- Uniformly sprinkle recommended amount of insecticide all over the heap.
- Using a clean shovel, hoe, large bowl, or a cut-off 20 litre jerrican, gently mix the powder into heap until all the grains are evenly coated.
- When you have finished mixing, you should not be able to see any patches of powder on the heap. Bag the treated grain and put it straight into a clean dry store. Alternatively pour the grain into a clean tight container, granary, silo or bin and make regular follow-up with appropriate storage management.

Note: There are a number of chemicals manufactured day by day by different companies and approved for use by relevant authorities and, quite often, a number of them continue to be banned from the markets once proved dangerous to consumers or environment. Thus, farmers should always follow manufacturers' recommendations while applying the chemical

4.4.6.3.3 How to measure the insecticide for use in a village situation

Dust chemical admixtures are usually packed in cans, tins or sachets in specific quantities to treat a definite volume/weight of crop (e.g. Actellic Super in 50 gm sachets to treat 90 kg of grain, or in 400 gm cans to treat eight 90 kg bags of grain). Application rate is normally indicated on the container label and must be strictly adhered to. Manufacturers may provide a "spoon" or measuring unit within insecticidal packet to measure a definite weight or chemical for a definite volume of grain. A normal safety match box container measuring 15 x 35 x 50 mm, level-filled with Actellic or with malathion dust, contains approximately 25 gm of the chemical. Other practical measuring units are available which are suitable for use by small holder farmers or by Extension Agents in a village situation.
It is important that only recommended chemicals officially approved for use to control insect pests in a given storage situation are used and, recommended dosage rates should be observed and adhered to. Farmers or those involved in storage should avoid the any insecticide they are not sure of And, should not treat produce shortly before consumption. Field insecticides or rodenticides should never be used to treat stored products. This is one of the major sources of chemical abuse and misuse in Eastern and Southern African countries Uganda inclusive.
It is important to always buy storage insecticides from a very reliable source, e.g. from approved agrochemical stores or agents. In other words, never buy insecticides from unlicensed traders or marketing agents; or from hawkers and unauthorized persons who move about selling chemicals. As an extra health precaution, it is advisable to re-clean the treated grain before use as food. In the case of food legumes, this can be achieved through winnowing followed by thorough washing before cooking.

4.4.7. Control of Rodents during storage

Rodents are small mammals with sharp front teeth. They are gnawing mammals and include rats, mice, and squirrels. Important information to note about the characteristics of rodents:

4.4.7.1. Prolific /fertile breeders:

Rodents produce a lot of young per litter. On average a female rat gives birth to 6-12 young ones each time it does so. Females may come on heat and mate a day or two after the litter is born. An average female may produce 4-6 times a year (4 or 6x12 = 48-72 young ones).

4.4.7.2. Generalists

Most rodent pests feed on a variety of foods e.g. grains, fruits, vegetables, even meat and eggs; all items of processed food and even refuse (rubbish) and containers like plastics.

4.4.7.3. Mobility

Rodents are fairly mobile and quickly re-infest areas where they have been eliminated by control measures. After harvest, they move from surrounding fields into villages.

4.4.7.4. Shy or nervous

Rodent pests are normally shy/nervous about new objects (e.g. baits, traps) in their environment. They prefer to use same runs/routes and do not like regular disturbance. They can detect and tend to avoid new objects in their familiar environment.

4.4.7.5. Food and shelter

In general rodents require food and shelter. It may be difficult to remove all food from stores but rodents can be denied access to food; shelter and refuse on the other hand can be removed.

4.4.7.6. Detection of the presence of rodents/rats

Presence of rats can be determined by signs which include:-droppings found in feeding areas and runways, tracks or footmarks may be seed on dusty surfaces., urine stains may be seen on runways, runways and burrows (holes) may be seen next to buildings or along fences and sounds of gnawing and squeaking can be heard

4.4.7.7. Methods of control

4.4.7.7.1 Exclusion

This is the best and most economical method of preventing rats from having access to the things which they attack is by rat proofing. All foodstuffs should be stored in rat proof containers. Food stores e.g. granaries and cribs should be raised above the ground and fitted with rat guards made of metal of at least 30 cm diameter. There should be no permanent steps up to the door as these will allow rats to gain access. The base of the store i.e. the lower section of the store should be covered with sheet metal about 20-30 cm in width. There should be no tall vegetation close to the store as rats can always climb them and jump on the store. An area of bare earth under and around the store also helps to reduce chances of rats entering. Maize cobs and other foodstuffs being dried suspended from rafters should have some barriers between the rafters and the suspended "ears" to keep out rats. Use of metal containers/plastics e.g. clean drums and jerrycans can be closed with lids to exclude rats.

