GOOD PRACTICES FOR ANIMAL FEED AND LIVESTOCK 2

training manual

MAINTAINING QUALITY OF FOOD AND FEED GRAIN THROUGH TRADE AND PROCESSING

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Preface

The grain produced by the farmer has a long journey to travel on its way to the consumer's plate or the animal's feed trough; it may be processed into value-added foods or feeds for consumption in urban or other areas that are remote from the site of production. There may be a long chain through which the crop will be transported, stored and processed, with accompanying losses in quality, quantity, nutrient content and monetary value at each stage. If these losses are allowed to occur and build up, there will be a significant loss in revenue for the producer and the end user. Therefore, no matter how many stages there are in the marketing chain, it is important that grain quality is maintained throughout the chain so that the end product fetches the best price possible, retains a high nutritive value, and appears attractive to buyers.

This booklet describes the causes of these potential problems and illustrates actions that should be undertaken to prevent or remedy them. Many of the solutions do not require technical methods or equipment, but do rely on attention to detail, perseverance and common sense. The booklet does not address problems that can, and do, occur on the farm; a separate booklet addresses on-farm situations. This account assumes that grain and grain products, including flour and animal feed, have reached the first point in the marketing chain after leaving the farm. The first point may be a small-scale trader who is buying directly from the farmer, or a middle-man. The situation of transit storage and long-term storage, such as would occur in hospitals, prisons and boarding schools is considered. Millers and feed compounders are also included. However, large-scale storage such as by marketing boards and private exporters who use silos and warehouses holding many thousands of tonnes of grain in central storage complexes is not included; large scale operations require addressing in a very specific manner not appropriate to smaller-scale organisations.

One of the problems in dealing with issues at this level of the marketing chain is that no one specific group or organisation has responsibility for providing advice to traders and millers. The booklet is not intended to be used solely by the ultimate beneficiaries themselves, though it may well be. It is intended to be used by anyone who is involved in providing practical advice to counteract the causes of deterioration of grain and grain products along the marketing chain. These may be pest control suppliers, retailers and wholesalers, extension personnel within and outside of government, staff of trading organisations including marketing boards, and trade unions.

Acknowledgements

I would like to thank the Natural Resources Institute UK for allowing me to reproduce photographs from its collection. The information is largely in the public domain. I have in particular referred to two text books for background material: 'Crop Post-Harvest Science and Technology. Volume 1: Principles and Practice' edited by Golob, P., Farrell, G and Orchard, J.E (2002), published by Blackwell Science, and World Food Programme Food Storage Manal (2003) ed. Walker, D. and Farrel, G.

Causes of deterioration

Grain at the time of harvest may be damaged by field infestations of insect, bird and rodents pests; fungal, viral and bacterial infection; or the ravages of flooding, high winds or drought. In essence, it is impossible to ensure that any harvested crop will be perfect. However, farmers should always strive to obtain the best crop they can, because this will ensure the best possible return on their investments and efforts. This grain will then be used to feed the family or, as is increasingly the case, sold for processing into value-added foods or feeds for consumption in urban or other areas that are remote from the site of production. There may be a long chain through which the crop will be transported, stored and processed before it reaches the consumer's plate or in the animal's feed trough, with accompanying losses in quality, quantity, nutrient content and monetary value at each stage. If these losses are allowed to occur and build up, there will be a significant loss in revenue for the producer and the end user. Therefore, no matter how many stages there are in the marketing chain, it is important that grain quality is maintained throughout the chain so that the end product fetches the best price possible, retains a high nutritive value, and appears attractive to buyers. This booklet describes processes by which grain quality and quantity can be maintained throughout this marketing chain.

The main causes of deterioration of grain and grain products are:

- *Physical factors*: wetting, heating, breakage, discoloration, contamination with foreign matter such as stones, rodent droppings, string;
- *Biological factors:* mould, insects, rodents, birds, goats;
- *Human factors:* theft, poor handling.

Physical factors affect food commodities particularly during transportation, although heat and moisture can also influence deterioration during storage. Biological factors predominate during storage and human factors occur throughout the marketing chain.

Losses can be substantial and result in a significant mark down in value. The commodity may be downgraded, deemed unfit for export, and thereby result in a significant loss of foreign exchange earnings. There may be a physical loss of weight, loss of seed viability, and a decrease in nutritive value - an important issue in much of the developing world where a large proportion of the population is undernourished.

LOSS OF QUALITY

Quality is difficult to define and to measure objectively, except in terms of monetary value. Traders and consumers purchasing or selling in the market place usually define quality in

TABLE 1 GRADE DEFINITIONS FOR MAIZE IN INDIA

Grade no.	Maximum limit of tolerance (%)					
	Foreign matter	Other food grains	Other varieties	Damaged grain	Immature grain	Weeviled grain
I	1.5	1.0	10.0	1.0	2.0	1.0
II	2.5	2.0	15.0	2.0	4.0	3.0
III	4.0	4.0	20.0	3.0	6.0	5.0
IV	4.0	5.0	20.0	5.0	6.0	10.0

Note: The moisture content must not exceed 12%. The grain must have uniform shape and colour.

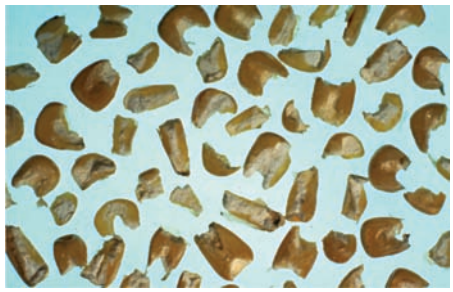
subjective terms. However, objective parameters may be established by governments introducing grading methods or by similar rules developed by autonomous trading organisations such as marketing boards, milling companies and grain exporters. Grain quality is usually assessed and grades assigned on the basis of appearance, shape, size and colour, although smell and uniformity will also be relevant. An example of the Indian standard for maize is shown in Table 1. Small scale traders and consumers will often assess on the basis of *fair average quality* (FAQ), which requires no quantitative measure of parameters but is a subjective assessment of whether the commodity meets a level which is generally acceptable to all.

Foreign matter content and contaminants are also factors that affect quality. These may include rodent droppings and hair, insect fragments and frass, weed seeds, parts of plants, soil, stones, glass and string. Contaminants that cannot be readily removed include urine, oils, pesticides, bacteria and viruses spread by rodents and mycotoxins. The higher the standard set by the consumer the greater will be the potential for loss; for example, produce to be sold in urban supermarkets will need to achieve a higher standard than the same produce sold at a local rural market.

LOSS OF QUANTITY

At primary selling points such as rural markets, grain is frequently sold by volume. This can cause problems when the unit of sale is not standardised. For example, in Southern Africa it is possible to fill a large jute sack with between 90 and 120 kg of grain depending on the sack's age, as older ones can be stretched more easily than new ones, and therefore have greater capacity . Furthermore, very dry grain will have a tendency to shrink and so occupy less volume for a given weight. It is also not unknown for sellers to add stones, dust and other extraneous matter to a sack to make up the volume.

FIGURE 1 **Rodent damaged maize**



Note: rodents feed on the germ and remove much of the protein and vitamins

Further along the marketing chain trading is carried out on the basis of weight. Then it is relatively easy to detect losses but these may not necessarily be due to a loss in food value. The loss may be due to a reduction in water content, which occurs during storage under conditions of low relative humidity; water is given up by relatively wet grain to the drier air.

Loss of food value is caused by pest damage, insects, rodents and birds feeding on grain, or by mould, yeast and bacterial infections. Pest attack will result in either whole grains being removed, as is frequently the case when rodents are prevalent, or parts of the grain being eaten *in situ*, commonly the result of insect infestations. Infections by fungi and bacteria frequently make the grain unappealing and should result in grain being discarded but, in practice, mouldy grain is often reserved for livestock or for brewing. It is however dangerous for mouldy grain to be used in this manner as often it contains mycotoxins that can have severe deleterious effects on the health of livestock.

NUTRITIONAL LOSS

Weight loss is a reflection of the overall food loss. Nutrient loss may be proportionately larger because of selective feeding by pests. Rodents and some insect moth larvae, e.g. *Ephestia* and *Plodia,* feed preferentially on the germ of the

grain, removing a large percentage of the protein and vitamin content. Weevils feed mainly on the endosperm and reduce the carbohydrate content. Many pests eat the bran of cereals, thereby reducing the vitamin content; book lice, *Liposcelis* spp., feed selectively on the germ and bran. High moisture content and the associated growth of micro-organisms also lead to changes in vitamin content of grain. Bruchids, such as the cowpea weevil, *Callosobruchus maculatus,* feed on the cotyledons of pulses and the loss of protein due to such infestation is serious, as up to 25% of the dry bean matter may be crude protein.

LOSS OF SEED VIABILITY

A reduction in seed germination may be caused by changes in temperature, moisture content, excessive respiration by kernels, light, insect infestation and by some methods of insect control. Attempts to control insects by subjecting grain to heat, either in a commercial dryer or over the kitchen fire in a farm may well affect the germination capability. This will not matter if the grain is designated for food or feed but will if some of it is earmarked for seed. Insects and rodents that selectively attack the germ will cause a greater loss of germination potential.

