GOOD PRACTICES FOR ANIMAL FEED AND LIVESTOCK **1**

training manual

ON-FARM MYCOTOXIN CONTROL IN FOOD AND FEED GRAIN

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2007

ISBN 978-92-5-105852-7

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Preface

When we eat food that we have grown or bought we are unwittingly consuming many substances other than the basic nutrients which we assume make up the food item. The same applies to the feed we provide for our domesticated animals. Many foreign substances are added by man to improve quality and prevent biological decay, these include insecticides, colourants, minerals, vitamins and preservatives. However, there are many materials that have a damaging effect and are not added by man, but are the result of infections by other organisms. For example, foods can contain bacteria that grow naturally on produce and which may lead to food poisoning if ingested. Other harmful substances may be picked up as a result of environmental pollution, such as undesirable pesticides and heavy metals.

One group of undesirable substances are mycotoxins. For the most part, their presence is beyond the control of man and can lead to severe harmful effects in both humans and livestock, culminating, in some instances, in death. Mycotoxins can be produced throughout the growing cycle but predominately after the crop has matured in the field, through the harvest and storage periods. Their presence affects farmers, their families and livestock, as well as consumers in town and cities who may ingest contaminated produce.

This booklet is directed at the farm situation, providing information that can be used to avoid mycotoxin contamination before food leaves the farm. A separate booklet addresses issues related to transport, marketing and urban consumption. Although it is aimed at farm situations, the booklet is intended to be used by extension personnel, both government and non-government employees, in their efforts to advise and assist rural communities. It is not a treatise on mycotoxins and fungi but rather provides practical advice to combat the problem. It is expected that those using this booklet will have a basic knowledge of biology and of agriculture, both production and post-harvest.

The first sections describe what mycotoxins are, how they are produced and how to recognise signs of their presence. The booklet is particularly concerned with recognising the presence of fungal moulds and provides advice on how to prevent moulds from growing. The latter half of the booklet provides information to enable farmers to minimise the risk from mould contamination whilst the crop is growing, during harvesting, and then after harvest, i.e. when threshing/shelling, and storing the crop. It also examines actions to take when storing flour and feed, silage and hay.

Acknowledgements

I would like to thank the Natural Resources Institute UK and the Fungal Research Trust for allowing me to reproduce photographs from their collections. I would like to thank Tanya Stathers for the information on the availability of resistant varieties in East Africa, and Professor Ray Coker for information on various issues relating to mycotoxin problems.

Glossary

Aflatoxicosis	(aflatoxicoses: plural) diseases resulting from consumption of aflatoxins
ATA	alimentary toxic aleukia, a mycotoxin disease in humans
DON	deoxynivalenol (a mycotoxin)
ELEM	equine leukoencephalomalacia, a disease of horses
Metabolite	a substance produced as a result of a chemical change occurring during a biological process, such as respiration, photosynthesis in plants, cell growth etc.
Mycotoxicosis	(mycotoxicoses: plural) diseases caused by ingestion of mycotoxins
OTA	ochratoxin A, a member of the ochratoxin mycotoxins
ppb	parts (of the active substance) per billion (parts of the target: body weight or grain weight)
PPE	porcine pulmonary oedema, a disease of pigs
T-2	a trichothecene mycotoxin

What are mycotoxins?

Mycotoxins are among the most potent causes of cancer. Ingestion through the diet can pose chronic health risks that may result in liver and kidney disease and a suppression of the immune system. Death may occur as a result of acute poisoning. In livestock, mycotoxins can also modify the nutrient value and therefore the metabolism of feed, and alter the hormonal balance.

Mycotoxins are chemicals produced by fungal moulds. These moulds grow during production, harvesting or storage of grains, pulses, nuts, roots and other crops. As the moulds develop, they produce different chemicals, some of which enable the fungal colonies to grow and multiply but others, including mycotoxins, appear to provide no obvious benefit to the moulds (some of these chemicals are actually beneficial to man as in the case of antibiotics, like penicillin). Mycotoxins are known as 'secondary metabolites' as they have no direct effect on the development of the mould, though they do give it an advantage over competing organisms, such as other moulds, yeasts and bacteria. These toxins, or poisons, disrupt cell structures and interfere with vital cellular processes, allowing the mould to compete successfully with other organisms. They also cause problems for humans and animals that ingest them. We will see just how dangerous these chemicals can be.

Not all moulds produce mycotoxins. Not even all strains of a species of mould that produces mycotoxins are able to do so. Nobody is aware of the precise factors that determine whether a growing mould will produce a mycotoxin or not. It is, therefore, not possible to anticipate whether a mould growing on a crop will release mycotoxin, but it is always better to assume that it will do so. It is better to be safe than sorry! By doing so, the chance of coming into contact with highly toxic substances can be reduced or avoided.

The most common mycotoxins known to cause health problems in man and livestock are:

- Aflatoxins
- Fumonisins
- Trichothecenes, especially T-2 toxin also known as vomitoxin
- Deoxynivelenol (DON)
- Ochratoxins, especially ochratoxin A (OTA)
- Ergot toxins
- Zearalenone

Some of the other toxins which may affect health are listed in Table 1.

SIGNS OF MYCOTOXINS AND MOULD GROWTH

Mycotoxins are not visible to the eye. Grain that shows no signs of mould infection may be contaminated with mycotoxin. These metabolites may be found on apparently uncontaminated grains that are in close proximity to others which show signs of mould growth. When a farmer sorts grain to be sold and removes the obviously discoloured, mouldy grain, even grain which shows no signs of mould growth may nonetheless be contaminated with mycotoxins, and thus find its way to the local market. However, this risk of contamination is relatively low, and for practical purposes, grain that does not show signs of mould infection can be regarded as being free of mycotoxin.

Moulds growing on grain and other commodities are generally clearly visible. They are often coloured and affect the appearance of the product on which they are growing. Produce infected with mould takes on an unappealing smell.

Physical signs of mould in animal feed include:

- Dustiness
- Caking
- Poor flow out of grain bins
- Feed refusal by animals for no apparent reason

FIGURE 1 **Mouldy groundnut (a), cassava (b) and millet (c)**

(a) (b) (c)

- 'Mouldy' and musty smell
- Darkening of feed and grain

The presence of mould has a major impact on the quality of grain. Nobody wants to eat mouldy food. Farmers will not allow mouldy grain to be used in the preparation of food for their families, unless there is a significant food shortage, such as when a famine occurs. Mould-contaminated grain is often discarded, is certainly difficult to sell, and will either cause grain to be rejected or at best, downgraded with a loss in value. However, mouldy grain is usually retained for brewing beer or is fed to livestock. We will see later why feeding poultry, pigs, goats, cattle and any other livestock with mouldy grain can seriously affect the health of the animals and be counterproductive.

FACTORS THAT AFFECT FUNGAL GROWTH

Fungal infection of food commodities can occur: during plant growth; once the plant has matured; during harvesting, drying and storage; during processing; and even when the processed product is waiting in the trader's store or on the consumer's shelf. Mycotoxin production, similarly, can occur at all these stages, from seed to shelf. Fungal growth and mycotoxin production are particularly influenced by moisture, temperature and oxygen content. Furthermore, grain and other food commodities that are damaged or stressed by drought, pests, and cultivation and harvesting practices, are more susceptible to mould growth.

Fungi multiply by releasing spherical spores. These germinate producing elongated projections known as hyphae. Hyphae multiply and branch and form a mass of fungal tissue, the mycelium, at which stage it is recognisable as mould.