Granary with rat guards

4.4.7.7. 2 Sanitation

Sanitation can play an important role in controlling rat populations. It is much easier to notice the presence of rodents if the store is clean and tidy. One way to ensure sanitation is through regular sweeping. This can help to remove loose grain and spillage which provide food for rats, disturbs, smears, scent marks and runways making returning rats feel uneasy thus reducing the length of their stay; sweeping eliminates potential hiding places of nest sites and it improves the efficiency of inspection of monitoring

In large stores, a strip of about 1 metre from the walls should be kept clear. Produce and especially grain should be cleared of weeds and materials because rodents are secretive and avoid open spaces. Any feed for domestic stock especially chicken feed should be removed and should not be left lying around after dark and, cracks in building should be repaired.

4.4.7.7.3 Storage Hygiene and Technical Measures: A Summary

- Keep the store absolutely clean! Remove any spilt grain immediately as it attracts rodents!
- Store bags in tidy stacks set up on pallets, ensuring that there is a space of 1 meter all-round the stack!
- Store any empty or old bags and fumigation sheets on pallets, and if possible in separate stores!
- Keep the store free of rubbish in order not to provide the animals with any places to hide or nest! Bum or bury it!
- Keep the areas surrounding the store free of tall weeds so as not to give the animals any cover! They have an aversion to crossing open spaces.
- Keep the areas in the vicinity of the store free of any stagnant water and ensure that rainwater is drained away, as it can be used as source of drinking water.

4.4.7.7.4 The use of traps

Break back and cage traps (live traps) are locally made and can be purchased at most markets. Decision has to be taken regarding the type of bait to be used and the location of the trap. Successful bait must attract the rat and be more attractive than the food on which it is already feeding. Successful baits should have strong smells to attract the rats.

4.4.7.7.5 The use of poison baits

Poison baits are not the best answer to the rat problem because they are poisonous to man and other animals such as domestic pets, rats soon become bait shy and thus avoid them, rat poison can be expensive, rats can develop resistance to rodenticide except Zinc Phosphide and, disposal of dead rats may prove difficult as they often die in inaccessible places. They may thus be eaten by other animals which then become poisoned. If not eaten they rot and produce a bad smell in the area.
The commonest acute poison in use in Uganda is Zinc Phosphide (poisonous to man and animals). It is marked with a skull and cross bones hence should be used and handled with care. When using acute poisons the following general steps are recommended:-

- Poison free bait to be to rats 3-5 days before baiting with poison. Use the same bait during this period.
- Select suitable bait likely to be accepted by the rats.
- Avoid handling the poison with bare hands
- Place bait in areas which are not accessible to children or pests
- Pick up and bury deep in the ground all the dead rats
- Always wash hands after a baiting operation

4.4.7.7.6 Use of glue

Special type of glue which comes in tubes or in a booklet has been one of the most successful methods of catching rats. These can be placed in routes or places commonly used by rats.

4.4.7.7.7 Use of fumigants

These are smokes of gases which can be released into rodent holes or buildings in which rodents occur. They are poisonous and should be used under guidance. The most common fumigant used in Uganda is

Phostoxin (Aluminum phosphide). When in contact with moisture from the air, Aluminum Phosphide releases poisonous gas which kills rats when inhaled.

4.4.7.7.8 Use of cats

This is probably the safest of all methods. It is a biological control method.

Note: Remember the above methods of rodent control can be employed in an integrated approach (applying more than one method at ago) for best results.

4.5. Periodical re-drying of produce

The purpose of re-drying the produce periodically is to ensure that produce which is under storage keeps dry. Sometimes, produce may pick up moisture (rewetting) due to inappropriate storage on the floor or in poor gunny or plastic bags. This produce therefore should be dried under the sun or using other means, to the required safe storage moisture content. Care should be taken during re-drying to ensure that the produce remains clean and avoid any form of contamination. Thus, the produce should not be dried on bare ground, but tarpaulins, mats or racks or other improved drying methods should be used.

CHAPTER 5.

5.0 FOOD PROCESSOR ACTIVITIES

Food processing is the action of performing a series of mechanical or chemical operations on food in order to change or preserve it. Thus, it involves the transformation of agricultural products into *food,* or of one form of *food* into other forms. There are 2 types of processing; primary processing and secondary processing.

Primary food processing

This is usually carried out on-farm and is necessary to make most *foods* edible. For example, drying of cereals, legumes and oil crops at households are primary processing methods.

Secondary food processing

This involves product development by turning the ingredients into familiar *foods,* such as turning wheat into bread or maize grains into flour. Thus, secondary food processing is always done at industrial level; whether small, medium or large processing industry.

During application of food processing techniques, there are several factors that can promote aflatoxin contamination of processed food and, the activities described in this chapter are geared towards addressing these factors.

5.1. Regular inspection of produce and processing premises

The quality of produce to be processed as well as the processing premises must be clean. In order to ensure that these are maintained under clean conditions, regular inspection of produce and premises prior and during processing is necessary. The inspectors should have knowledge of good quality produce being inspected as well as knowledge on what should be checked for hygiene and sanitation. The processing environment should be dry and free from foreign materials including dust and all sorts of chuff that may habour insects, rodents and moulds. Overall, strict hygiene and sanitation (GHP) should be adhered to.