COMMERCIAL LOSS

This may occur as a direct consequence of the above, or indirectly as the cost of remedial measures required, for example the fumigation of insect damaged grain. Downgrading may be required and this will reduce the price to the seller; grain may be then designated for animal feed rather than for human food. Commercial losses may be expressed in terms of monetary loss, a loss of goodwill, and loss due to legal action. Commercial losses may affect inter-country trade: for example, after an outbreak of the destructive maize pest *Prostephanus truncatus* in Tanzania, Malawi and Somalia refused to accept Tanzanian maize because of the risk of the insect spreading to their countries.

These losses occur throughout the marketing chain. The following sections examine how and why they occur, and identify methods by which they can be reduced and quality and value maintained.

Factors affecting quality

The maintenance of quality of food or feed commodities depends upon the same principles and practices whether the quantities be small, perhaps a few tonnes, or whether national food reserves are to be considered. The suggestions and recommendations described will focus on quantities that might be stored by small to medium traders or millers, lots of up to 100 tonnes, but will be applicable whatever quantities are held.

The following factors will influence actions that might be necessary to take.

- The ***type of material*** being stored, whether it is cereal, pulse or oilseed; entire grain or milled products;
- The ***end use*** of the commodity, whether it be for animal feed or food for human consumption; commodities for local or national consumption or for export;
- The ***duration of storage***, i.e. transit, medium- or long-term;
- The ***climatic conditions*** to which the commodity was exposed before receipt; what conditions are likely to occur whilst commodities are held in storage;
- What ***pest management practices*** have been put into place before receipt; the cost benefit of pest control; what pest control materials and equipment are available; what training in pest management have staff received; what pest control services are locally available and their cost.

The type of commodity will determine which insect pests are likely to be present. Whole cereal grains, such as maize, wheat, rice and sorghum will be at risk particularly from weevils, including *Sitophilus zeamais* and *S. oryzae,* the maize and rice weevil respectively, and in Africa and South America from the larger grain borer, *Prostephanus truncatus.* Small grains will also be at risk from the lesser grain borer, *Rhyzopertha dominica*. Flour beetles such as *Tribolium castaneum,* the red flour beetle, infest flour and grain products and are generally not associated with entire grain unless it has sustained physical damage and is cracked or split. Moths, including *Cadra cautella* and *Plodia* and *Ephestia* species, also cause problems to milled grain and grain products. Figure 2 illustrates some of the major insect pests of stored grain and grain products found in the tropics and sub-tropics.

Pulses, beans, cowpea, gram, lentils etc. are attacked by a group of insects known as bruchids. Unlike the cereal pests, which do not discriminate between host type - the maize weevil will quite happily attack and develop on wheat – bruchids are quite specific in their host range. *Acanthoscelides obtectus,* the bean beetle, will only develop on the common bean and other members of the *Phaseolus* family. *Callosobruchus maculatus*, the cowpea weevil, will develop on cowpea and some grams but not on beans. Groundnuts in West Africa are at risk from *Caryedon serratus,* the groundnut beetle but nowhere else in the world.

The varietal type will also influence quality maintenance. Some varieties are much more susceptible to insect pests than others. Many soft hybrid maize varieties are extremely susceptible to insects and could lose up to 25% of their weight in just a few months in store if they are not protected with insecticides. Other maize varieties, especially those that originate through lines grown traditionally by farmers may well be relatively resistant to insect pests and only lose 1-2% by weight in a six-month period in store. Furthermore, grain that is unthreshed, such as paddy rice and groundnut in shell, is much

FIGURE 2 Some common tropical and sub-tropical storage insect pests of grain and grain products

Acanthoscelides obtectus
bean beetle

Callosobruchus maculatus
cowpea beetle

Sitophilus sp. weevils

Trogoderma granarium
Khapra beetle, larva and adult

Tribolium castaneum
red flour beetle

Ephestia sp.
tropical warehouse moth

less susceptible to insects than threshed grain, white or brown rice and groundnut kernels or redskins.

Milled commodities do not keep as well as intact grain. Flours, which consist of relatively finely divided particles, are able to absorb water from the air much more readily than whole grains. They are then prone to infection by *Aspergillus* and *Penicillium* moulds, which are able to produce mycotoxins such as aflatoxin and ochratoxin. Furthermore, these finely divided flour particles are much more easily oxidised by oxygen in the air. This is particularly important in feed that has a high fat content, such as fish meal or cotton seed cake, as the fat is converted into free fatty acids producing rancid and noxious odours. Therefore, to avoid these problems it is important not to store finished flour and feed for long periods.

The end use of the commodity will also influence how it is managed in store. Commodities that are designated for animal feed are generally of inferior quality to that used for human food. This should not be the case as livestock thrives on good quality feed although it can tolerate feed of poorer quality. However, frequently this attitude leads to livestock being given poor if not toxic feed, which may then suffer the consequences of disease and perhaps death. It is not uncommon, for example, for mouldy grain to be down-graded for animal feed when it really ought to be discarded and destroyed; sometimes it is used in brewing. A classic example of animals suffering from inferior feed was demonstrated in the UK in the 1960s when thousands of turkeys died as a result of eating aflatoxin contaminated groundnut meal.

Commodities that are designated for export require a higher level of management than those to be sold internally. Importing countries and organisations, such as the European Union, lay down stringent restrictions on imported food commodities. For example, to export cereals to the EU the grain must have less than 2 µg/kg of aflatoxin B1, less than 1 mg/kg of the insecticide deltamethrin and less than 0.03 mg/kg of the fungicide imazalil. Many countries will require imports to be accompanied by a phytosanitary certificate, which guarantees that the commodity is free of live insects, contains only a minimum of foreign matter and has chemical residues below specified limits. If these conditions are not adhered to the consignment may be rejected or the exporters may be forced to fumigate the consignment at their own expense. It is essential, therefore, that commodities designated for export remain free from all contamination.

Grain that is only in transit, perhaps in store for up to a month or so, will not be subject to the same infestation pressure as grain to be kept for six months or more. **The duration of storage** will, therefore, influence the degradation of the commodity and what management practices will be needed to rectify any potential problems. The life cycle of insect pest species in the tropics and sub-tropics takes about a month. If the commodity is only to be stored for a short period and is uninfested or very lightly infested on intake, it would not be economic to undertake any pest control whilst it remains in transit. However, in six months this very light infestation could become severe. Then it will be necessary to undertake fumigation and/or spraying with contact insecticide to restrict the damage.

Climate will play a very important role in determining what happens to a commodity in store. In hot, humid conditions food commodities will deteriorate rapidly. Moulds require the relative humidity to be above 80% for optimum growth and for insects this is 70%. For both types of organisms, increases in temperature to 27-32°C will enable the maximum rate of reproduction to be achieved and so maximise the damage that they can inflict. Good storage conditions in high humidities are very difficult to achieve and to enable commodities to be kept for more than a month will require artificial aeration, ventilation systems or refrigeration, methods generally

unavailable or too expensive for small to medium trader enterprises in the developing world. Similarly, methods to reduce temperatures in stores are also difficult to put into practice. As a result, in the tropics it is not possible to keep grain or grain products for very long in one location, and the commodity must pass rapidly along the marketing chain so that the consumer has access to a good quality product.

In areas where the relative humidity is less than 70% problems created by moulds and insects are not as severe, although some species are adapted to these less optimal conditions. For example, the Khapra beetle, *Trogoderma granarium,* develops best at 35°C and is able to grow at a relative humidity as low as 2%. This beetle pest is particularly prevalent in the Middle East, Asia and Africa and is a proscribed, quarantinable pest where found outside its normal range. It goes into diapause in adverse conditions and so is extremely difficult to control with insecticides.

Generally, it is possible to store grain for longer periods in dryer conditions without fear of deterioration and it is possible for this period to be extended for as long as two years with appropriate management. Nevertheless, pests are still able to operate in dryer, cooler climes so that good management needs to be maintained.

At intake, grains will often be infested with insects or may even show signs of mould contamination. Mouldy grain may need to be dried in order to prevent the mould from spreading. If insects are present then the grain may not have been treated with insecticide, the effects of the treatment may have worn off over time, or the treatment was ineffective (it may have been badly applied; it may have been old and under strength; it may have been fake). If insects are absent it is essential to know whether the commodity has been treated before receipt so that duplication of treatment can be avoided. It may be that the consignment has not been treated but that previous good management has enabled it to be kept free of pests. Even if this is the case it cannot be guaranteed that even with continued good management it will remain pest free without treatment.

It is therefore essential to apply the appropriate **pest management** initiatives to fit the circumstances. Disinfestation is best achieved by fumigation with phosphine gas. This treatment has the advantage of requiring very little application equipment but, to be effective and safe, knowledge of the correct procedures is essential. Thus trained personnel only should be allowed to conduct fumigation.