FIGURE 2A **Fungal life cycle *(Aspergillus)***

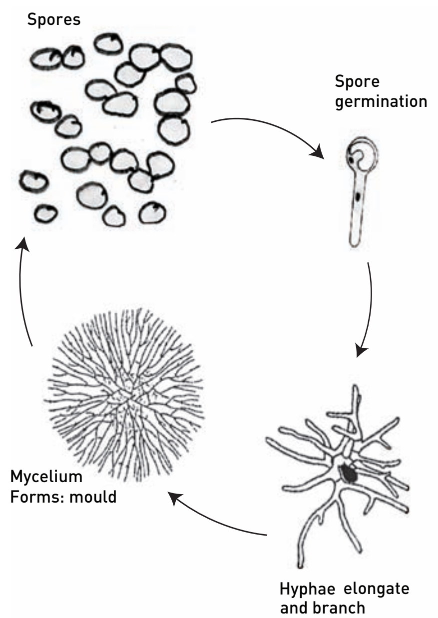
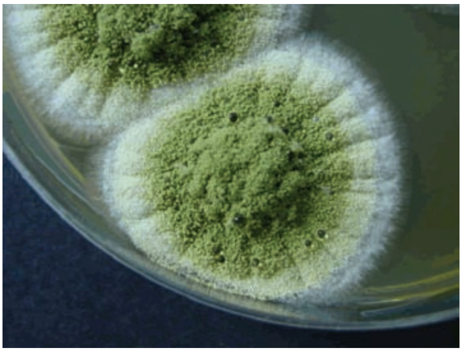


FIGURE 2B *A. flavus* mycelium (b)



Climate characteristics

Moulds require water for growth, reproduction and other biological processes. The amount of water in a plant or seed that is available to support these processes is known as its *'water activity'*. A minimum water activity of 0.70 will sustain growth of storage moulds, though for field moulds that produce mycotoxins water activity should be above 0.85. Water activity is similar to *moisture content* but is dependant on temperature and the chemical composition of the commodity. Thus the ambient temperature which affects the temperature of the grain and the type of commodity, whether it a cowpea grain, fresh tomato, groundnut pod or maize cob will affect how a mould will grow. For every 10°C, water activity rises 0.03.

The amount of moisture that is contained in air is known as the *humidity*. As air gets warmer it is capable of carrying more water; so humidity increases. The water in the air is in a state of balance with that contained in grains and other food products. When the air contains about 70% moisture, at a temperature of 27°C, most cereal grains will be able to hold 13-14% moisture; groundnuts will hold about 7% because of their high oil content. If the temperature then decreases the air will give up some of its water, which will be picked up by the grain. Conversely, if the temperature increases the air will take moisture from the grain and the grain moisture content will decrease. The relationship between water in the air and moisture content of grain is the relative humidity. As a very general rule and approximate guide *relative humidity* is about 100 times greater than water activity, so a relative humidity of 70% will equate to a water activity of maize of 0.70 when the temperature is about 25-30°C.

Most mycotoxin-producing fungi require the relative humidity to be above 70% in order for them to develop. So for wheat, maize, sorghum and millets stored in the tropics and sub-tropics a relative humidity of 70% will allow the grains to be kept safely without problems of mould contamination, as long as the moisture content of the grain itself is at 13-14% for cereals and 7% for groundnuts. If the moisture content for maize for example, is 20%, the grain will not be safe to store and moulds will grow.

Farmers cannot influence the moisture carried in the air or the ambient temperature. They may, however, influence the amount of moisture in their grain by drying it. They have to forcefully expel water and so upset the natural balance between the environment and their commodity. Where the climatic conditions are hot and humid, artificial drying may be the only way to reduce grain moisture content to prevent mould growth. In dryer climates this will be more easily achieved because the grain will naturally release water into the dry air until a balance or equilibrium is reached.

Other factors

Mycotoxin-producing moulds attack crops both before and after harvest. Pre-harvest fungal invasion is influenced by in-field damage caused by insects, birds, rodents, husbandry practices and adverse weather. Stress caused by drought, nutrient deficiency and untimely or excessive fertiliser application may also predispose towards fungal establishment. Cracked grain may be readily invaded by air-borne, fungal spores. Maize cobs, heads of sorghum and millet, pods of legume crops such as groundnuts, beans and cowpeas that fall to the ground may be readily invaded by soil or detritus borne spores. Repeated planting of the same crop in the same or nearby fields favours fungal infection by increasing both the fungal innoculum and the insect population that attacks the growing crop.

Poor handling at harvest, during carriage from the field, whilst threshing and winnowing and during storage will similarly assist to encourage mould. Post-harvest pest attack, especially by insects, will make grain more susceptible to entry by fungal spores, and the production of water as a result of insect respiration will enable these spores to germinate and form mycelial clusters.

WHAT ARE THE EFFECTS OF MOULD ON ANIMAL FEED?

Mouldy feeds are less palatable and animals may eat less. This will lead to a reduction in nutrient intake and so decrease weight gain and milk production. Even if mycotoxins are not produced it has been estimated that the presence of mould alone will cause a loss in performance of 5-10%.

Mouldy feed may not be as digestible and the energy content will therefore be reduced. Furthermore, the mould itself will use the protein, carbohydrate and fat from the feed for its own development, reducing that available to the animal. Fat intake, especially, is reduced in mouldy feed and energy availability may be reduced by as much as 10%

Mould itself may cause health problems, especially respiratory disease. Breathing in mould spores for example, causes farmer's lung in man.

Numerous highly toxigenic species of Aspergillus, Penicillium and Fusarium have been found in damp hay and straw. As a result, a large range of toxins including patulin, aflatoxins and sterigmatocystin can be found in insufficiently dried hay and straw. In store, these moulds continue to be present for many months.

FIGURE 3 **Mould growing in a chicken's lung**

WHICH MOULDS PRODUCE MYCOTOXINS?

There are more than 300 known mycotoxins but we know very little about most of them. This manual focuses on the most common and important of these. The main mycotoxin producing species are shown in Table 1.

The genus *Fusarium*, which is a pathogen occurring during plant growth, produces more than 70 different toxins of which the most important are fumonisins, deoxynivalenol (DON), zearalenone and trichothecenes, which include T-2 toxin or vomitoxin, toxins that have only in recent years begun to be studied in depth. Some species of *Fusarium* can produce up to 17 different mycotoxins simultaneously.

Fusarium is responsible for head blight and scab in wheat and barley and ear rot in maize in cereal growing areas of Africa, Asia and North and South America. It can also be found on forage in the field. *Fusarium* species generally require a water activity of above 0.88 to develop so are rarely carried over in to stores after harvest, though they it may still develop on the standing crop if harvest occurs during periods of rainfall. However, although the mould may not, itself, be carried over into the store the mycotoxins it produces may well be. *Fusarium verticillioides* and *F. pallidoroseum* predominate on cereals in the tropics and sub-tropics; *F. graminearium*, perhaps the most common of the genus, prefers humid-temperate conditions, which do occur in many parts of sub-Saharan Africa and Latin America. *Fusarium* toxins are not apparently carried over into meat, milk or eggs.

The most common, important and widely studied mycotoxins in tropical and semi-tropical areas are those of the aflatoxins complex, produced by *Aspergillus*, a post-harvest mould. There are several different aflatoxins; B1 is the most toxic. The other post-harvest genus of importance is *Penicillium*. Higher temperatures and humidities in the tropics mean that both these moulds have species that can develop on crops pre-harvest, once the grains have begun to dry, sometimes causing significant damage. For example, *A. flavus* and *A. niger* cause ear rots of maize and *A. flavus* can produce aflatoxins in the field. Ear rot infection and aflatoxin production starting in the field can carry over into store. *P. verrucosum* produces ochratoxin A (OTA) as does *A. ochraceus.*

FIGURE 4 ***Aspergillus*** **ear rot (a) and** ***Fusarium*** **ear rot (b)**

(a)

(b)

Slow drying of grains and oilseeds after harvest can allow the continued growth of *A. flavus* and a rapid rise in aflatoxin concentration. If the commodity is improperly dried or allowed to become wet after drying a succession of fungi can then invade the grain dependant on the water activity. Species of *Eurotium* are the most common early invaders of improperly dried grain, leading to a loss of germination and quality. A succession of *Aspergillus* and *Penicillium* species then invade if the water activity is high enough. Species of fungi from these three genera are the most frequently isolated organisms from most stored durable crops.