5.2. Processing and equipment

Produce for processing should not be mouldy, damaged, shriveled or discoloured. In other words, only clean, dry, sorted and sound produce must be processed. During processing, processors should not add/sprinkle water to raw materials for processing. This is common for those processors of unshelled groundnuts and maize. Addition of water will lead to rewetting of the produce and, small scale processors who have no means of drying the produce further, will have their products easily becoming mouldy. For example, small-scale millers of maize add water during maize milling to remove the bran, the flour will start lamping soon during storage, a condition indicating moulding and possibility of being contaminated with aflatoxins.

Processors should use only food grade processing equipment, preferably made of stainless steel. Use of mild steel or equipment fabricated from any metal is dangerous because these will tear and wear during processing and affect the quality of the products. Besides, these equipment are not easy to clean which may lead to cross contamination. In addition, the equipment should be clean and dry to avoid contamination and rewetting the produce being processed.

After processing, products should not be stored in non-food grade materials. Rather, they should be properly packaged in containers that will protect them against moisture pick-up and contamination with moulds and insects.

5.3. Aflatoxin testing in the raw produce and finished products

Processors should do on-spot aflatoxin tests in raw produce and finished products in order for them to know the levels of aflatoxins in both produce. This is because, according to Uganda UNBS regulations, any produce/product containing 10ppb and above aflatoxin levels, is not suitable for trade or processing. Thus, raw (unprocessed) produce must contain less than 10 ppb aflatoxins in order for this to be processed. By carrying out on-spot aflatoxin testing, one prevents aflatoxin-contaminated materials from continuing in the value chain but also saves money and labour that would have been used during processing.

5.4. Acquisition of a Quality Mark from Uganda National Bureau of Standards (UNBS)

In order to ensure that the processing premises, equipment and raw materials are of the required good quality standards hence less chances of aflatoxin contamination, UNBS will inspect and award the processor a Quality Mark. This mark will be used by the processor during trade including supply of the products to all markets in the country. Supermarkets for example, would like to see this mark on the container label before accepting the product. There will be costs involved in acquisition of this mark but will depend on the size of the business.

UNBS Quality mark

5.5. Packaging and storage of processed products

Packaging and storage of processed products are key in safeguarding against mould and aflatoxin contamination. It should be particularly noted that some processed products for example maize and groundnut flour have their surface area increased and therefore can very easily absorb moisture. Besides, the form in which these processed products are can very easily attract moulds and insects. Therefore, they need real protection from the environmental effects where they are stored.

First of all, the storage environment of these commodities should be clean and dry to avoid moisture pick-up. Strict hygiene and sanitation should be adhered to in order to have a good, conducive environment. The store must be clean, dry and well-ventilated to allow adequate aeration and maintain the correct temperature and relative humidity. The processed products should be packaged in clean, dry food grade containers that are capable of protecting the commodities against moisture pick-up, dust, moulds and insects. During storage, the containers should be properly sealed and if they are bags, they should not be put directly on the floor but should be stacked on pallets, off the walls of the store and, the bags should not be stacked without allowance for aeration. Processors should avoid use of torn bags that can lead to spillage or insect and mould contamination.

They should also avoid storage of processed products in the open where they can be rewetted. Some of the products like groundnut flour and paste can be affected by direct sunshine inducing offensive smells and tastes/flavours.

Inadequate packaging and storage of processed groundnuts

CHAPTER 6.

6.0 ANIMAL FEED PROCESSOR ACTIVITIES

Animal feeds are one of the commodities which are commonly contaminated with aflatoxins. This is because, the ingredients/raw materials that make animal feeds (maize, maize bran, maize germ, soybean, cotton seed cake, sunflower, fishmeal (dry silverfish), brewers waste among others) are all susceptible to aflatoxin contamination. Many feed processors including commercial farmers, usually utilize poor quality raw materials. In fact, most of the poor quality grains end up being used for animal feeds or are directly fed to animals.

All domestic animals (cattle, sheep, swine, rabbits, goats, sheep, poultry and dogs) are susceptible to aflatoxin poisoning. Fish, which is domesticated through aquaculture processes, is also susceptible to aflatoxin poisoning. In addition to direct poisoning of animals (acute and chronic toxicity) as a result of consumption of aflatoxin-contaminated feeds, the toxins end up in milk, eggs and meat, eventually leading to human exposure.