Treatments to protect grain against infestation can be achieved with liquid contact insecticides. However, these need to be applied to the grain with a sprayer and, once a sack has been filled, are difficult to apply without emptying the sack. Spray applications to sack surfaces are not recommended because insects can penetrate sack fabric very quickly and avoid picking up a lethal dose of the protectant. Because of the awkwardness of using liquid protectants the trader may chose, instead, to fumigate at regular intervals to keep the infestation pressure at negligible levels. This works where large quantities of grain or grain products are to be stored for long periods, but for short periods and with small quantities this may be uneconomic.

If the trader or miller does not have the expertise to carry out pest control operations, there are usually private sector companies available to fill this role. Using such expertise increases the cost of storage and may not guarantee that good practice is implemented. There are many charlatans involved in the pest control industry and it is not uncommon for them to underdose, use the wrong chemicals, apply the chemicals with inappropriate equipment or even not treat the grain at all. In southern Tanzania it has been know for a company to carry out a 'fumigation' by spraying only the outside surfaces of a stack of bags, and then the spray contained no insecticide but just water!

It has been common practice to spray the walls and floor of stores with contact insecticides to provide residual protection against insects. However, in most environments in the tropics and sub-tropics such treatments only persist for two weeks or so and would then have to be repeated. This would not be cost effective and such practices are no longer recommended. However, if the conventional insecticide is replaced with a diatomaceous earth (DE), the persistency of the treatment is much longer and much more effective. It is still very uncommon for DEs to be used in this way as they are not widely available and they are not easy to apply.

Before applying pest control procedures the store owner must estimate the cost-benefit of the treatment. Decisions regarding treatment must take into account the equipment needed and the level of competence of the staff who would undertake the procedures. As a last resort, if external contractors are employed they must adhere rigidly to requirements and specifications established by the store or mill owner.

Creating an enabling environment

GOOD HUSBANDRY

The essence of minimising losses is to ensure that the rail wagon, truck, store or mill are clean and in good condition. It is essential that good hygiene is practised and 'equipment' well maintained.

Dirt and dust help pests to survive. They provide food for insects and rodents, and because they absorb moisture from the air they can cause the moisture content of grain and feed to increase and lead to mould and mycotoxin development. Dirt and dust will also interfere with the action of any pest control treatment and in particular, will reduce the effectiveness of any solid formulations of insecticide that are applied.

So the truck, container or store must be swept regularly. But this is not enough. Pests hide in places that are difficult to access. They live in heaps of empty sacks or in piles of old, disused boxes and similar containers. Rats often hide in rubbish, which accumulates against the walls of stores, either inside or outside the store (Figure 3). They also hide at the back of grain stacks, especially if the sacks are leaning against or are close to a wall.

FIGURE 3 **Sacks piled up against store make excellent harbourages for rodents and insects**

It is therefore absolutely essential that these obstructions are removed from around the store and from sidings where rail trucks are left. The ground must be kept free of vegetation. Heaps of empty sacks should be removed from the main grain or feed store and kept in a separate area, as should pesticides and tools. If sacks have to be stored in the main store they should be moved frequently so that the area can be cleaned. Any rubbish that collects must be removed and burnt, buried or taken away for disposal.

Cleanliness will be helped if the store is in good condition. A badly repaired and maintained store or freight container will leak when it rains and may result in the grain becoming wet and then mouldy. If rain entering a store comes into contact with aluminium phosphide tablets during a fumigation it is quite possible that the tablets will ignite and cause a fire. An accident of this nature occurred in Mpanda in Tanzania in 1985 when half of the store building fabric (concrete) and many thousands of tons of maize and cassava that were being fumigated were destroyed.

Holes in the walls and doors will allow rodents and birds to enter. Cracks and crevices in the fabric of buildings will allow dust to accumulate and will provide harbourages for insects. Walls and floors must be repaired or made good where necessary. Trucks must not be permitted to be driven inside a store if the floor has not been designed to take the weight as it will crack and break up.

Machinery in flour and feed mills must be kept swept and brushed regularly and routinely. At frequent intervals, areas in buildings must be cleaned to remove waste from machinery, especially where access is difficult. Flour beetles, which feed especially on milled cereal products, are able to hide and accumulate in and around milling machinery, conveyors and hoppers that

FIGURE 4 **Badly broken floor allows dust and insects to accumulate**

are not easily inspected and cleaned. Where this is the case it may be necessary to shut down the building for a period to carry out a whole building fumigation. This will necessitate either completely enclosing the building within a fumigation sheet, possible if the building is small, or more commonly, sealing it so that it is gas tight. Sealing doors, windows and ventilators to make the building gas tight is usually very difficult to achieve, especially in developing counties where the mill has not been purpose built. It is usually more appropriate to clean the building as thoroughly as possible and then to spray the fabric with a synthetic contact insecticide; any commodity, flour or feed, can then be treated quite separately.

Open trucks and rail wagons should be covered with tarpaulins when carrying grain or grain products to prevent wetting by rain, access by pests and theft.

New sacks are often reserved for high quality products such as coffee and cocoa, whereas second-hand sacks are used for carrying cereals, pulses and animal feed. Sacks may be reused several times and with each occasion the fabric deteriorates further. Woven polypropylene sacks are particularly vulnerable and should not be used more than three times. Sacks should be repaired, and stitched as necessary between use. Empty sacks can also provide hiding places for insects and should be fumigated, sprayed with a contact insecticide spray or boiled in water before use. Boiling sacks is convenient when small numbers are involved, perhaps an amount that would be handled by a small trader. This method is cheap and environmentally neutral – assuming there is no shortage of water – but the sacks will need to dry thoroughly before use.

STOCK MANAGEMENT

Stacks

Store keepers must be able to make plans and decisions regarding the management practices to be introduced into the store, mill or godown. To achieve this it is essential that the quality of the commodities be continually assessed by inspecting them at regular intervals. Inspection will only be effective if there is access to as much of the stock as is possible. Of course, it is not practical to break down stacks to scrutinise bags kept in the middle of the stack, but it should be possible to view the commodity at all sides of a stack and in the uppermost layers.

Bag stacks should be built 1 m clear of all walls, buttresses and roof supports. If more than one stack is built the gap between stacks should also be 1 m. The tops of stacks should be clear of the roof and roof supports so that it is possible for a person to pass easily around all sides and over the top of each stack. This space is essential not only for inspection but also for fumigation or other pest control work.

Grain and grain products in jute, hessian or woven polypropylene sacks should not be stacked directly on the floor. They should be stacked on a moisture-proof floor covering, such as polythene sheeting, or on dunnage such as wooden pallets, poles or timber. Stacks must be built in an orderly manner that allows inspection. Badly built stacks, or ones that are too high, may collapse and injure people, causing damage to the commodity or to the fabric of the store (Figure 5). Stacking against walls will prevent inspection and may cause structural damage to the walls.

FIGURE 5 High stacks

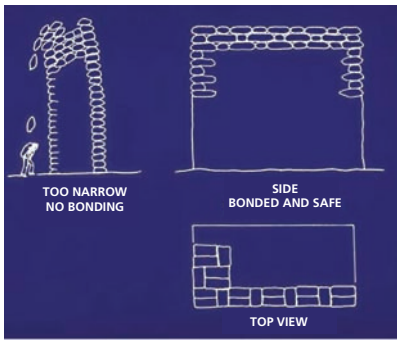


FIGURE 6 Main factors in choosing a stacking pattern

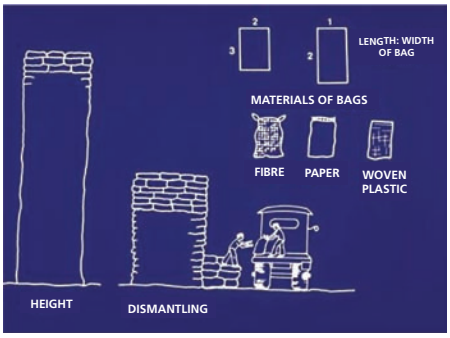


FIGURE 7 One type of continuous bonded stack pattern

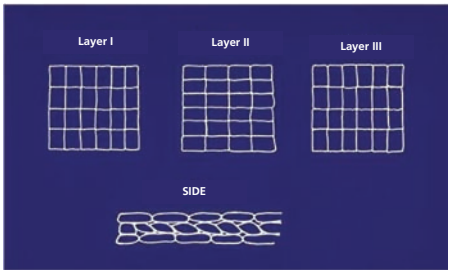
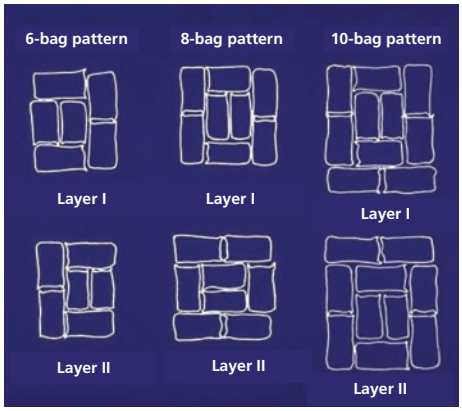


FIGURE 8 Choosing a stack pattern



Stacks in contact with the roof may cause solar heat to be transmitted to the commodity.