Mould and mycotoxin problems are unlikely to occur if storage takes place mainly during dry periods of the year. Critical periods for contamination are: at the end of the growing season; when the crops are mature and begin to dry; during harvesting; and during the first months immediately after the harvest is brought to the farm. At maturity, when the plants begin to die back, continuous rain will slow the drying process and facilitate the development of *Fusarium* and production of its mycotoxins. Colonies of these fungi may well be carried over into the store and continue to grow if the relative humidity remains elevated. Prolongation of the rains during harvest – crops can remain in the field for many weeks before being removed for storage – similarly provides ideal conditions for many post-harvest fungi and particularly for *Aspergillus*. During the early months of storage, when grain may have a moisture content of 20% (water activity of 0.8+) or higher, fungal development will occur in the moist crop unless it is dried rapidly.

TABLE 1 MAJOR MYCOTOXIN PRODUCING GENERA

Fungi	Mycotoxin	pre or post harvest	Climatic requirements	food commodities contaminated	COMMENT
Fusarium verticillioides (moniliforme), F. proliferatum	Fumonisin	Pre-harvest	Cosmopolitan	Wheat, maize and products, hay	Very stable, can survive cooking, soluble can be removed by wet milling and nixtamalisation
F. graminearum F. graminearum	Deoxynivalenol (DON or vomitoxin) Zearalenone	Pre-harvest	Cosmopolitan	Wheat, maize, millet, hay (zearalenone)	Very stable, can survive cooking, soluble can be removed by wet milling; not transferred to milk, meat or eggs
F. graminearum, F. culmorum, F. poae *F. sporotrichioides*	Trichothecenes T-2 toxin	Pre-harvest	Temperate to cold	Wheat, maize (overwintered), hay	Very stable, can survive cooking
Aspergillus ochraceus *Penicillium verrucosum*	Ochratoxin A Ochratoxin A	Post-harvest Post-harvest	Warm, humid Temperate	Cereals and cereal products, pulses, dried vine fruit, beverages, spices, groundnuts	Has been found in pig meat
Penicillium sp., Aspergillus sp.	Citrinin				
Penicillium sp., Aspergillus sp.	Cyclopianzonic acid				
Aspergillus sp.	Sterigmatocystin				
Claviceps purpurea	Ergot	Pre-harvest	Mainly temperate	cereals	
Various	Patulin	Post-harvest		Mouldy fruit, vegetables, cereals, other foods.	Destroyed by fermentation
Aspergillus flavus, A. parasiticus	Aflatoxins (B1, B2, G1, G2, M)	Mostly post-harvest	Tropical and sub-tropical	Maize, wheat, groundnuts, other edible nuts, figs, spices, soya bean, cotton seed, oil palm kernels, copra, coconut oil, cassava	Moulds do not grow in silage but aflatoxins can survive ensiling process.

Fusarium toxins are apparently not carried over into milk, meat and eggs (M. E. Doyle (1997): http://www.wisc.edu/fri/fusarium.htm :5). Although fumonisins and DON are not the most toxic of the *Fusarium* toxins they are the most frequently detected and therefore the most associated with human and animal illness (this applies to US in particular and maybe also Europe, but may not be relevant for Africa).

Other mycotoxin producers including the growing crops *Claviceps purpurea* (ergot). This fungus produces toxic alkaloids from dark brown to black bodies (sclerotia or ergots) that stick out from the seed head of infected plants, commonly cereals and especially rye. Ergots are visible to the naked eye and look like rat droppings when removed from the seed head. They may grown up to 2.5 cm in length. Ingestion can result in 'ergotism', neurological disorders, including tremors, staggers, convulsions and necrosis, and gangrenous disorders such as sloughing of the hoof or feet and tail as well as dry gangrene. A cessation of milk production in post-partum females is also common.

Another important genus is Stenocarpella (Diplodia), which causes stem and ear rots in maize. The composition of its mycotoxins are as yet unknown but the effects can be severe in livestock. Mycotoxins of *S. maydis* cause diplodiosis in cattle, symptoms of which are loss of co-ordination, nervous system defects, paralysis and death. In sheep, diplodiosis causes abortions, and in poultry reduced egg laying and growth. It is not known whether these moulds have any effect on humans.

Some other disease causing fungi include *Neotyphodium*, which causes dry gangrene, and *Rhyzoctonia*, which produces slaframin causing sialorrhea or excessive salivation in ruminants.

WHAT ARE THE SYMPTOMS OF MYCOTOXIN POISONING?

In livestock, aflatoxins B1 and M1, ochratoxin A (OTA) and sterigmatocystin have been found to be carcinogenic. In humans, aflatoxins and OTA have been classified as carcinogenic, and fumonisin B1 as a possible carcinogen. Patulin, a toxin produced by both *Aspergillus* and *Penicillium* species on fresh fruit, and which occurs particularly in fruit juices, is also a health hazard.

The effect of mycotoxins on animal production is influenced by the type and concentration of toxins present; the exposure period; the age and type of animal; and its nutrition and health status. Mycotoxins tend not to be recognised by the body's defence mechanism so that antibodies are not produced in response to their ingestion. Thus the effects of mycotoxin poisoning are often chronic and gradual, so making it frequently difficult to diagnose or monitor the effects before symptoms become severe. The situation is made worse because more than one mycotoxin may be present; for example aflatoxins and sterigmatocystin may be produced at the same time by *Aspergillus flavus.*

In man and animals mycotoxins target different organs. The following is a summary of which organs in the body and which physiological systems are attacked by different mycotoxins (it must not be assumed that ingestion of these toxins will always have the same effect as the dosage ingested will influence what the mycotoxin does).

• Digestive system including liver, mucous membranes – fumonisins, T-2 toxin, patulin and DON;

FIGURE 5 Ergot on millet

FIGURE 6 *Stenocarpella (Diplodia)* damage

- Respiratory system, lungs – trichothecenes, fumonisins;
- Nervous system – fumonisins, trichothecenes, cyclopianzoic acid and ergot;
- Cutaneous system, skin – trichothecenes;
- Urinary system, kidneys – fumonisins, ochra toxin A;
- Reproductive system, T-2 toxin, zearalenone;
- Immune system – aflatoxins and many others;
- Vascular system including blood vessels, liver –aflatoxins, sterigmatocystin.

Symptoms occurring in individual animals and man are described in more detail below.

Humans

Aflatoxins are at present the only mycotoxins that have caused human fatalities as a result of acute poisoning. Known fatalities were first recorded in India in 1974, when unseasonal rain and food scarcity forced people to eat maize that was heavily contaminated with this mycotoxin. Thereafter, contaminated maize consumption has resulted in human deaths in Kenya in 1982 and, more recently, in 2004 and 2005 when more than 200 people died.

Aflatoxins, like many of the other mycotoxins, suppress the immune system in humans and so increase the susceptibility to infection by other microbes. Aflatoxins have similar effects to those caused by HIV/AIDS and these toxins may even make people more readily susceptible to HIV/AIDS.

Aflatoxin B1 is a very potent human carcinogen, in particular causing liver cancer. Liver damage results in abnormal blood clotting, development of jaundice, haemorrhaging and a reduction in the immune response.

The trichothecene, T-2 was thought to be responsible for causing Alimentary Toxic Aleukia (ATA) in Siberia during WWII. Thousands of people were affected when they had to eat grain which had been allowed to over-winter in the fields. Symptoms included vomiting, acute inflammation of the digestive system, anaemia, circulatory failure and convulsions. ATA also occurred in Kashmir, India in 1987, where people ate bread made from mouldy flour; symptoms included vomiting, diarrhoea, inflammed throat and bloody stools. T-2 may be carcinogenic.