Aflatoxins poisoning in animals produce quite different effects: acute liver damage, liver cancer, induction of tumours and teratogenic (disturb the development of the embryo or fetus) and other genetic effects. Aflatoxin poisoning is primarily a hepatic disease (liver disease). The susceptibility of individual animals to aflatoxins varies considerably depending on species, age, sex, and nutrition. In fact, aflatoxins cause liver damage, decreased milk and egg production, and recurrent infection as a result of immunity suppression. While the young of a species are most susceptible, all ages are affected but in different degrees for different species. Clinical signs of aflatoxin poisoning in animals include gastrointestinal dysfunction, reduced reproductivity, reduced feed utilization and efficiency, anemia, and jaundice. Nursing animals may be affected as a result of the conversion of aflatoxin to the metabolite aflatoxin excreted in milk of dairy cattle. Domestic animals (pets and agricultural), monkeys and laboratory rats and mice have been the subject of a large body of research on the adverse effects of aflatoxins. These effects include adducts and mutations, cancer, immunosuppression, lung injury and birth defects. In cows as a result of acute toxicity, calves develop a disease that features blindness, circling and falling down, twitching of ears and grinding of teeth. Spasm of the rectum is seen in most cases. Death usually follows within two days of onset of severe clinical signs. Postmortem findings reveal pale, firm and fibrosed liver. The kidneys are yellow and surrounded by wet fat. Other pathological features in cattle are blood coagulation defects (failure of blood to coagulate).

For these reasons, it is imperative that animal feed processors, whether commercial or those who mix at home, should follow the procedures suggested below to prevent or minimize aflatoxin contamination of feeds.

6.1. Selection of raw materials

The raw materials selected to use for processing animal feeds should be of good, sound quality. Animal feed processors should therefore NOT use poor quality raw materials (diseased, rotten, damaged, discoloured, shriveled or broken/split, germinated, dry to safe storage moisture content) depending on the raw material. This is because, such raw materials are in most cases contaminated with moulds and aflatoxins. Prior to processing, the raw materials should be tested for aflatoxins and must contain less than 10 ppb aflatoxins in order for them to be processed. Animal feed processors should carry out on-spot aflatoxin testing. This helps to prevent aflatoxin-contaminated materials from continuing in the animal value chain and also saves money and labour that would have been used during feed processing.

Poor quality maize should not be used for processing animal feeds

6.2. Processing and equipment

Processing of animal feeds may be at commercial level involving large or small scale processors; or can be done at home by farmers acquiring ingredients and mixing them. Large/small-scale animal feed processors should use food grade processing equipment preferably made of stainless steel.

The environment used to mix feeds whether in a processing plant or at home, should be clean. Animal feeds should not be mixed on bare ground. If the mixing is on the floor, this should be cemented, dry, clean, and smooth with no cracks. At home, mixing must not be on the verandah, but on cemented, dry floor with no dust of chuff. The equipment used for mixing the feeds should be clean and dry. In other words, all processors should strictly observe good manufacturing practices (GMP) involving good hygiene and sanitation.

Mixing animal feeds on bare ground should be avoided.

6.3. Incorporation of aflatoxin binders during processing

One of the methods of preventing aflatoxins in the feeds from entering the blood stream of animals where they can cause serious harm is to add binders. Aflatoxin binders are nutritionally inert substances added to animal feeds in small amounts in order to tightly bind/trap and immobilize aflatoxins in

the gastrointestinal tract (digestive system) of animals, thus reducing their bioavailability (digestion and absorption). These binders are manufactured and are commercially available. Both commercial animal feed processors and those who mix at home can acquire these binders and add them to feeds during processing, but they should strictly follow manufacturers' recommendations. In other words, the dosage/quantities and mixing process recommended should be strictly adhered to during mixing.

6.4. Acquisition of a Quality Mark from UNBS

In order to ensure that the feed processing premises, equipment and raw materials are of the required quality and therefore less chances of aflatoxin contamination, UNBS will inspect and award the processor a Quality Mark. This mark will be used by the processor during trade including supply of the products to supermarkets (All supermarkets would like to see this mark on the container label before accepting the product). This builds customer confidence about the quality of the feeds.

UNBS Quality mark

6.5. Packaging and storage of ingredients and feeds

Packaging and storage of both raw materials/ingredients and feeds are key in safeguarding against mould and aflatoxin contamination. First of all, the storage environment of these commodities should be clean and dry to avoid moisture pick-up. Strict hygiene and sanitation should be adhered to. The store must be clean, dry and well-ventilated to allow adequate aeration to maintain the correct temperature and relative humidity. The raw materials and finished feeds should be packaged in clean, dry containers that are capable of protecting the commodities against moisture pick-up, preferably interwoven polypropylene bags. These, during storage, should not be put directly on the floor or touching walls of the store and, should not be packed without allowance for aeration.

Feed processors should avoid use of torn bags that can lead to spillage or insect and mould contamination. Insect infestation of both raw materials and feeds is very common and these have been directly linked to enhancement of mould contamination with subsequent aflatoxin production. The raw materials and feeds should not be stored in the open where they can be rewetted by rain or due. The ingredients if stored and suspected to have picked moisture, should be constantly re-dried using clean drying materials.