Stacks may be built up in many different patterns (Figure 6). Larger stacks, which are completely bonded, may utilise the basic 3 or 5 bag design as shown in Figure 7. Smaller stacks are better constructed with a larger basic unit of 8 or 10 bags as shown in Figure 8. The pattern used to construct the stack will be determined by the size of the sacks themselves, especially the ratio of length to width, the overall stability required and ease of dismantling (Figure 9). Stacks built with a 3-bag basic unit will be quick to dismantle; one side can be removed whilst leaving the remainder intact, but are relatively unstable.

To be built safely, high stacks must have a sufficiently large number of bags to be stacked; the stack must be well bonded. The more bags there are in a stacking pattern the better should be the bonding and stability.

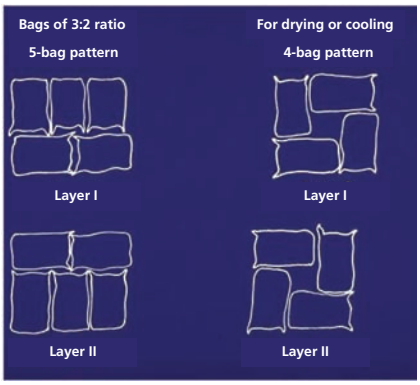
The main factors that influence the choice of a stacking pattern are:

- Height of the stack
- Ease of dismantling
- Ratio of length to width of bags
- Material the bags are made of (fibre, paper, WPP)

A stacking pattern with great stability is one in which each bag in each layer is bonded into neighbouring bags so that there are no continuous vertical sacks or divisions between sacks.

The pattern chosen will be a compromise

FIGURE 9 Special stacking patterns



between safety and convenience in stacking and dismantling. To increase safety, patterns of 6, 8 or 10 bags can be used, but only if the ratio of bag length to width is 2:1.

If the ratio of the length to width of the bags is 3:2 (not 2:1) then the 5 – bag pattern can be used. If the bag requires cooling or drying then the 4 – bag pattern will be better.

Paper and polypropylene sacks are more difficult to stack properly than jute sacks because there is less friction between them. Corners are the least stable areas of stacks and care must be taken to ensure they are safe. It is better not to have vertical sides but rather to have sides sloping inwards from the base upwards, this improves stability. Such a design will also facilitate access to the top of the stack.

If space allows, it is better to keep commodities separated in different stacks, as it is to keep different types of sacks or containers separated.

Inspection

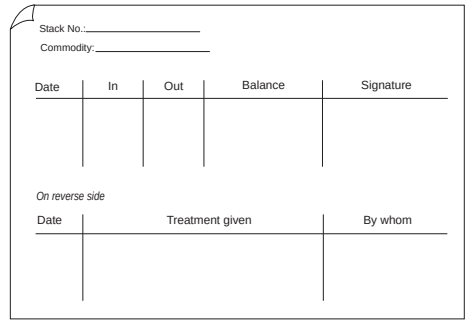
The purpose of inspection is to gather information about the store and its contents so that decisions can be made regarding procedures needed for quality maintenance. In essence, inspecting will allow the storekeeper to decide if and when to carry out pest control. It will also make the manager aware of the progress of the commodity whilst in store, and its shelf life. Inspection must be accompanied by effective record keeping so that the history of the commodity can be followed. Record keeping will inform the storekeeper of when the commodity was received and what pest management practices have been carried out. Record cards must be attached directly to the stack to avoid any possible ambiguity. It is good practise to keep a record card even if only one small stack is in store as this will enable the owner to remember details about the commodity. Figure 10 shows an example of a stack record card and inspection report.

Inspections must be done regularly and not less than once a week, irrespective of the size of the store or of its contents. They should include a complete walk around the store both inside and outside, around the stock, including food and non-food items. Where appropriate, a torch should be used to examine dark areas and those in shadow, gaps between stacks and between bags.

The inspector must look carefully for:

- signs of pest infestation, including live insects, rodent droppings, rodent urine trails;
- dampness;
- mould damage;
- spillage;
- contamination of sacks by foreign matter such as oil, fertiliser, pesticide;

FIGURE 10 Stack record card



- roof leaks and other structural faults;
- theft or other security problems.

Insects accumulate in cracks and crevices, along sack stitching and where sack surfaces make contact. If the presence of insects is suspected in a sack this can be confirmed by agitating the bag, when adults will move to the upper surfaces. If the storekeeper has access to a sampling spear, this can be used to collect samples from a number of sacks to check whether insects are present. The condition of pest control measures such as rodent bait traps and proofing which might be disturbed by loading and unloading, should be noted and rectified if necessary. Assessments of fumigation and/or contact insecticide application should be made. Any structural damage should be made good as soon as possible.

Rodents can leave many different signs of their presence. Many species prefer to use familiar, safe routes when moving around so that they repeatedly run across the same ground compacting it and leaving it dust-free. As they move rodents leave behind greasy smears from their fur as they brush against surfaces. The damage caused by biting can also be easily recognised; rodents tend to remove the germ from maize so creating a half-moon shaped cavity in maize grain. Similarly, burrows or holes are also indicative of rodents gaining access to particular areas. Rodent urine can be often spotted when it forms pillars as the animals frequently urinate on the same spot. The presence of rodents can be detected by footprints left in a fine sprinkling of flour over the sack surfaces. Perhaps the most reliable and simplest way to detect their presence is to look for droppings. Figure 11 illustrates some of the signs to look for when inspecting for rodents.

FIGURE 11 **Signs of the presence of rodents**

droppings

damaged box

damaged sack

urine pillars

footprints

damage to structures

damage to cable

Transportation

Losses that arise during transportation occur mainly due to damage to the packaging, such as tears or rips in woven polypropylene sacking, resulting in spillage. For longer haul carriage, for example by rail or lorry to distant markets, other problems may occur including: water penetration or wetting and subsequent mould damage and mycotoxin contamination; insect or rodent pest infestation; changes due to the micro-climate as a result of moving grain from cool, high altitude to lowland, humid altitude; accidental contamination.

Care of grain must be of paramount importance no matter what type of transport system is used. Even the largest and most sophisticated means of transport, such as a ship bulk carrier, will require human intervention to make sure that grain quality does not suffer during the voyage or journey.

The most basic method of transport from farm to market is the head load. Women regularly carry water, fuel and grain on their heads. Although grain may well be exposed to the elements during carriage, the short duration of journeys means that little if any change in quality is experienced. However, if this head load is interspersed with travel on a bus or train then problems may occur particularly due to spillage.

Less arduous methods of delivering grain from the farm use animal or motor driven carts or more. Oxen are used in many parts of the world to pull carts, which may contain 2 tonnes or more of grain in sacks. Replacing the oxen with a motor driven vehicle such as a tractor will enable the load to be increased. However, both types of transport are relatively slow and only allow short journeys to be undertaken.

The short journeys made in the transport so far described do not allow time for biological deterioration to take place. However, once trucks

FIGURE 12 **Woman with head load of maize cobs on the way to market**

FIGURE 13 **Ox cart (a) and (b) motor driven cart**

(a)

(b)

are used to transport grain, journeys can be much longer and the effects of pests and diseases may become evident when the commodity is inspected on arrival.

Trucks transporting any grain or other food commodities must be clean. They must be swept free of dust and debris. Insects must be eliminated to ensure the new consignment is not subjected to infestation from residual populations. Bodies of trucks should be sprayed with a synthetic contact insecticide such as Actellic emulsifiable concentrate or wettable powder.

Loading the truck must be done with enough care to avoid damaging sacks. Woven polypropylene and paper sacks should not be handled with hooks as these easily damage the fabric resulting in spillage; it is not good practice to handle any type of sack with a hook. Loading should be done manually or using a small conveyor (Figure 14) Trucks must be loaded only to their stated capacity as overloading will make the truck unstable and likely to tip over, a not uncommon occurrence (Figure 15).

All commodities should be accompanied by documentation, which records the origin of the consignment and any pest management treatment that has been applied. This documentation will be especially needed where a consignment is to cross an international border; it is likely that phytosanitary and fumigation certificates will be required. However, this certification may also be required for internal grain movements, particularly when grain has to be moved into and out of areas of quarantine. For example, in Tanzania, an outbreak of the larger grain borer, a major pest of stored maize, resulted in several areas of the country being quarantined, so that all movements of maize into or out of these areas were restricted. However, other crops that were not affected by this pest had to be treated with insecticide or fumigated, and proof of their being so was demanded at check points established along roads leading to the quarantined areas (Figure 16). Trucks approaching these checkpoints with documentation were stopped from entering or exiting, causing substantial financial penalties to the owners of both the commodity and the truck. In some cases the consignments were tempo-

FIGURE 14 **Loading a truck**

FIGURE 15 **Overturned truck**

FIGURE 16 **Checkpoints for stop and search, may require examination of documents**

FIGURE 17 **Freight containers can be fumigated if they can be made gas tight. Sealing end ventilators on this container will be difficult**

rarily confiscated and fumigated by government inspectors before being released back to the owner who bore the cost of treatment.