In combination with T-2 and other trichothecenes, DON resulted in human illness (mycotoxicosis) in India. Similar outbreaks occurred in Japan and China, the latter in 1984/5 from ingestion of mouldy maize and wheat, causing nausea, vomiting, abdominal pain, diarhhoea, dizziness and headache; the onset of symptoms occurred within 30 minutes. Human oesophageal cancer in Transkei, South Africa and China has been associated with presence of *F. verticillioides*, which produces fumonisins.

Cattle

Initially, the reduction in performance as a result of mycotoxin ingestion may not be recognisable. Within days or weeks the effects of continued mycotoxin consumption becomes more pronounced. Animals go off their feed, may suffer from diarrhoea, haemorrhaging, ketosis (excess sugar in the blood: diabetes) and from a displaced abomasum (4^{th} stomach). Furthermore, reproductive effects, such as swollen vulvas and nipples, vaginal and rectal prolapse, may occur.

Mycotoxins can be detoxified in the rumen but cattle may still suffer the effects of the toxins. It is not possible to predict just what the effects are likely to be so it is always better to avoid feeding cattle mouldy feed if possible. Dairy cattle are more susceptible than beef cattle.

All livestock is affected by aflatoxins. Mature animals tend to be less susceptible than breeding and growing stock but young, pre-ruminant animals are the most at risk.

Feed levels of 60-100 ppb aflatoxins may effect performance. Chronic symptoms can occur with continued intake of 700-1000 ppb in 200-kg cattle and death has occurred within five days in feeding trials when the diet has contained 10,000 ppb.

BOX 1 SYMPTOMS OF AFLATOXICOSIS IN CATTLE

Acute effects
- reduced feed intake
- reduced weight gain or weight loss
- reduced feed efficiency
- increased susceptibility to stress
- decreased reproductive performance
- severe haemorrhaging resulting in death

Chronic effects:
- unthriftiness
- anorexia
- prolapse of the rectum
- liver and kidney damage, resulting in prolonged blood clotting time
- depression of the immune system
- oedema in the abdominal cavity and gall bladder

Even lower levels of aflatoxins may cause these effects when other mycotoxins are also present.

In dairy cattle, milk yield is reduced by aflatoxins and DON consumption, and both reduce reproductive efficiency. Aflatoxin M1 (a metabolite of aflatoxin B1) can be secreted into the milk at 1-2% of dietary intake when feed levels are 50 ppb or more. However, if contaminated feed is removed, milk residues disappear in 48-72 hours.

Zearalenone may give rise to abortions in dairy cattle, as well as reducing feed intake, milk production and cause vaginitis, vaginal secretions, poor reproduction performance and mammary gland enlargement in virgin heifers. T-2 causes feed refusal, gastroenteritis and may lead to death.

Poultry

Aflatoxins were responsible for the first major acute mycotoxin outbreak. In the United Kingdom in the early 1960s, aflatoxins caused 'Turkey X' disease, which was associated with the death of thousands of turkeys, ducklings and other domestic animals that had eaten a diet containing contaminated groundnut meal.

Less than 20 ppb aflatoxins in the diet will reduce resistance to disease, decrease ability to withstand stress and bruising, and make birds unthrifty and their condition generally poor. Young birds are more susceptible than laying hens, and ducks and turkeys are particularly at risk.

Zearalenone causes impaired fertility, stillbirths and reduced sperm quality. T-2 toxin and other trichothecenes may: suppress the immune system; reduce feed intake and cause weight loss; cause skin irritation (feather loss) and mouth lesions, diarrhoea, internal haemorrhaging and severe oedema of the body cavity. Death may well result.

Pigs

Nursing or nursery age swine are sensitive to aflatoxins. Feed levels of 100-400 ppb affect breeding stock, unweaned and growing pigs (less than 100 kg). As with other animals, there is usually a reduced ability to convert feed leading to a reduced rate of weight gain. Levels of 400-800 ppb have caused liver damage, bleeding disorders, suppression of the immune system, abortion and death.

BOX 2 EFFECTS OF AFLATOXICOSIS IN POULTRY

- stunted growth as a result of poor food conversion
- increased mortality
- reduced egg size
- reduced egg production
- liver and kidney disorders
- leg and bone problems
- suppression of the immune system with increased susceptibility to bacterial infections
- decreased blood clotting results in down grading and rejection due to massive bleeding and bruises

Zearalenone has similar effects as it does in poultry, causing swollen vulvas, and vaginal or rectal prolapse in pre-pubertal gilts. It also causes the uterus to enlarge and swell or become twisted, and the ovaries to shrink. In boars, the testes atrophy and mammary glands enlarge. Generally, there is a decrease in fertility.

DON can cause severe vomiting and may induce pigs to reject feed.

Fumonisins cause porcine pulmonary oedema (PPE), an accumulation of fluid in the lungs. OTA is associated with kidney damage.

Sheep and goats

The effects of aflatoxin ingestion are similar to those occurring in other ruminants. The liver and kidneys may be damaged, and the animals become anaemic. Early symptoms include depression, loss of appetite, weakness and slow movement.

Feed containing patulin cause nasal discharges, and loss of appetite and rumination, and body weight.

Horses

As non-ruminants horses may be more susceptible to mycotoxins, which may be responsible for:

- colic
- neurological disorders
- paralysis
- hypersensitivity
- organ deterioration
- reduced rate of growth
- poor feed efficiency
- impaired fertility
- death

The cumulative effects of feeding low levels of mycotoxins may result in a gradual deterioration of body organ function. This affects growth rate, feed efficiency, fertility, respiration rate, the ability to perform work and life span.

Working horses have a high energy requirement and require high concentrate intake, and would be most susceptible to problems with mycotoxin-contaminated grain. Lightly worked horses fed less grain are more likely to eat mycotoxin-contaminated hays or forages, such as cereal stover. Since mouldy forages are less palatable than normal forage, horse may well refuse feed before ingesting sufficient to do severe intestinal damage. Instead they may suffer mild colic. Moulds affecting feed grain do not usually affect palatability and so those horses fed grain are those most often exposed to mycotoxins.

Maximum aflatoxins levels for non-breeding, mature horses (2-yr and above) should be 50 ppb. Growing, breeding and working horses should receive aflatoxin-free diets. However, as the effects on horses are not well understood all horses should be fed diets free of mycotoxin.

Fumonisins, which seem to be particularly toxic to horses, cause ELEM (see Table 2), which is characterised by lesions in the brain. Incidences of ELEM have been reported in USA, Argentina, Brazil, Egypt, South Africa, China; it may well occur in other countries where insufficient expertise prevents diagnosis.

General effects of mycotoxins

A summary of the more specific effects of mycotoxins is shown in Table 2. Aflatoxins are carcinogenic, with the liver being especially susceptible. Trichothecenes, and T-2 in particular, are responsible for causing haemorrhaging in farm animals. Fumonisin B1 is a central nervous toxin, and also affects liver, pancreas, kidney and lung in many animals.

Aflatoxins and ochratoxins have been found in milk, meat and eggs. This is a particular concern for human health in developing countries where monitoring is not a routine or regular procedure, and where animals are likely to consume high levels of these toxins in feed.

Penicillium species are also responsible for producing two toxins, penitrem-A and roquefortine C, that induce tremors. These symptoms have been mostly observed in dogs that have been allowed to roam around trash and composting mouldy food, especially dairy products. Low quantities of the toxins may cause tremors which last for several days but larger doses may cause seizures and result in death. Other animals that have been affected by these mycotoxins include cattle, sheep, rabbits, poultry and rodents.

It is clear that mycotoxins can have serious repercussions for the livestock industry. Even though our knowledge of the effects of many of the toxins is sketchy it is best to err on the safe side and prevent animals from ingesting mouldy grain and feed.

The following sections describe how we can avoid grain becoming contaminated with mould.