Inappropriate storage of raw materials (soybean)

Inappropriate storage of raw materials (sunflower seed cake)

Inappropriate storage of raw materials (cotton seed cake) in torn bags

CHAPTER 7.

7.0 TRADER ACTIVITIES DURING TRANSPORTATION, STORAGE AND MARKETING

Aflatoxin contamination of produce can take place at any stage of the value chain including during transportation and marketing. Marketing activities vary a lot, depending on the produce but, some of the activities include transportation of produce from farm to market and storage. In addition, traders can be transporters, wholesalers or retailers and, any of these, can influence produce quality including aflatoxin contamination if good practices are not adhered to. The following stages are important for traders as far as aflatoxin management are concerned and highlights are given on what should be done to control or prevent these toxins from contaminating produce.

7.1. Produce purchase and before storage

Traders should ensure that the produce purchased is of good quality; i.e. clean and dried to safe storage moisture content of ≤13.5%. This moisture can be measured using a moisture meter, the salt test or the dry card. Before storage, the produce should be checked for smell, moisture content, diseased/ mouldy and discoloured grains, broken kernels, soil contaminated grain, foreign matter (soil, dust, chuff and stones), insects and insect damaged grain as well as aflatoxin contamination and ensure that the produce is graded to the required quality standards.: Should be ≤13.5%.

Poor quality maize and groundnuts should not be purchased

Good quality groundnuts suitable to be purchased

7.2. Produce storage

Traders should store sorted, clean, and graded produce only with recommended moisture content in clean, dry environment. The dried produce should be placed and stored in food grade containers such as gunny, plastic or hermetic bags, and drums that will maintain suitable environment and prevent or restrict moisture pick-up and insect/rodent infestation. The store should be well-ventilated and, packaged produce should not be over-packed or placed on the ground. Stack packaged bags on pallets and off walls to ensure adequate aeration and prevent moisture pick-up from the walls. If the produce is suspected to have picked moisture, it should be re-dried to recommended storage moisture content periodically. Traders should control insects and rodents using recommended storage pesticides in the right dosage. The produce should be accessible throughout the storage period for additional treatment if necessary especially where pesticides are to be used. During storage and utilization of the produce, traders should apply first-in-first-out principle to ensure that produce that was stored first, is utilized first. This will help the produce not to overstay in storage which gives chance for mould and aflatoxin contamination.

Maize over-packed in a store with no ventilation is a bad practice

7.3. Transportation

During transportation, a number of factors can affect the quality of the produce enhancing mould and aflatoxin contamination. Many traders transport produce susceptible to aflatoxin over long distances from rural areas with bad roads (bumpy, no tarmac) using trucks which may not protect produce from rain and dust and are usually in poor mechanical condition. Prior to transportation, traders should ensure that produce is dried to required moisture content. The longer wet produce remains in transit, the higher the chances of moulding and aflatoxin production. Thus, transporters should protect produce from rain and dust during transportation by ensuring that it is correctly packaged in clean bags and covered using clean tarpaulin. The produce should not be exposed to moisture, dust and foreign materials during transport. The produce should be transported as soon as possible to avoid delays. In addition, transporters should not transport un-bagged or poorly bagged produce to avoid spillages. Un-bagged produce also easily picks up moisture and becomes mouldy. Transporters should use clean vehicles in good mechanical condition to avoid contamination. The produce should be offloaded as soon as possible, upon delivery to avoid delays because once it delays, chances of moulding are high. The vehicles used should not be dirty and in bad mechanical condition. These can easily breakdown

causing unnecessary delays' Dirty vehicles will contaminate the produce with chances of aflatoxin contamination. In addition, the produce should not be offloaded on bare ground because the soil which is a good source of moulds will enhance contamination. Furthermore, there should be no mix of produce with other products like petroleum containers, pesticides, charcoal etc. to ensure good quality produce. Some of the products mentioned here are poisonous to consumers (humans and animals).


Poor transportation of produce compromises quality

7.4. Marketing by retailers and wholesalers

Retailers and wholesalers may store the produce for some time depending on the market demand and supply forces including availability of clients. If not properly stored, the produce may be subjected to conditions that will favour moisture pick-up as well as contamination by dust, moulds, insects and rodents leading to aflatoxin contamination. It is therefore important that retailers put into consideration the following practices in order to minimize or prevent aflatoxin contamination.


Inappropriate storage of maize by retailers and wholesalers

CHAPTER 8.

8.0 CONSUMER ACTIVITIES

This is the last stage of the value chain where aflatoxins show their real impact if consumed in food. Consumers have a big role to play in the prevention of aflatoxin effects even if the food to be prepared for consumption is contaminated. It should be particularly noted that because of our nature of tropical climate in Uganda, including temperatures and rainfall, it is difficult to avoid aflatoxin contamination of food. Therefore, consumers should know that the aflatoxin susceptible foodstuffs could always be contaminated thus need to take the necessary precautions.