Open rail wagons should be treated in the same way as road trucks. Freight wagons that can be closed off can be fumigated if they can be made air tight (Figure 17). When empty, freight wagons must be thoroughly cleaned. Once the commodity has been loaded, preferably on pallets, tablets of aluminium phosphide, which release phosphine gas on exposure to air, should be placed under the pallets and the container then sealed. A fumigation will take 7 days or longer depending on the temperature, during which time access to the commodity will not be possible. Fumigation can also be undertaken when the container is empty to disinfest the fabric, although this is generally unnecessary; it is however useful to disinfest bales of empty, used sacks placed in the unloaded container.

Grain carried in freight containers can also be fumigated whether transported by road, rail or sea. This is a practice that is becoming increasingly common, although the treatment frequently fails. Failures are due to the leakage of gas out of the container so that the concentration inside is insufficient to kill insect pests. Most containers, like rail wagons, have ventilation openings. These may be located at the top of the walls, sometimes in the roof, and more often in the floor. For a successful fumigation these ventilators have to be sealed to prevent gas leakage. This may be difficult to achieve, especially if the ventilators are difficult to access, either because the container is full or because their position under the floor makes them inaccessible. If the container cannot be adequately sealed, fumigation should not be attempted as to do so would be dangerous - personnel would be at risk from escaping gas – and ineffective because insects would not receive a fatal dose.

Pest management

Preventing losses from occurring is always better than having to introduce remedial measures afterwards. However, the trader or storekeeper must decide whether it is cost-effective to undertake precautionary measures. This will depend on the type of commodity to be stored, its intrinsic value, and the period for which it will remain in store. However, even though a grain consignment might only be in transit and in storage for a few weeks, successive deliveries and despatches of grain may well require prophylactic treatments be undertaken to ensure that none of the consignment is put at risk. In areas of high humidity, such as in much of South East Asia, insect development can be very rapid and it is not uncommon for overwhelming populations of *Psochidea* or book lice to appear in a matter of a few weeks.

Good hygiene and store maintenance are prerequisites for employing measures to prevent losses from occurring. Pest control measures will fail if the store is dirty or in poor condition (Figure 18). Another essential is to ensure a high level of store and stock management. In a clean, well-managed store pest control practices can be easily employed. This is very often not the case if the stock is not well stacked; if bicycles are repaired in the store; if metal drums, old sacks and pesticide containers are left haphazardly; if spilt grain is not swept up; if the store is used as a meeting place or café.

FIGURE 18 **Example of a badly managed store in which it is impossible to undertake pest management procedures**

CONTROL OF INSECT PESTS

Fumigation

Grain and grain products can be protected against storage insect pest damage by eliminating existing populations, i.e. by disinfestation, or by preventing infestation occurring in the first place. Fumigant gases are used for disinfestation and contact insecticides are used as protectants to prevent infestations.

Fumigation is achieved by the action of a gas, phosphine, which is released from aluminium phosphide or magnesium phosphide when these come into contact with moisture in the air. Phosphine is extremely poisonous to insects, man and animals, and so very great care must be taken when it is used. Fumigation must only be undertaken by trained personnel.

Fumigation must take place inside a gas-tight container or enclosure. This can be a metal or plastic structure such as a 20 or 40 tonne freight container, a 3-4 tonne high density polytank, or a sealable 200 litre oil drum. Most commonly, fumigations are carried out in food stores under a non-porous fumigation sheet, which is held down onto the floor with 'sand snakes', long narrow tubes of cotton cloth or similar material filled with sand. The weight of the sand snakes keeps the sheet flat on the floor and prevents gas leakage (Figure 19).

If the container or enclosure is not gas-tight phosphine will escape into the environment and be a hazard to people and livestock in the vicinity. Gas leakage will also result in an ineffective

FIGURE 19 **Measuring phosphine gas concentration in stack covered with thick polythene sheeting and anchored to ground with sand snakes**

fumigation as phosphine will not be in sufficient concentration long enough to kill all the insects in the commodity. If insects survive they may become resistant to the gas so that in future, even when good quality fumigations are undertaken, they may not be fully effective.

Some of the commercial formulations of phosphine are shown in Table 2 below. Of these, tablets of aluminium phosphide, which release 1 g of phosphine, are in most common use in grain and feed stores in the tropics and sub-tropics. Pellets are useful for disinfecting individual sacks.

Once a bag stack has been properly covered with a fumigation sheet the tablets are introduced under the sheet, which is then resealed. Tablets can be put inside a small paper envelope or piece of cotton cloth. They must be spread out around the stack, no more than six tablets in one lot. The application rate is 3-5 tablets for every tonne of grain or cubic metre of store volume (Table 3). It is easier calculating the dosage on the weight of grain to be treated if the stack is under a sheet. If the grain is in a polytank or metal container the dosage should be calculated on the volume to be treated, it should be the same whether the tank is completely full, half full or nearly empty.

Fumigation with phosphine takes a minimum of seven days to complete whatever type of container or enclosure is used (Table 4). If the fumigation is ended after a shorter period it is very likely that some insects will survive, the treatment will be a failure and will probably need to be repeated.

Once a fumigation is complete the stack or container must be fully aired to blow off any remaining gas before the trader can take the produce away. Airing is a short process that can be completed in 2–8 hours depending on the size of the stack. By the end of the fumigation, the aluminium phosphide tablets will have degraded leaving a grey powder, aluminium hydroxide. This powder must be stirred into a bucket of water and then poured away.

Individual 50 kg lots of grain or feed can be separately fumigated when placed inside a suitable sack. The sack must have an inner polythene liner of at least 500µm and a second outer layer of jute, hessian or woven polypropylene to protect the liner. Ideally, once a pellet is placed inside the sack the polythene should be heat sealed. However, it is acceptable to twist and

TABLE 2 FORMULATIONS APPROPRIATE FOR SMALL TO MEDIUM SCALE USE

Formulation	Unit weight (g)	Phosphine released (g)
Pellets	0.6	0.2
Tablets	3.0	1.0
Mini bags	9.0	3.0
Bag (sachet)	34.0	11.3
Bag (sachet) with strings or chains	340.0	113.0
Blanket	3,400.0	1,130.0
Plates	117.0	33.0

TABLE 3 RECOMMENDED DOSAGE RATES FOR PHOSPHINE

Type of fumigation	Recommended dosage[a]	
	g PH_3 per tonne	g PH_3 per m^3
Bulk fumigation in gas-tight silos	2 to 4	1.5 to 3.0
Bagged commodities under gas-proof sheets	3 to 5	2 to 3.5
In-bag fumigations	0.2 g per bag[b]	
Space fumigations, e.g. empty store		1.0

turn the mouth of the polythene on itself and tie it off with string. Pellets of aluminium phosphide, releasing 0.2 g phosphine were designed to be used in this manner.

Contact insecticides

Inspection will indicate the need for pest control measures. In many storage complexes insect control is conducted on a routine calendar basis. Fumigation may be carried out every three months and spraying the store walls every two months, regardless of real need. This is a costly and inefficient way to control insect pests because frequently, the fumigation will be applied to a commodity with no pests or because the spray application may only be effective for one or two weeks. It is therefore important to undertake pest control operations only when needed and this will be indicated by inspection.

Before any control operations are undertaken the store or mill areas to be treated must be cleaned. Walls, floor and machinery must be swept with brooms and the sweepings removed. Immediately prior to fumigation, the internal store fabric and any machinery should be treated with a contact insecticide spray to kill off any insects that might be lurking in cracks in concrete or in concealed places around machinery. This treatment is designed to kill at the time of application, not to provide residual protection.

TABLE 4 MINIMUM EXPOSURE PERIODS RECOMMENDED USING PHOSPHINE

Temperature (ºC)	Exposure period (days after application of the fumigant)
below 15	do not use
15 to 25	10
above 25	7

It is always advisable to clean and spray an empty store immediately before a new stock is to be received. This will disinfest the building of any over-wintering insect pests, which otherwise could attack the incoming commodity. It is usually not necessary to spray the roof fabric as it generally becomes too hot during the daytime to support insect development. However, if there is a ceiling present below the eaves this should be treated.

Hand-operated sprayers are convenient for small to medium sized stores. These may be of two types, continuously pumped or pre-pressurised. The former have to be pumped by the operator throughout the procedure (Figure 20a) but pressurised sprayers do not, and therefore require only one hand to operate. Pressurised sprayers should be fitted with a self-regulating valve and operated at about 4 bar (4 kg/cm^2). Larger areas can be covered with sprayers operated with petrol engines (Figure 20b), including motorised knapsack sprayers. These last tend to be very wasteful of liquid as much of the spray is lost into the airspace.

Sprays are best applied with a nozzle producing a flat fan pattern, although cone patterns are also acceptable. The nozzle head should be kept about 15 cm from the wall to provide adequate cover, but to prevent too much bounce and back

FIGURE 20 Hand operated pneumatic sprayer

(a)

(b)

spray. Sprays should be applied until run off occurs, as this will allow the liquid to penetrate into cracks and crevices where insects may be hiding.