TABLE 2 SYMPTOMS OF MYCOTOXINS IN ANIMALS CONSUMING CONTAMINATED FEED

Mycotoxin	Fungi associated	Symptom/toxicology
Fumonisin	*Fusarium verticillioides (moniliforme), F. proliferatum*	Equine leukoencephalomalacia (ELEM), porcine pulmonary oedema, liver and kidney damage in other domestic animals, *(oesophagal cancer in humans: no proven causal link)*
Deoxynivalenol (DON or vomitoxin)	F. graminearium	Feed refusal, reduced weight gain, diarrhoea, vomiting, reduced reproductive performance, increased mortality, reduced egg or milk production, (nausea and headaches in humans)
Zearalenone	F. graminearium	Oestrogenic syndromes, mammary and vulvar swelling, uterine hypertrophy, infertility, increased blood clotting time, increased mortality, reduced growth, increased susceptibility to disease
Trichothecenes	*F. graminearium, F. culmorum, F. poae, , F. solani, F. nivale F. sporotrichioides, (T-2 toxin)*	Alimentary toxic aleukia (ATA), digestive disorders, reduced feed efficiency, reduced growth, bloody diarrhoea, reduced egg and milk productionnecrosis, haemorrhages, oral lesions in broiler chickens, increased blood clotting time, increased mortality.
Ochratoxins	*Penicillium verrucosum (temperate climates), Aspergillus ochraceus*	Porcine nephropathy, renal toxicity, immunosuppression, various symptoms in poultry
Citrinin	*Penicillium citrinum., Aspergillus sp.*	Kidney damage
Cyclopianzonic acid	*Penicillium cyclopium, P. commune, P. camembertii, Aspergillus flavus, A.versicolor*	Neurotoxin
Sterigmatocystin	*Aspergillus nidulans, A. versicolor*	Carcinogen, mutagen, affects liver
Ergot	*Claviceps purpurea*	Vertigo, staggers, convulsions, temporary posterior paralysis, and death. Decreased blood supply. Reduced growth, tail loss, reduced reproductive efficiency in pigs.
Patulin	Various	Depress immune system, carcinogen, neurotoxin, stomach irritant, nausea, vomiting, ulcers, haemorrhages
Aflatoxins	*Aspergillus flavus, A. parasiticus*	Liver necrosis, liver tumours. Reduced growth, depressed immune response, carcinogen;

How to take care of food and feed

PREVENT MOULD DAMAGE BEFORE HARVEST

It is essential that precautions are taken during the cultivation of the crop to prevent *Fusarium* in particular, and other moulds such as *Stenocarpella* and *Claviceps* from becoming established during the growing period.

There are various factors that influence the potential for pre-harvest fungi to develop, including the physiological and morphological state of the plant and climatic conditions. A plant that is not healthy is prone to infection by these parasitic fungi. In turn, the health of the plant is determined by its water and nutrient status and whether it is subject to other stress mechanisms, such as being attacked by pests.

Firstly, it is important to ensure that the seed used for planting is free from disease. Buying and planting certified seed is perhaps the best guarantee that the seed is disease free. However, not many farmers are able to afford certified seed, and usually resort to farm-saved seed, produced from the previous year's crop. Farm-saved seed will be safe to plant as long as it has not been infected whilst stored at the homestead. It is vital that such seed is free of pests and disease before planting, to ensure healthy, vigorous plants develop, i.e. those that are capable of withstanding attack during the growing season. Seed that is not free of infection will either not germinate or will produce weak plants that have a low threshold of resistance to pests and disease, and which will either succumb before a crop is produced, or will under yield.

Drought stress, caused by a lack of water, is known to facilitate attack by mould. Lack of water allows the plant to crack, and so opens passage ways through which fungal spores can enter. This can happen to the stem or to the head. Moulds can develop in the drying stems, which might be used for animal forage or hay, or in the grain, which will go to food or feed. Therefore, where irrigation systems function, farmers should always try to supplement local rainfall to avoid drought stress. If it is not practical to irrigate, plant and harvest as early as possible.

Good husbandry practices will generally help to fight against fungal invasion. It has become popular in recent years for farmers to practice zero or minimal tillage. This saves time and money, and where tractors or oxen are in short supply or where labour is difficult to hire, can save farmers and their families many days of tedious toil. However, these benefits have to be traded off against some negative effects. For example, without tillage, crop residues remain on the soil surface and these gradually deteriorate. These residues will harbour soil borne fungal spores, allowing them to over-winter, in time to infect the next crop. Similarly, without tillage these spores will remain in the surface layer of the soil in readiness to germinate.

Therefore, the benefits of minimal tillage have to be weighed up against the drawbacks. What is clear, though, is that with any minimum tillage operation, it is vital to keep the plot weed free and tidy whilst the crop is growing, to ensure the new plants avoid any potential infection arising from old vegetable material deteriorating in the vicinity.

Practising good plant husbandry, including weeding, will also help the plant fight against insect pests. Insect pests which damage the growing plant allow fungal spores openings through which to invade plant tissues. Thus action to reduce insect pest attack will keep fungal problems away. Thus in addition to practising good plant hygiene by keeping plots weed-free and tidy, insects must be kept at bay by using commercial insecticide applications or other recommended methods of control, such as botanical pesticides or biological control.

Actions must be taken to minimise the damage from *all* pests that attack the growing crop, not just insects. Rodents, such as common and Norwegian rats and the house mouse, must be excluded. This is often difficult to achieve but every effort must be made. Once again, good plant husbandry, keeping the area clean and free of plant matter, will reduce the risk of rodent damage by limiting the number of harbourages. Removing vegetable matter in this way will reduce the amount of food available to the rodent and it may look elsewhere for a food source.

If possible, crops should be rotated from one season to the next. Crops grown on the same plot in successive years have been shown to have a much higher level of mould infection than when they are rotated. Rotation prevents a mould that is well established on one type of plant from having access in the following season, making it less likely for infection to reoccur. This applies not only to moulds but to other pests, such as insects and nematodes, as well.

Plant stress may occur even if the water available is adequate. If the nutrient content of the soil is lacking then the growing plant will always be stressed. This will be seen when plants become misshapen and internal tissues may be exposed as the stem breaks open. Lack of adequate soil fertility can be overcome by the judicious application of organic or inorganic fertiliser. However, applying too much fertiliser will also put the plant under stress and make it a prime candidate for attack by insects and moulds. It is therefore essential that fertiliser application is timely and in the correct quantity.

Timing the production cycle is also key to obtaining a healthy crop at harvest. Planting must take place at the recommended time to avoid problems caused by the crop maturing too early or more particularly, too late, during periods of prolonged rainfall. If plants mature when the relative humidity is high or whilst it is raining they will be prone to invasion by *Fusarium*, as well as being subject to pre-harvest damage by storage insect pests, which themselves will help with the diffusion and multiplication of mould spores.

It is always advisable to plant seeds varieties that are pest resistant. Varieties with resistance to insects and to viral and bacterial disease are available and should be used where the opportunity arises. In Tanzania and Uganda in East Africa, for example, farmers are able to grow maize and sorghum varieties that are resistant to Maize Streak Virus, Sorghum Leaf Blight, Grey Leaf Spot and Striga. Of course, this is not always possible because seeds of this type are not always available to buy, either locally or nationally. Furthermore, these varieties are usually more expensive to cultivate than non-resistant varieties, and certainly more so than locally produced seed. Nevertheless, if farmers do have the opportunity and the financial wherewithal to buy and use resistant varieties they should do so.

Cultivar differences exist for many pre-harvest factors including pest resistance, drought tolerance, stalk strength and husk cover. There are significant differences in keeping qualities between different crop varieties. 'Local' varieties of maize, which have small cobs with tight, elongated husks that completely enclose the ker-

FIGURE 7 **Tight husk of local maize variety**

nels, are relatively resistant to insect attack and therefore less susceptible to fungi. The sheathing leaves provide a physical barrier to entry. Composite and more particularly, hybrid varieties tend to have much poorer husk cover, the leaves fail to fully enclose the larger cobs of these varieties. Consequently, they are much more prone to damage by insects and moulds and extra care must be taken during crop maturation and drying to ensure that these varieties are not invaded by pests and diseases (in practice, without artificial drying, this is difficult to achieve where rains are prolonged). Conversely, the tight husks of small local varieties restrict water loss and slow drying.