8.1. Type of food to consume

Consumers should always consume good quality foodstuffs which should be clean and safe. For those foodstuffs susceptible to aflatoxin contamination, they should be well-dried before consumption. Consumers should avoid consuming mouldy foodstuffs because, these have higher chances of being contaminated with aflatoxins.

Mouldy bread and cassava should not be consumed

8.2. Purchase of foodstuffs

Quite often, consumers purchase foodstuffs from markets or shops. The foodstuffs purchased should be clean and safe, generally of good quality. The foodstuffs should not be mouldy. If purchasing processed foodstuffs, these should be with a quality mark to ensure that their quality is guaranteed. Overall, consumers should purchase foodstuffs from clean/hygienic environment to minimize chances of consuming contaminated foodstuffs.

8.3. Food processing/Preparation

During preparation, can minimize consumption of aflatoxin-contaminated foodstuffs. It should be remembered that aflatoxins cannot be eliminated from food through cooking (boiling, steaming, roasting or baking) and fermentation which are common ways of preparing food. Thus, the food prepared should be clean, not mouldy and, if it he foodstuffs are aflatoxin susceptible, they should be well-dried. Thus, consumers should sort to remove mouldy, diseased, discoloured and other poor quality foods before preparation, in order to reduce chances of aflatoxin contamination. All chuff/ foreign materials should be removed from foodstuffs before preparation. For groundnuts, if possible, consumers should process these at home either through pounding using a mortar and pestle or grinding using a blender made of stainless steel if electricity is available.

Overall, the environment in which food is prepared, should be well-organized, dry and clean/hygienic to minimize chances of harbouring various contaminants including moulds, insects and rodents associated with aflatoxins.

If possible, pound your own groundnuts or cassava

8.4. Storage of food

Many consumers also store food before or after preparation. Prior to storage, consumers should sort the food to remove poor quality foodstuffs and foreign materials, to ensure that only clean food is stored. Foodstuffs susceptible to aflatoxins should be stored when dry. Thus, packaging containers that protect the foodstuffs from moisture pick-up should be used. For example, if someone stores maize flour after using part of it, this should be stored in well-sealed polythene bags in a dry environment. When preparing food, use first in-first-out principle. Overall, the environment in which food is stored should be well-organized, dry, and clean. Good hygiene practices should be adhered to during storage of food.

Disorganized storage of food at home should be avoided

8.5. Dietary Interventions

Dietary diversification to contain relatively higher proportions of fruits and vegetables is an approach that aims to enhance the availability, access and utilization of foods with a high content and bioavailability of micronutrients throughout the year. Common foods rich in micronutrients include fresh fruits and vegetables, including biofortified foods like orange fresh sweet potato and iron rich beans. The main purpose of recommending consumers to diversity food is to minimise overdependence on cereals, legumes and oil seeds and starch-based foods many of which are susceptible to mould and aflatoxin contamination. For example, maize, is the staple food consumed in Uganda while groundnuts are the second most consumed legume next to beans. In Uganda, high levels of aflatoxins have been found in maize, groundnuts, sorghum, cassava, sunflower, simsim, and soyabean while elsewhere in the world, rice has also been reported. All these are foods highly consumed in Uganda. Therefore, consumers should strive to diversify daily dietary intake and deliberately consume fruits and vegetables in order to minimize chances of aflatoxin poisoning. Besides, currently, it has been confirmed that chlorophyll, the green colouring matter in fruits and vegetables is effective in limiting the absorption of aflatoxin in humans. Thus, consumption of dark green leafy vegetables is an excellent strategy against aflatoxin effects and should be strongly recommended.

The other dietary intervention that has been found to be every effective against aflatoxins in maize is to cook dried maize grains in water with food-grade lime (calcium hydroxide) or wood ash at temperatures near boiling, for 35–70 min, with a steeping period of 8–16 hours, rinsing the maize to remove the outer kernel cover (pericarp) and milling it to produce dough that can be consumed in different ways, including porridge or posho. This process is known as nixtamalization and, currently is used in many parts of Latin America like Mexico, and other countries like Kenya and Tanzania to make many other maize based products. In addition to reducing aflatoxins, nixtamalization treatment also facilitates the pericarp removal, controls microbial activity, enhances water uptake, increases gelatinization of starch granules, and improves nutritional value through an increased availability of niacin which is a very important vitamin. The lime treatment makes niacin nutritionally available and reduces the chance of consumers developing pellagra which is common in people who obtain most of their food energy from maize especially in Africa. In addition, food-grade lime is rich in calcium, also providing nutritional and health benefits. As long as consumers in Uganda can get used to the flavor of nixtamalization maize products, this is a very excellent way of utilizing maize with improved quality and safety.