Only sufficient spray solution should be prepared to treat the areas to be covered. Inevitably, some dilute spray solution may remain once the operation is completed. If this happens the remnants of the solution should simply be applied to the walls or floor until the sprayer is emptied. After completing the operation the sprayer must be washed out thoroughly with water.

Contact insecticides are sold in several different formulations. Those that are appropriate for treating surfaces include wettable powders (wp: solids which are dispersed in water), emulsifiable concentrates (ec: liquids which are dispersed in water to form an emulsion) and soluble concentrates (sc: liquids diluted in a solvent such as oil to form a true solution). Ecs tend to be the most commonly available and are the most convenient to use in hand operated sprayers. Insecticide concentrates generally contain 20-40% (some deltamethrin formulations only contain 2.5%) active ingredient and must be diluted before use.

Manufacturers' recommendations on the label must be adhered to when applying contact insecticides and other pesticides. Depending on the chemical used, between 0.1-1.0 g of active ingredient must be applied per m^2, and usually the application rate of the diluted solution to cement surfaces is 5 l/100 m^2. The appendix provides an example of how to calculate the dilution of a contact insecticide to be applied to the walls of a store.

Freight wagons and containers should be treated in the same way except that less diluted solution needs to be applied as the metal surfaces do not absorb any of the solution; a rate of 2 l/100 m^2 is usually sufficient.

There are several commercially-available insecticides that can be used for this purpose. These are broadly classified into two groups, organophosphates (OP) and pyrethroids (P) (see Box 1). Each chemical is known by a common name and a commercial name. Although common names remain constant the commercial name changes depending on which company is marketing the product.

Some of these chemicals, such as dichlorvos, are highly volatile and give off a lot of chemical vapour. These are particularly useful for flushing insects out of cracks and are also used for spraying or fogging the air space in stores to kill flying insects especially adult moths. OP and P chemicals are often used together to control different

BOX 1 INSECTICIDES AVAILABLE FOR SPRAYING SURFACES

Common name	Commercial name
Organophosphate (OP)	
Pirimiphos-methyl	Actellic
Chlorpyrifos-methyl	Reldan
Fenitrothion	Folithion; Sumithion; Accothion
Dichlorvos	Nuvan; Vapona
Malathion	Cythion; MLT; Agrothion
Pyrethroid (P)	
Permethrin	Ambush; Talcord; Eksmin
Deltamethrin	K-Othrine; Decis
Fenvalerate	Sumicidin; Fenkill; Sumitox
Bioresmethrin	Isathrine

insects; the former are particularly effective in controlling weevils whilst the latter are better at dealing with borers, especially the larger grain borer. Diatomaceous earths (DE) are not suitable for treating store fabric in this way prior to fumigation as their rate of activity is too slow to ensure rapid kill; but they can be used to provide persistent, residual protection.

These chemicals, especially the organophosphates, have high or moderately high mammalian toxicity, so great care must be taken when they are handled. Gloves must always be worn when handling concentrates as should other protective clothing, such as overalls and boots, during spraying. During any spraying operation a bucket of water must be close to hand to pour over affected areas that become contaminated accidentally. Spraying should never be undertaken by a single person, a second individual must be present to ensure remedial measures are put into place in case of accidents. A summary of safety considerations is given in Box 2.

FIGURE 21 A space sprayer in position on the roof lintel

FIGURE 22 Fogging a store

CONTROL OF RODENTS AND BIRDS

Stored grain and grain products must also be protected against rodents and birds. This may be almost impossible to achieve if doors are left open. Even when closed, rodents may still gain access if there are gaps between doors and walls, if ventilators are left open, through gaps in the roofing and through entry points for cabling

BOX 2 SAFE USE OF CONTACT INSECTICIDES

- Always read the pesticide label and follow the instructions
- Wear clean and appropriate clothing; gloves are essential; a face mask is advisable but if not available a clean piece of cloth should be tied over the mouth; boots should be worn, trousers should be worn outside the boots; a face shield is useful to protect eyes
- Always keep insecticides under lock and key and when in use, never leave bottles unattended
- Never transfer insecticides to other containers, particularly soft drink bottles
- Never reuse insecticide containers for other purposes; dispose of empty containers, ensure they cannot be reused
- When working with insecticides do not eat or drink, do not rub your eyes, do not smoke
- Keep food and drink away from insecticides
- Have plenty of soap and water available, and a change of clothing
- Always wash after handling insecticides
- Destroy heavily contaminated clothing; after spraying wash clothing and protective gear
- If spills occur wash the area immediately; wash off any dribbles that might have contaminated the outside of the insecticide container and any vessel used for dilution
- Nobody except those involved in the insecticide application should be allowed in the store whilst spraying is in progress; nobody should be allowed to handle insecticide containers except authorised personnel
- Workers should be made to cover their feet to prevent contamination from the floor
- The electricity supply should be turned off before spraying begins
- Excess spray solution should be applied to the walls or floor

and ducting. Similarly, birds are able to enter through ventilators and doorways. To prevent entry, all gaps should either be filled in with cement or fitted with wire netting. If doors have to be left open they should be fitted with a metal kick plate which will prevent rodents from gaining access; a flexible curtain will keep out birds.

Thus it is important to manipulate the environment to restrict access by these pests. Water and food are essential for rodents and birds so that by restricting availability the pests will look elsewhere. This of course is very difficult to achieve around buildings holding grain and grain products. However, it is possible to restrict access by proofing, which prevents pests from accessing the food in the store or mill. This has to be undertaken by manipulating the surroundings outside of the store as well as managing conditions inside.

FIGURE 23 Screening a drain pipe to prevent rodent entry

All holes in the fabric of the building must be blocked up, either with cement or with wire netting; the netting must be fine enough (5mm

or less) to prevent small mice gaining access if these are known to be present in the vicinity. Doors must not have gaps larger than 5 mm and if a kick plate is fitted it should be a least 1 m high to prevent rats jumping over. The ends of rainwater pipes should be fitted with mesh, and down pipes, for rainwater and electrical cables, should be fitted with metal baffles to prevent rodents climbing. Debris and vegetation must be cleared away from the sides of buildings. A trench 30 cm depth and 20 cm wide should be dug around the exterior walls and filled with fine gravel. To prevent rodents tunnelling, a concrete layer 10 cm thick and extending 60 cm below ground, with the base turned out to form an L shape for 50 cm should be laid. Food spillage must be immediately removed and sources of water either proofed, turned off or removed.

It may not be feasible, because of the design of the premises or their location, to put into practice all of the requirements to make a building rodent proof. Nevertheless, it is important to try as far as possible to achieve this aim. If the store is adjacent to other storage buildings, such as in a market, it is essential that all the stores be treated together because if one is left unproofed it will become a magnet for pests and will facilitate access to all the other stores.

Cleanliness inside the store, the separation of stacks and the removal of non-food items will assist in keeping rodents out. However, this may not be sufficient to prevent losses and it may be necessary to use rodenticides.

Unlike insecticides, which work simply on contact, rodenticides must be ingested to exert their effect. Rodenticides fall into two main groups, acute and chronic poisons. Acute poisons have been in use for very many years. They kill the target very rapidly, perhaps in a matter of minutes or hours. The effect can be very dramatic as the rodent dies out in the open and is visible. However, many individuals will not be affected so that damage and nuisance levels will remain significant, especially as the rodent population will quickly recover. Acute poisons may be of use in rapidly reducing a population so long as mass baiting is done. These chemicals are cheap, widely available and commonly used.

All rodenticides must be offered in the form of a bait. It is generally useful to lay down bait before adding the rodenticide to allow the rodents to familiarise themselves with something new in their environment. Many rodent species, especially the house mouse, are neophobic, suspicious of and avoiding new objects, so they must be allowed to become used to objects. Even when they begin to eat bait, they may only nibble at it and consume a sub-lethal dose. The acute poison will cause unpleasant feelings that will prevent further feeding in the future, the rodent becoming 'bait shy'. Pre-baiting will allow the rodent to become familiar with the bait but may take several days and even weeks with house mice. Even so, it remains difficult to achieve complete mortality with acute poisons.

There are some compounds, sub-acute poisons, which are similar to acute poisons but where the symptoms are slower to appear. A lethal dose may therefore be consumed in several feedings rather than in a single meal. Death may be delayed for several days.

Chronic poisons are all anticoagulants. Death may occur in 2-3 days but more usually in 7-8 days. The discomfort felt by the rodent is much less than with acute poisons so that feeding will continue unabated, until death occurs. However, it is necessary to ensure that the bait is placed correctly so that it is consumed by the rodents regularly. Therefore, care must be taken to ensure that rodents are given the best opportunity to feed; the bait must be sited optimally. When rodents regularly feed nest partners, young and adults will be encouraged to feed in the same location. Furthermore, rats like hoarding and often take bait back to the nest to eat in familiar surroundings, where others may share. In this way, it is possible to achieve 100% kill in a target population.

Warfarin was the first chronic poison to be marketed some 50 years ago. Others quickly followed but there is now widespread resistance to most of these early, first generation chronic rodenticides. More toxic, second generation compounds have largely superseded earlier chemicals but there is increasing evidence that rodents are becoming resistant to these as well. It is therefore important to ensure that the application of rodenticides is as efficient as possible and is carried out by a trained pest control operator.