The absence of a protective sheaf makes sorghums and millets more susceptible than maize. However, these crops do vary in their susceptibility due to the size and chemical constituents of the grain. Larger, soft grain varieties are more susceptible than those with small, hard grains, and the phenolic content of maize and sorghum is directly correlated with resistance to pest damage; red and brown sorghum is less susceptible than white. Sorghum heads that are open are more easily damaged by birds and so more prone to fungal invasion. Small grain millet is much less damaged by insects than larger sorghum grains and both are less susceptible than maize.

Unfortunately, there are few cereal varieties that are resistant to fungal attack and none have been developed that will resist *Aspergillus*. Varieties that will resist other moulds have mostly been developed for use in cooler, temperate climates and will not be of practical use to most tropical and sub-tropical farmers. These resistant varieties include, for example, a wheat variety developed in the US that is resistant to Fusarium Head Blight (not yet commercially available).

There are no *Claviceps purpurea* (ergot) resistant varieties but as sclerotia cannot survive for more than one winter in the soil, planting a non-susceptible crop in infected fields for two years will clear them out. The areas surrounding infected fields should also be cleared of susceptible plants. In severe cases, deep ploughing to bury sclerotia is also helpful.

BOX 3 ACTION TO TAKE BEFORE HARVEST TO REDUCE THE RISK OF MOULD CONTAMINATION AND MYCOTOXIN PRODUCTION

- use certified seed or ensure seed is free of fungal, bacterial or viral infection;
- avoid drought stress – irrigate if possible;
- sow seed as early as possible so that crop matures early;
- if practising minimum or zero tillage remove crop residues;
- weed regularly;
- control insect, mammal, bird and virus pests;
- rotate crops;
- avoid nutrient stress – apply appropriate amount of organic or inorganic fertiliser;
- plant resistant varieties where these are available.

PREVENT MOULD DAMAGE DURING HARVEST

The two most important factors that influence mould growth once the plant is mature are water activity and physical damage. When the maize cob, sorghum head, cowpea pod and groundnut pod have begun to dry in the field it is essential to dry them down to a safe moisture content as quickly as possible, and to do so with as much care as is practicable.

Rapid drying requires that harvesting be undertaken as soon as possible. However, delays to harvesting may be unavoidable if, for example, it is still raining; harvesting may then limit the rate of drying if the crop has to be kept in a heap which restricts aeration.

The decision to harvest must take into account several factors including:

- the prevailing climate,
- the likelihood of insect, rodent and bird damage, which might occur the longer the crop remains in the field; and
- the availability of drying facilities at the homestead or local storage complex after the crop is transferred from the field.

Where a farmer has access to drying facilities, for example at a buying centre, early, rapid harvesting and transporting of grain to the dryer within a day or two will be ideal. By this means, the crop can be dried to a safe storage moisture content and so mould attack and mycotoxin production can be avoided.

Most farmers will not have access to artificial drying facilities or will not be able to afford to use them. Nevertheless, whatever their circumstance, farmers must enable the crop to dry as rapidly as possible. The rate of drying will depend on harvesting practices, which vary greatly. Some producers simply leave the crop standing in the field for several months, especially if weather is dry and hot. In this case, ambient air movements and temperatures are sufficient to continually dry the crop down without the risk of moulds developing. There is a risk, of course, if unexpected rainfall occurs during this period, that moulds can develop.

The rate of drying in the field depends on the crop itself - maize kernels enclosed in sheathing leaves will dry more slowly than open sorghum heads – and on how it is treated. In many countries, it is common practice to bend the heads over on the standing plant as early as possible to speed drying. Farmers also cut cereals at the base of the stalk and pile the stalks with cobs or heads into conical bundles, known as stooks. This allows the field to be ploughed whilst the soil is still moist and soft but the tightly formed stooks may inhibit ventilation and slow drying. Some farmers lay bundles of stalks on the soil, and this is dangerous as it creates an opportunity for fungal spores in the soil to invade the grain. This happens with legume crops in particular, and has been a major cause of groundnuts becoming infected with *Aspergillus*. This problem can be avoided by placing a barrier between the crop and the soil, for example a layer of millet or sorghum stalks. Better still, place the crop on a platform raised above the ground.

Care must be taken not only to dry the cereal or pulse crop effectively but also the same practices must be used for drying stover, straws and haulms that are to be used as animal feed. Crop residues left lying in the field will dry slowly and are likely to be infected with mould spores. They should be placed on platforms so that there is no chance of contact with the soil, or tied together in upright heaps or stooks.

Still, it is better for the farmer to remove the crop from the field as quickly as possible and to dry it at the homestead.

FIGURE 8 **Maize stook**

BOX 4 ACTION TO TAKE DURING HARVEST TO REDUCE THE RISK OF MOULD CONTAMINATION AND MYCOTOXIN PRODUCTION

- harvest as quickly as possible
- avoid field drying
- transport the crop to the homestead as soon as possible
- if lack of labour or time prevents removal from field then dry on platforms raised above ground (if climate is hot and dry crop can be left to stand in field or cut and tied into stooks) to dry
- bundles of stover should also be placed on platforms to dry and not left to lie on the soil

Harvesting must be rapid but care must be taken to avoid damaging the crop. If the crop has been dried in the field then careless handling will not only result in grain shattering and weight loss, but will also cause grain damage and allow insect and fungal pests to invade. When harvesting with a tractor it is essential to ensure that the equipment is set up correctly to avoid grain breakage due to mechanical damage; this is especially important when using a tractor to thresh the crop.

Care must also be taken to ensure that silage is made under good anaerobic conditions with a low pH, to ensure that it remains free of mould and is safe to feed to livestock.

PREVENT MOULD DAMAGE AFTER HARVEST

Drying

Although drying begins before harvest it must be continued until the crop is put into store and, even then, further drying may still be necessary. Cereals harvested on the stalk or pulses in pods can be transported to the home and placed on platforms or frames to continue the drying process. Platforms must be raised so the floor is at least 0.7 m above the ground, the legs fitted with metal guards to prevent rodent access, and treated if necessary, to prevent termite attack.

The platform may be converted into a drying and storage crib having walls made from wire netting, bamboo, sisal poles, sawn timber or similar materials, which allow free movement of air across and through the crop. Maize cobs, sorghum or millet heads and legumes in shell should be less than 0.5 m in depth in the drying crib so that air movement is not impeded and drying restricted. The structure itself should be

FIGURE 9 A drying platform (a), drying frame (b) and drying crib (c)

(a) (b) (c)

no more than 1.5 m wide, and erected so that the long sides traverse the prevailing wind to allow a good flow of air.

Farmers often build these platforms above a cooking fire. This has the advantage of speeding the drying process and may also help to prevent pest damage whilst the crop is relatively exposed.

Drying crops spread thinly over the floor, whether on compacted soil or a concrete plinth, is acceptable if it is clean and well swept. Better still, a sheet of polythene or a tarpaulin-preferably black in colour to better absorb the sun's heat- or a layer of empty sacks, should be placed on the floor on which the grain can be spread. This will allow the crop to be quickly moved under cover when rain is imminent. Care must be taken to prevent the grain from being exposed to dust and other contaminants in the air, and to insects, rodents and browsing livestock.

FIGURE 10 A solar dryer being used for drying chilli peppers

Relying on ambient climatic conditions when the crop is spread out on the floor, tied to a frame, placed on a platform or in a crib may not dry the crop fast enough to prevent mould damage from occurring; such drying may take a month or more in high relative humidities. Only the use of a purpose built dryer will achieve the rate of drying required. The simplest are solar dryers, which collect the sun's heat inside a specially designed chamber that has adequate ventilation for removal of moist air. The most basic of these are natural convection dryers in which the airflow is induced by thermal gradients. These can be relatively cheap and simple to construct and are appropriate for use by individuals or small groups of farmers.