Examples of fruits and vegetable rich diversified diet for aflatoxin mitigation contains mainly fruits and vegetables and less carbohydrates

9.0 CONCLUSION

Aflatoxin contamination of food in Uganda is real and, given the nature of the country's climate, this cannot completely be avoided. Its health and economic impacts are greatly affecting the population of all ages as well as domestic animals in the country. Thus, the need to put into practice actions that help to minimize contamination of food and feed by the moulds that produce these toxins. All stakeholders that handle food (farmers, traders, transporters, processors and consumers) ought to change their cultural and traditional behaviours of prodcution and postharvest handling of food and feed. Everybody should be made aware of this toxin including its effects and management strategies. There is need to adhere to the recommended good agricultural practices, good storage practices, good hygienic practices as well as good manufacturing practices. This will guarantee quality control and assurance of food for enhanced food and nutrition security leading to a health populace in the country. Fortunately, MAAIF, which is the ministry charged with coordination of aflatoxin mitigation actions in the country, has made considerable strategies to manage the menace. The ministry has revived the public extension services; it has established the Aflatoxin Technical Working Group ATWG) and the Uganda Mycotoxin Mitigation Steering Committee (UMMSC) and has mainstreamed the Aflatoxin Mitigation Action Plan (AMAP) into the Agriculture Sector Strategic Plan (ASSP). Furthermore, in October 2018, the aflatoxin IEC materials (Annex 1) were launched in the country. All these approaches will see the aflatoxin problem addressed in this country.

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AFLATOXINS

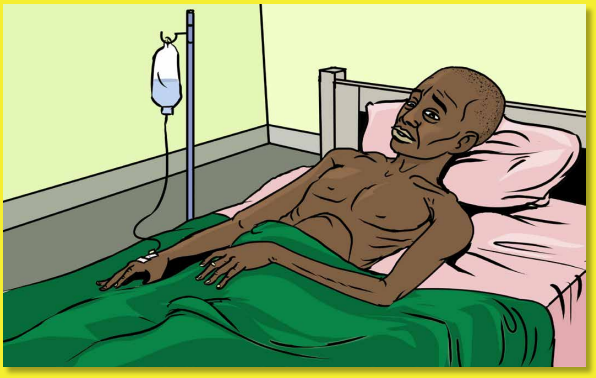
WHAT ARE AFLATOXINS?

Poison produced by moulds when they attack produce which is not well-dried.

Once in food or feed, this poison is difficult to remove even by cooking or roasting.

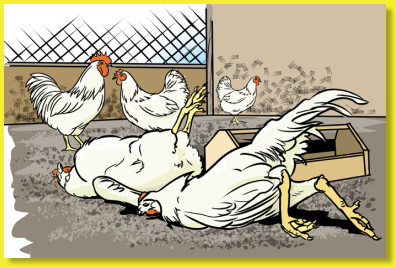
WHY CARE ABOUT AFLATOXINS NOW!!

This poison affects agriculture, health and trade.

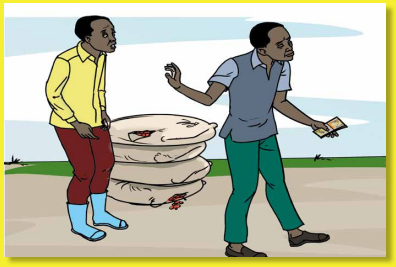


How? At high levels, aflatoxins cause death of humans and animals. It is one of the major causes of liver cancer.

In children, leads to stunting and kwashiorkor thus reduced growth. Generally, aflatoxin weakens the body immune system leading to other illnesses.



It can kill all animals when taken in higher quantities and also reduces productivity such as egg production and growth.



It affects trade, social and economic status. We lose money as we cannot sell contaminated produce in the national, regional and international markets.

Which produce are most contaminated?




Mainly produce dried at farm and their products;

- Cereals: maize, sorghum, rice, millet
- Legumes: groundnuts, soyabean
- Oil crops: sunflower and simsim or sesame
- Dry spices like chilli, ginger, turmeric
- Dried roots & tubers: cassava, sweet potato (amukeke)
- Most dried produce including fish (mainly silver fish/mukene)

Processed products;

- Animal feeds, peanut butter, flours (groundnut, maize, soya, mukene, millet, cassava, sorghum) and pressed simsim or sunflower cake etc.
- Dairy and poultry products: milk and products, and eggs when animals feed on contaminated feeds

Why are aflatoxins common in our produce?

Most people are not aware of the poison and do not apply good agricultural, handling, storage, transportation and processing practices.

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AFLATOXINS

WHAT SHOULD FARMERS DO ON-FARM TO PREVENT AFLATOXINS?

When the crop is in the field, farmers should follow recommended good agricultural practices so that the crop remains healthy throughout the growth period, to resist mould infection.

YOUR HEALTH, YOUR WEALTH, YOUR LIFE!!!