There are a number of ready-made edible baits available including loose cereals and other foods, pellets, wax blocks, gels and pastes. Soluble forms of rodenticide may be added to water, useful in food stores where free water supply is usually absent. Loose baits are perhaps the most effective but have to be used with care especially in food storage and preparation premises. It is probably most efficient to buy the rodenticide concentrate and mix it in with whatever food is locally available and cheap. Great care must be taken doing this as concentrates are themselves highly toxic. Rodents are mammals like man, and any chemical toxic to rodents will also be toxic to man.

BOX 3 RODENTICIDES

ACUTE
Alphachloralose
Mono sodium fluoroacetate
Fluoroacetamide
Red squill (extract of plant Drimia maritima) or purified as Silmurin
Thallium sulphate
Zinc phosphide

SUB-ACUTE
Bromethalin
Calciferol

CHRONIC *(2ND GENERATION)*
Defenacoum
Bromodialone
Brodifacoum
Floucamfen
Difethialone

Baits can be laid directly on rodent pathways either loosely or placed on trays, in bait boxes or containers. The use of a closed container will prevent bait being disturbed in public areas, where people work, such as in stores or mills. In these locations it may be useful to provide a source of water next to the bait as an attraction to rodents.

Untreated baits can also be used in rodent traps. There are two types of trap, those that kill and those that capture. Kill traps are 'break back' traps (Figure 24) in which a spring, released by the activity of the rodent, is released and drives down a metal bar, breaking the back of the rodent. Live traps entice the rodent into a cage from which it cannot leave (Figure 25). There are many designs but all are passive, depending entirely on the behaviour of the rodent. Many rodents are 'trap shy'. Traps may play a part in controlling the population in a store but it is likely they will lose their appeal over time; traps should be moved to different locations to counter the learning capability of rodents. Their main advantage is that they are non-toxic and will not contaminate the food store.

Birds enter stores and mills to gain access to food. Their main deterrent is to ensure that no food is available. It is vital, therefore, that all spillage of grain, flour or feed be swept up as soon as possible and taken out of the building for disposal. However, birds can easily make holes in sacks of grain, flour or feed and action must be taken to deprive them of the opportunity of doing so. For most small to medium sized stores the most effective way of preventing damage by birds is to exclude them from the premises by fixing wire netting over entry points, for example, ventilation openings. Plastic or metal curtains can also be affixed to doorways to prohibit bird entry,

FIGURE 24 Rat being enticed to a break back trap by loose groundnuts

particularly useful where the door has to remain open for long periods.

CONTROL OF MOULDS

Fungi gain access to grain through openings created by damage due to poor handling. They gain easier access to flour and feed as the 'openings' are purposely produced by the milling process; finely divided foods are relatively easily invaded by fungal spores.

Physical damage usually occurs in the field just before or during harvesting, then during threshing and winnowing. By the time the grain enters the store it may well be infected with fungal spores or even by fungal mycelia, which are recognised as mould growth. Spores germinate and moulds grow because the water activity of the host is sufficient to allow development. In humid conditions mould growth will occur quickly, less so in dryer climates. Flour and feed readily pick up moisture from the air, much more easily than grain, and thus provide an excellent substrate for moulds. Flour will go mouldy much more quickly than grain so it is imperative that flour is not stored too long, unless it is packaged in a non-porous container, such as a plastic bin or in polythene lined sacks. However, flour must have a water activity below 0.7 so that it does not release water to condense on the inside of the container. It is generally recommended that flour or feed are stored for no longer than two weeks in moderately hot and humid conditions and even shorter where the relative humidity exceeds 80%.

FIGURE 25 Rats in a live trap

The most common way to prevent mould is to dry grain down to a 'safe' moisture content. At 27°C, the lower limit of water activity that will permit mould growth is 0.7. This is equivalent to an equilibrium relative humidity in the air of 70%. For cereal grains this is a moisture content of 13-14%, for pulses 11-13% and for oilseeds such as groundnuts 7%. If grain is found to be wet at the point of purchase it is usually rejected. If the grain takes up moisture during storage then it must be dried artificially by the store owner.

However, mould growth can also be prevented by reducing the temperature of the grain. This can be achieved during storage by ventilating the stock, either using natural aeration or by forcing air through the commodity using a fan. Although this can be achieved in temperate climates – maize can be stored for a year at 15% moisture at 15°C – it is not so easily achieved in tropical countries; at 15% and 30°C maize would only last three months. A system for aerating a bag stack is illustrated in Figure 26. Drying depends on the moisture content of the air in the store as the system is dependent on aeration alone, there is no artificial drying. Drying bags is dif-

ficult because the air tends not to pass through the intergranular spaces but rather between the sacks, the line of least airflow resistance. However, the system is convenient because the grain can remain in sacks. For artificial drying grain must be unloaded from sacks, placed in the dryer and then put back into sacks after drying. Even grain stored in bulk must be shifted to a dryer.

There are many types of artificial dryer each designed for different throughput rates. A detailed description of all the types is beyond the scope of this booklet but a summary of the main types is given below.

Tray dryers: Tray dryers, sometimes called flat bed dryers are the simplest of the batch dryers. Grain is loaded onto mesh trays within the dryer to a depth of 600 to 700 mm and warm, dry air is blown through the trays until the grain has been dried sufficiently.

Radial dryers: The basic design of the radial drying bin consists of two vertical metal mesh cylinders, one inside the other (Figure 27). Grain is loaded into the space between the two cylinders and air is blown into the inner cylinder, from there, it passes through the mesh wall and the bed of grain, and out of the outer mesh wall. Air can be sucked out of the central cylinder, reversing the air flow through the grain. These dryers are popular, but there is a risk that grain nearest to the inner cylinder can be over-dried as this is where hot, dry air first makes contact with the grain. Grain towards the outside, where the air leaving the grain, is cooler and wetter. Transportable dryers can be rented out for occasional use; this makes drying affordable for even small-scale farmers who do not have sufficient capital to purchase a dryer of their own.

Continuous flow dryers: These are designed to remove moisture from the grain rapidly by blowing or sucking hot air through the grain as it passes through the system from top to bottom. The simpler designs of continuous flow dryers have a holding bin on top of the tall drying section. A final cooling section, where air at ambient temperature is blown through the grain is usually incorporated at the base of the dryer to avoid conveying hot grain into the rest of the system. The bed of grain may be vertical, horizontal or inclined. Grain may be moved by vibration, scrapers, conveyors, or by gravity. The degree of drying is determined by the rate of grain flow through the dryer, and is usually controlled by varying the speed of outlet conveyors or the size of the outlet itself.

Tower (mixed-flow) dryers: These dryers resemble tall rectangular storage bins, fitted with a large number of horizontal, triangular shaped ducts across the width of the dryer. Approximately half of these ducts introduce warm, dry air into the grain whilst the others remove the cooled, damp air. Grain is fed in at the top and passes down, around the ducts, by gravity. With the dryer full of grain, the grain moves slowly down through the dryer, first through the drying section and then a final cooling section using ambient air.

Louvered-bed dryer: This dryer is similar in design to the tray batch dryer except that the grain is dried as it passes over louvered-beds through which heated air is blown rather than being dried in situ. The depth and speed of the moving bed of grain is controlled to determine the degree of drying. There are two basic designs, the cascade dryer and conveyor dryer.

FIGURE 26 **Ventilation of conventional bag stack**

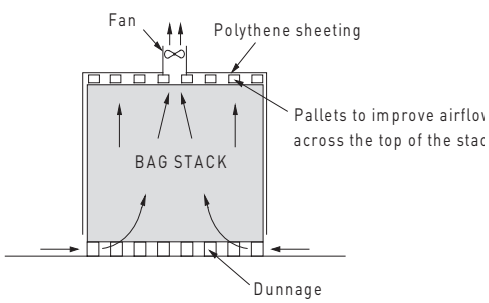
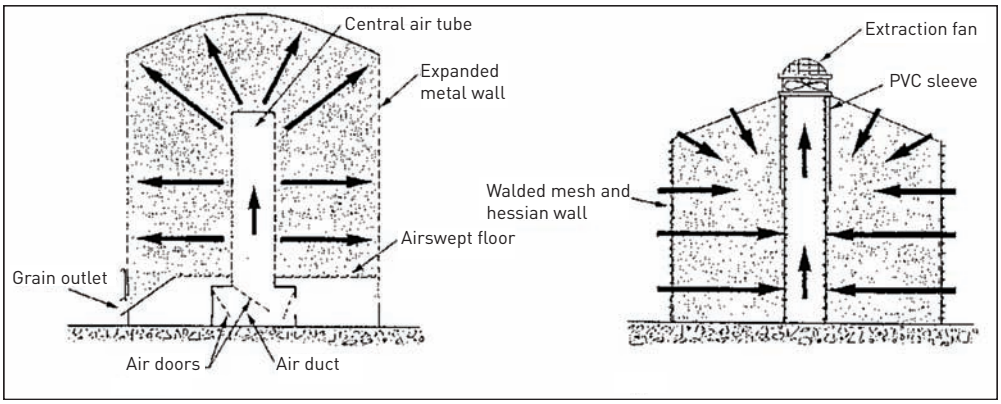