A second type of solar dryer is one in which a fan is used to force air through a solar collector and the grain. This type can handle larger quantities of grain, which can be loaded onto trays and placed in layers within the dryer.

Some commercial farmers and farmer groups may have access to larger-scale dryers operated by marketing boards, grain buying companies and millers and feed compounders. The opportunity to use such facilities should be taken, especially in areas where the prevailing relative humidity remains high through much of the year, for example, in much of West Africa and South East Asia.

Threshing, shelling and winnowing

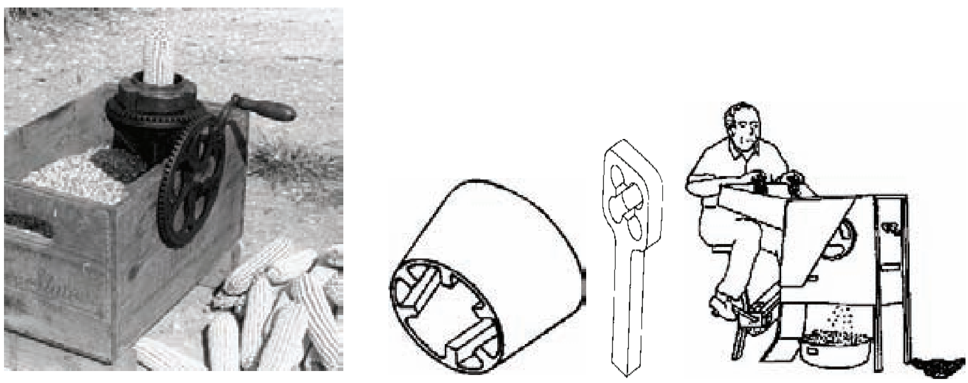
Careful handling of the crop once it has dried can contribute significantly to the avoidance of mould damage once the grain is put into store.

In may parts of the world farmers and their families thresh or shell cereals and grain legumes by beating the crop, either loose or placed inside a sack, with a stick. This method is quick and simple but does cause heavy damage to the grain, especially of larger kernels of maize, beans and groundnut. It is also common for small grain millets to be threshed in a mortar and pestle, a method that produces a large proportion of brokens. Storing broken grains may result in heavy mould infection and mycotoxin production especially in periods of wet weather or high humidity; where the relative humidity remains low for long periods, such as in Central and Southern Africa, mould attack may not occur. Furthermore, where grains are consumed quickly after threshing the presence of brokens will not matter.

Farmers often use their hands to shell maize, breaking grains from the cob between thumb and forefinger. Although this method can be laborious - it is usually a social occasion allowing family and friends to meet and talk – damage to the kernels is usually low and the quality remains good. Maize can also be shelled using a variety of hand-held gadgets or pedal-operated mechanical devices. All of these tend to produce good quality grain but are relatively scarce in farming communities. To work effectively, all these methods require the grain to be sufficiently dry for safe storage; if grain is wet threshing is difficult to undertake.

Commercial farmers may use tractor-driven shellers and threshers. Even these can result in substantial quantities of brokens if they are not correctly calibrated or set up, a common occurrence when farmers are not thoroughly conversant with a machine they may only have on hire.

FIGURE 11 Various hand-held, bicycle operated and mechanical shellers



Storage

Unthreshed produce

Once grain has been dried sufficiently it may be threshed before storage or left unthreshed. Small quantities of cereals on the head or grain legumes in pods may be stored loose within the house or store, on the floor, in containers such as used oil drums, in woven cribs or baskets, or on top of or beneath the roof.

It is bad practice to place food commodities directly onto an earthen floor as there is nothing to prevent moisture in the soil migrating into the grains. This will lead to mould and mycotoxin contamination. The same will apply even if the floor is concrete as it is still porous. However, if a water barrier, such as a polythene sheet, has been laid above or inserted into the concrete then the crop will remain dry.

Unthreshed commodities remain exposed to insect and rodent pests unless protective measures are introduced. For insects, this requires the application of either a conventional insecticide, such as Actellic 2% dust, or more traditional

FIGURE 12 **Rodent in a break-back trap**

protectants such as those derived from plants, e.g. 'neem kernel powder'. Commodities can be stored in the loft or roof space or on a platform above a fire. The fire will not only dry the grain but the heat and smoke may kill insects or drive them out of the grain. However, this is not always effective, as some insects, such as *Prostephanus truncatus*, the larger grain borer, can tolerate these conditions.

Against rodents, farmers storing crops in their house may, by themselves, provide sufficient disturbance to keep rodents at bay. Storage elsewhere may need more specific protective measures, such as baffles on the support poles of cribs, laying break-back traps, keeping the areas around stores clean and free of debris, and perhaps acquiring a cat. Rodent control is difficult to achieve because of the ability of the animals to avoid unfamiliar situations. The use of synthetic rodenticides on small-scale farms is not appropriate because of the inherent toxicity of most of the products marketed; their use would put at risk young family members, domestic animals and browsing livestock.

Threshed produce

Increasingly, farmers are storing cereals and pulses as loose grain. Grain can be stored in traditional or improved woven structures, in metal tanks or drums, in plastic containers or sacks. Plastic and metal containers sold for water storage make ideal grain stores but the grain must be very dry to prevent mould growth and mycotoxin production.

Farm storage structures may be relatively simple cylindrical, tightly woven baskets that may or may not be plastered with mud and/or cow dung; cylindrical or oblong mud brick stores; burnt brick structures with or without compartments, or ornate house-like structures. There is a wide range of storage designs and a variety of different materials from which they are fabricated, including sisal poles, tree bark, bamboo, twigs from various trees and grass twisted into rope; sawn timber; grass thatch and corrugated iron are used in roof construction. Designs vary in shape, diameter, height, longevity, cost, and in the skill required for construction.

Such storage structures must have:

- A roof with a overhang, which is sufficient to take rain water away from the grain, and provide shade to reduce diurnal temperature fluctuations that might otherwise result in night time condensation and wetting of the contents. Grass thatch provides excellent insulation but requires regular repair and needs to be renewed every few years. Corrugated iron sheets are much more durable and any temperature fluctuation they create inside the store can be minimised by painting white the external surfaces of the sheets. Cement tiles are both durable and poor heat conductors so meet both needs but tend to be expensive.
- A support structure that raises the container above the ground to prevent moisture entry from the soil. If the supports are long enough, at least 1 m, then rodent baffles can be fitted. Supports are best made of burnt brick but mud bricks or wooden poles will do, as long as precautions against possible termite damage are put into place. Wooden poles can be protected against termites by using commercial insecticide such as ben-

FIGURE 13 Farm storage structures

diocarb or by soaking or dipping the pole in used engine oil.

- A method of accessing the commodity in the store; this is usually achieved by having an opening or door in the structure or by raising the roof.

The quality and type of materials used in construction will determine the stores longevity. Raising the store above the ground will also enable the area around it to be cleaned and inspected for signs of termites, storage insects and rodent activity. Stores made from woven materials can facilitate aeration as long as the weave is not too tight. During periods of rain, stores can be plastered with mud to restrict water entry; the mud plaster also helps to prevent theft by animals and humans.

In some counties, farmers store grain in underground pits. These provide excellent security against theft. However, because they are impervious to ambient conditions and are not able to be aerated, grain placed in such pits must be very dry in order to prevent mould developing. Even so, some air usually does penetrate around the door of the pit, and it is not uncommon for condensation to occur on the surface layers of the grain, which do then go mouldy. It is important for farmers to be aware that grain near the surface of pits may well be contaminated with mycotoxin even if there is no obvious sign of mould decay.