Good Practices to do

Timely land preparation and planting in rows with good spacing

Timely application of recommended fertilizers

Control pests and diseases using non chemical and approved chemicals in correct dozes, following manufacturers' directions for use

Good water management especially irrigation

Harvest on time as soon as crop is ready, minimising damage of produce

Bad Practices to avoid

Do not dry crops in the field especially maize and groundnuts

Do not damage produce during harvesting e.g. groundnut pods

Do not harvest late

Never place produce on bare ground during harvesting

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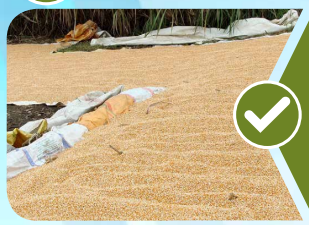
AFLATOXINS

WHAT SHOULD FARMERS DO DURING DRYING, SHELLING AND THREASHING TO PREVENT AFLATOXINS?

YOUR HEALTH, YOUR WEALTH, YOUR LIFE!!!

Good Practices to do	Bad Practices to avoid
 If shelling has been done in the field, further dry the grains	 Do not store produce before further drying
 Use appropriate shelling methods such as motorised shellers to avoid breakage	 Do not Shell produce by beating or trampling
 Dry produce off bareground using clean materials such as black drying sheet materials or cemented floors	 Do not dry produce on bare ground
 Winnow and sort all the damaged, shrivelled, diseased grains and foreign material	 Do not dry produce on the road or tarmac to avoid contamination with dust and vehicle fumes and oils
 Dry crops using faster drying technologies	 Do not dry good grain with bad grain
 Check crop dryness using the salt method or moisture meter	 Do not allow produce to be wetted and soaked by rain

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AFLATOXINS

WHAT SHOULD FARMERS DO DURING STORAGE TO PREVENT AFLATOXINS?

YOUR HEALTH, YOUR WEALTH, YOUR LIFE!!!

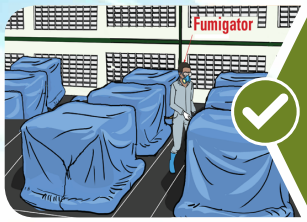
Good Practices to do

Clean, disinfect and repair the store

Place and store dried produce in food grade containers such as gunny, plastic or hermetic bags–drums

Place bagged produce on pallets and away from walls during storage

Bag produce when storing in a traditional silo or granary



Control insects and rodents using recommended storage pesticides

Periodically redry produce during storage

Bad Practices to avoid

Do not pile bagged produce in a store without good aeration

Do not heap unbagged produce in store especially maize

Do not place bagged produce directly on the floor

Do not mix new with old season produce

Do not store produce in torn gunny or plastic bag

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AFLATOXINS

WHAT SHOULD FEED PROCESSORS DO TO PREVENT AFLATOXINS?

SAVE OUR ANIMALS AND US!!!

Good Practices to do

Do on–spot mould and aflatoxin tests in the raw produce and finished products

Use feed grade processing equipment

Acquire a quality mark (Q–mark) from Uganda National Bureau of Standards

Incorporate aflatoxin binders during processing of the feeds

Bad Practices to avoid

Do not Process poor quality produce (diseased, damaged, broken/rotten shrivelled, discolured)

Do not mix feed raw materials with impurities such as mixing silver fish and Sand

Do not mix feeds on bare ground at home or factory

Do not pack or store ingredients in poor quality materials

Do not store feeds on bare ground and in premises without good aeration

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AFLATOXINS

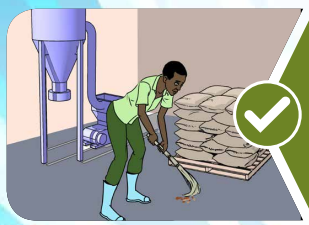
WHAT SHOULD FOOD PROCESSORS DO TO PREVENT AFLATOXINS?

IT IS NEVER TOO LATE!!

Good Practices to do

Inspect produce and processing premises regularly

Process only clean, dry, sorted produce



Maintain clean and dry working environment

Use food grade processing equipment preferrably stainless steel

Do on–spot mould and aflatoxin tests in the raw produce and finished products

Acquire a Quality Mark (S or Q) from Uganda National Bureau of Standards

Bad Practices to avoid

Do not process poor quality produce (mouldy / rotten, broken, damaged, shriveled, discolored)

Do not add water to raw produce for processing

Do not store processed products in non–food grade materials

Do not store processed products in dirty, unconducive environment

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AFLATOXINS

WHAT SHOULD CONSUMERS DO TO PREVENT AFLATOXINS POISONING?

YOUR HEALTH, YOUR WEALTH, YOUR LIFE!!!

Good Practices to do

Consume well dried, clean, sorted and safe foodstuffs

Store food in a clean and dry environment

Process your own clean and safe food e.g. pounding groundnuts where possible

Buy foodstuffs with a quality mark

Diversify daily dietary intake and deliberately consume fruits and vegetables

Bad Practices to avoid

Do not consume mouldy foodstuffs

Do not purchase and consume foodstuffs from unhygienic premises

Do not store foodstuffs in a dirty, disorganized environment

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