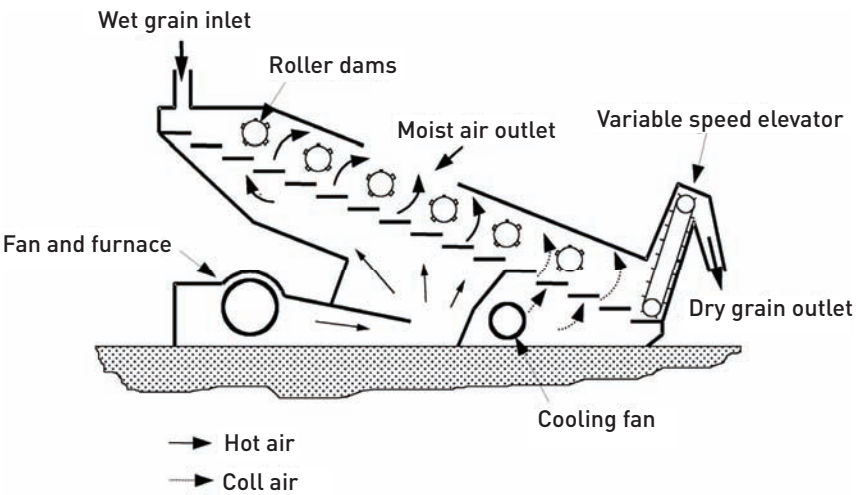
FIGURE 27 Operating principle of simple radial drying bins



The cascade dryer is a gravity fed cross-flow dryer with grain depth controlled by a series of roller dams along the length of the louvered-bed. The degree of drying is controlled by the speed of the output elevator. To avoid excessively long lengths, larger dryers may involve several changes in direction of grain flow.

In conveyor dryers grain is also supported on an inclined louvered-bed through which air is blown, but grain flow through the dryer is by a variable speed, heavy duty, roller chain conveyor. These dryers may be single-directional, two-directional or multi-directional. The changes in direction of grain flow mixes the grain, allows some of the dried waste material to be blown from the grain and reduces the overall size of the machine.

FIGURE 28 Operating principle of a single direction cascade dryer



Summary of actions needed

HYGIENE AND STORE MANAGEMENT

- Clean all areas where stock may be kept in stores, mills, around machinery; sweep at least once a week;
- Remove from store and dispose of sweepings and other rubbish;
- Remove from store all empty sacks and pesticides where other space is available; otherwise keep non-food items separated from grain and other food stock;
- Keep store well maintained and in good repair; repair cracks and crevices, make good where the floor has broken up, fill in holes in structure; make sure ventilators can be open and closed;
- Fit wire mesh to openings to stop rodent and bird entry; fill in holes in doors, floor and walls;
- Spray the fabric of the building, freight container or truck with contact insecticide solution to kill off insect pests in the empty store;
- Make sure that any sacks that are reused are free of pests.

STOCK MANAGEMENT

- Build stacks using an appropriate stacking pattern so that they are stable but easy to dismantle;
- Leave a gap of 1 m between stacks, from the walls and beneath the roof eaves; ensure that it is possible to gain access easily to all exposed surfaces, including the top;
- Build the stack on dunnage of pallets or poles, or on a polythene sheet if floor is level;
- Inspect the stock and the store itself at least once a week; check for the presence of pests and to confirm the effectiveness of pest control procedures that had been carried out;
- Use cards attached to stacks to record the history and performance of the commodity; use record cards/sheets to record pest control procedures and inspections

TRANSPORT

- Make sure truck or cart is clean and well swept;
- Spray the fabric of the transport with contact insecticide;
- Ensure that all paperwork related to the load is in order;
- Do not use hooks to load and unload sacks, rather use man handling or a conveyor;
- Do not overload;
- If transport can be made airtight, fumigate if pests are present.

PEST MANAGEMENT

- Fumigation should only be undertaken by trained personnel;
- Only fumigate in airtight enclosures or where it can be made airtight;
- Fumigation should last at least 7 days, before aeration begins;
- Aerate thoroughly;
- Dispose of spent fumigation tablets by tipping residue in water;
- Spray store with contact insecticide to kill off insects present before fumigation takes place; do not use insecticides to provide residual protection;
- Only trained personnel should handle and apply contact insecticides;
- Never work alone;
- Ensure a supply of clean water is to hand;
- Wash off spillages from the body or from other surfaces immediately;

- Accidents should be immediately reported and details of the chemicals used should always be made known to the doctor;
- Wash equipment thoroughly after each use or at he end of each day;
- Use a clean change of clothes each day.
- Always have warning notices posted for fumigation and pest control taking place.
- **Take care when handling synthetic** rodenticides; ensure bait is placed appropriately;
- Make sure stock is dry at intake; use appropriate drier if it gains moisture during period in store;
- Ensure that all non-essential people are not allowed access to the store.

Appendix
Calculation for the application of contact insecticide to store walls

There are three steps:

- Calculate the area to be treated
- Calculate the amount of insecticide solution needed
- Calculate the amount of diluted solution needed

The store is empty. The area to be treated will be the area of four walls and the floor (the roof will not be sprayed, there is no ceiling). The dimensions of the two short walls are 5 x 5 m. and of the two long walls 20 x 5 m. The floor dimensions are 20 x 5 m.

The total surface area of each short wall is 5 x 5 = 25 m^2.

The total area of both short walls is 25 x 2 = 50 m^2.

The total surface area of each long wall is 20 x 5 = 100 m^2.

The total area of both long walls is 100 x 2 = 200 m^2.

The surface area of the floor to be treated is 20 x 5 = 100 m^2.

Therefore, the total surface area of the store to be treated is: 50 + 200 + 100 = 350 m^2.

The insecticide to be used is 20% Actellic emulsifiable concentrate (e.c.) volume/volume (v/v). This solution therefore contains 20 ml of active ingredient (a.i.) per 100 ml of solution.

We want to apply the chemical at a rate of 1.0 g a.i./10 m^2 of surface. As we need to treat a total of 350 m^2, we will need: 350/10 * 1 ml of a.i. = 35 ml a.i.

However, the insecticide is only 20%. Therefore 100 ml contains only 20 g of a.i. 1 g a.i. is contained in 1/20 * 100 ml = 5 ml.

Therefore 35 ml a.i. is contained in 35/1 * 5 = 175 ml of 20% Actellic.

Thus we will use 175 ml of the insecticide in a water based solution. This solution has to be applied at a rate of 5 l/100 m^2. To treat 350 m^2 we will need: 350/100 * 5 l = 17.5 l.

Therefore to spray the store fabric we will take 175 ml of 20% Actellic and dilute it with just under 18 l of water (it is impractical to try to measure out the water more accurately).

If the store had three bag stacks in place we would need to calculate the floor space occupied by the stacks and subtract it from the total store area before calculating the amount of insecticide needed. This is because we cannot spray the floor occupied by the stacks.

If the three stacks were of equal dimensions: 3 x 4 m, then each would occupy 12 m^2, and the total occupied by the three would then be: 3 x 12 = 36 m^2.

As the total floor area is 100 m^2 (from above), the actual floor area we can spray will only be: 100 – 36 m^2 = 64 m^2. Then the total surface to be treated will be:

50 + 200 + 64 m^2 = 314 m^2.

We want to apply the chemical at a rate of 1.0 g a.i./10 m^2 of surface. As we need to treat a total of 314 m^2, we will need: 314/10 * 1 ml of a.i. = 31.4 ml a.i.

However, the insecticide is only 20%. Therefore 100 ml contains only 20 g of a.i.

1 g a.i. is contained in 1/20 * 100 ml = 5 ml.

Therefore 31.4 ml a.i. is contained in 31.4/1 * 5 = 157 ml of 20% Actellic.

If we do not have an accurate measure for the Actellic, we can measure out 160 ml.

We will also need less of the diluted solution: 314/100 *5 l = 15.7 l or, less precisely, 16 l.

The food produced by the farmer has a long journey to travel on its way to the consumer's plate or the animal's feed trough. There may be a long chain through which the crop will be transported, stored and processed, with accompanying losses in quality, quantity, nutrient content and monetary value. These losses can be substantial, and if they are allowed to occur and build up, will result in a significant loss in revenue for the farmer and the end user.

This booklet describes the causes of these potential losses and illustrates actions that should be undertaken to prevent or remedy them. It assumes that grain and grain products, including flour and animal feed, have reached the first point in the marketing chain after leaving the farm. The situation of transit storage and long-term storage is considered, and millers, traders and feed compounders are also included.

The booklet is not intended to be used solely by the ultimate beneficiaries themselves, though it may well be. It is intended to be used by anyone who is involved in providing practical advice to counteract the causes of deterioration of grain and grain products along the marketing chain. These may be pest control suppliers, retailers and wholesalers, extension personnel within and outside of government, staff of trading organisations including marketing boards, and trade unions.