Increasingly, producers are storing grain in sacks. These may be woven polypropylene (WPP), sisal or jute. Sacks may be stored in drying cribs or other purpose built stores but are frequently kept inside the house to improve security. To avoid moisture migration into the grain, sacks should never be stacked directly onto the floor. They can be stood on polythene sheeting, or raised off the ground on poles. It is also advisable to ensure that a gap remains between the sacks and the walls so that they can be easily inspected and remedial actions taken if rodent or insect damage occurs.

Grain that is to be stored for several months, whether in a storage structure or in sacks, should be treated with insecticide to protect it against insects, which are the most common form of storage pests. This is best done by mixing the grain with a dilute insecticide dust, such as Actellic 2%, before the sacks or stores are filled. Insecticide is added and mixed in the same way as sand and cement are mixed to make concrete, a maximum of 50 kg being treated at one time. Dilute dust insecticides are cheap to buy and have the advantage of requiring no special equipment for application; a shovel is all that is needed.

In store

Grain can remain in store for a matter of days, months or for a year or more. Whilst in the store grain should be inspected regularly to ensure it remains in good condition and free from pest damage. Inspections should coincide with grain removals for food preparation, or when it is needed to brew beer, feed animals or removed for sale. Inspections should take place at least once a week.

The storage structure must also be inspected to ensure that it is in sound condition and has not sustained damage from browsing livestock and termites. Sacks must be inspected for holes made by rodents though which grain may be taken or spilt. The presence of rodents is often denoted by the presence of droppings on sack surfaces. The areas around the structures or stacks must be kept clean, swept and free of rubbish and other extraneous material to eliminate breeding sites. Sacks must be opened and grain examined for signs of mould growth and insect damage. Similarly, the contents of other structures must be observed with equal diligence.

FIGURE 14 Entrance to underground storage pit

Storing flour and compounded feed

The fine particles of flour are very attractive to water particles in the air. Dry flour stored for even very short periods will quickly become moist, the rate being dependent on the ambient conditions in which the sack is stored. Moist flour will allow fungal spores to germinate and very quickly a dense mycelium will become visible. Thus it is essential that flour is only stored for very short periods. However, small quantities can be kept safely in airtight plastic containers as long as the

FIGURE 15 Sacks of grain stored in the house raised off the floor on poles.

FIGURE 16 Mixing insecticide dust with grain for storage

flour fills the container, expelling the air inside; if the flour only partially fills the container then it could go mouldy.

Feed pellets similarly attract moisture so should only be stored for relatively short periods. Pellets are actually formed when water is added to them and this additional water is removed as the pellets cool down at the end of the process. If cooling is not fast the moisture present can permit mould development.

Flaked feed and other components that have a large surface area to weight ratio, such as wheat feed, bone meal and fish meal can all readily become mouldy if stored for too long, particularly in relatively humid conditions. Livestock keepers should only buy sufficient feed to last a maximum of 10 days; in some really hot humid countries even this period will be too long.

Silage and hay

Storage containers should be airtight. Mould problems only occur if silage is exposed to oxygen in air. This could happen at the periphery of the storage system, for example at the edges of plastic sheets used to cover the silage, especially if these are damaged in any way. Repairs must be made as quickly as possible and then the development of mould in aerobic conditions can be stopped.

More importantly, fungal spoilage can occur when silage is being fed out to livestock, as it is then constantly exposed to the air. Some spoilage at this time is, therefore, inevitable. However, to minimise this problem silage containers, pits and heaps should be kept relatively small so that they can be completely emptied in a relatively short time, 1-2 days. Thus it is better to have several small silage containers, which can be opened in sequence, rather than one large one that may result in significant spoilage.

The fungus *Penicillium roqueforti* has been identified as being the predominant fungus in different types of silage. This and other silage moulds, which include the *Aspergillus* and *Fusar-*

ium genera can be inhibited by additives that prevent aerobic conditions from occurring. Such additives include proprionic, benzoic and sorbic acids, and whilst commonly used in the developed world, are generally prohibitively expensive for use by small-scale farmers in the tropics.

Proprionic acid can similarly be used to inhibit mould growth in bales of hay whilst they are sweating and curing down by evaporation to safe moisture levels. Proprionic acid is sprayed onto the hay as it enters the baler and is commonly used in the developed world. Where hay is not baled but simply left as loose forage, mould development is restricted by simply allowing the hay to dry quickly.

DISPOSAL OF MYCOTOXIN CONTAMINATED GRAIN

Despite all precautions, it may happen that stored grain will become damaged by mould. It must then be assumed that the grain is also contaminated with mycotoxins.

If the farmer has plenty of grain in store, he can afford to lose a small quantity that has turned mouldy. Ideally, the farmer must discard

BOX 5 **ACTION TO TAKE AFTER HARVEST TO REDUCE THE RISK OF MOULD CONTAMINATION AND MYCOTOXIN PRODUCTION**

Drying

- Crop should be spread on a (black) polythene sheet, tarpaulin or empty sacks laid on the ground or on a concrete plinth.
- Unthreshed crop can be laid on platform or in ventilated crib to dry; cobs can also be tied in pairs and suspended from a vertical frame to dry.
- In wet or humid conditions crop should be artificially dried in a solar dryer.

Threshing, shelling , winnowing

- Handle crop carefully to avoid broken or damaged grain.
- Use hand or pedal operated threshers if possible.
- Avoid beating the crop with sticks as this creates lots of damage leading to mould development unless the grain is to be used quickly and not stored.

Storage

- Store unthreshed produce or grain in a suitable container which is raised above ground level. If the crop has to be stored on the ground ensure a suitable waterproof barrier is in place.
- Treat a crop that is to be stored for more than two months with a suitable grain protectant to prevent insect damage.
- Protect the crop against damage by rodents.
- External storage structures must have a good roof with suitable overhang to provide shade and to take away rain. They should be protected against rodents and termites. Access to the crop inside should be easily achieved by having an opening or door in the wall or a roof that can be raised.
- Sacks must be stored on a platform raised above the floor.
- Produce must be inspected regularly to ensure that it is free of mould, insect and rodent damage; if damage is present remedial treatment must be put into place.
- Flour and feed must only be stored for short periods to avoid mould development. Small quantities can be kept longer in airtight containers.

mouldy grain and any that is suspected of being contaminated with mycotoxins; this will include apparently clean grain that is in the vicinity of the mouldy produce. This grain should be burnt or buried.

Most farmers in the developing world, however, do not have a surplus they can afford to waste. It may well be absolutely necessary for the mouldy grain to be used, especially in times of sever food shortage. When this happens, mouldy and suspect grain must be diluted with a quantity of clean grain before it is used, the greater the dilution the better. Then this grain can be sold, used for brewing, or fed to animals.

If used as livestock feed it should be first fed to ruminants; ruminant microbes can detoxify some mycotoxins. Beef cattle should be fed before dairy cattle, and cattle fed before sheep and goats. Mature ruminants should be given the grain before growing and pregnant animals, and young stock should not be fed this grain if at all possible. Similarly, young chicks should not be fed contaminated grain or feed and mature birds should be fed before growing poultry. No suspected contaminated grain should be fed to ducks or turkeys as these are particularly susceptible.

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Mycotoxins are among the most potent causes of cancer. Ingestion through the diet can pose chronic health risks for both humans and livestock. Death may occur as a result of acute poisoning. Mycotoxins are chemicals produced by fungal moulds. These moulds grow during production, harvesting and storage of grain, pulses, nuts, roots and other crops.

This booklet is directed at the farm situation, providing advice that can be used to avoid mycotoxin contamination before food leaves the farm. The booklet describes what mycotoxins are, how they are produced and how to recognise signs of their presence. It provides advice to enable farmers to minimise the risk from mould contamination whilst the crop is growing, during harvest and through storage. Although aimed at farm situations, the booklet is intended to be used by extension personnel, both government and non-government employees, in their efforts to advise and assist the rural communities. A separate booklet addresses issues related to transport, marketing and urban consumption.