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Storage Losses in Feedstuffs and How to Prevent Them

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ABSTRACT

The reduction of post-harvest losses is an important contribution to the increase in agricultural production and ensuring food security. Biological deterioration of feedstuffs entails losses both in quantity and quality, including deterioration in chemical composition, contamination by mycotoxins, rancidity, loss in nutritive value and change in colour and smell. In this paper, the conditions for the safe storage of feedstuffs and also the methods for the prevention of losses in stored feed raw materials, including hygiene and the use of pesticides have been discussed. Also discussed are the safeguards to avoid pesticide toxicity to man and his livestock.

INTRODUCTION

Food security relates to access by all people at all times to enough food for an active life. Expansion of food production may be achieved, depending on the circumstances, either by extensification of the cultivated area or by intensification of land use. But according to Schulten, Roorda and Russell (2009), there is no point in increasing yields and areas under cultivation, if similar or even larger quantities are lost or decreased in quality by biological deterioration. Reduction in losses after harvest is therefore an important contribution to the increase in agricultural production and ensuring food security.

Biological deterioration of stored agricultural products, including feed raw materials, are caused by pests, namely, insects and mites, micro-organisms (bacteria, moulds and yeasts), rodents and birds. The purpose of this paper is to examine the nature (and therefore, the importance) of the losses in stored feed raw materials and to discuss in some detail the protective measures against the agents of spoilage.

Types of Storage Losses

Loss in weight

The most obvious form of loss in stored feed raw material is loss in weight which results from the products being eaten by pests. According to Schulten et al (2009), most of the mean loss of weight estimates reported in literature are based on data from controlled experiments. FAO (2007) estimated that yearly 10 per cent of all harvested cereals and pulses are not available to the consumer because of deterioration. Losses in pulses alone amount to 20-30 per cent. According to the available published data on losses in the post-harvest system compiled by N.A.O.S. (National Academy of Sciences, 2006), the overall loss in maize is 9.6-20.2 per cent, caused mainly by insects and to a lesser extent by micro-organisms and rodents. For millets and sorghums, in developing countries, the figure is 1-15 per cent during storage. The loss of cowpea in Nigeria was put at 5 per cent. From the above figures it is clear that the loss in weight of stored raw materials is quite significant.

Loss in Quality

Loss in quality in stored fee raw materials occurs in various forms, namely, deterioration in chemical composition, contamination by mycotoxins, rancidity of fats, oxidation of fats, loss in nutritive value, change in colour and change in smell.

Deterioration in Chemical Composition

The chemical composition of the products can deteriorate by the addition or increase of unwanted compounds, such as the dropping of insects, rodents, and birds, or decrease of certain nutrients.

Contamination of Mycotozins

Moulds have a tremendous capability to thrive and metabolize a wide range of substrates, including feed grains, under certain conditions of temperature, pH and moisture. However, as one or more growth conditions become limiting sporulation begins. During this phase of the lifecycle, secondary metabolic pathways are activated and can cause various saprophytic or phytopathogenic fungi or moulds to produce toxic end products called mycotoxicoses Doerr, 1988). Mycotoxicoses are acute or chronic intoxications due to the ingestion of feed contaminated with mycotoxins. The most important of these mytocotoxins are: *Vomitoxin, zearalenone or F-2 toxins, T-2 toxin and aflatoxin.* Aflatoxin is perhaps the best known of these (Coelho, 2008).

Aflatoxins are produced by Aspergillus flavus and A parasiticus on groundnuts, soyabeans, maize and other cereals in the field or during storage as seeds, processed meals and cakes, especially, groundnut cake, palm kernel cake and coconut cake which have not been dried properly after harvest.

A Flavus is more likely to occur and presents a greater toxin hazard in oil seeds than in other grains (Coelho, 2008).
Small grains such as wheat and barley, appear to be less susceptible to mycotoxin formation than larger grains such as maize (Wilby, 2008).
In practice, the major impact of mycotoxins beneath the surface, because the effect of the continued low-level consumption is variable and not easily recognized.

Rancidity of Fats

Fats in nature are hydrolysed under the influence of enzymes collectively known as lipases, to a mixture of mono-and diacylglycerols with fatty acids. Most of these fatty acids are odourless and tasteless but some, example, butyric and caproic have extremely powerful tastes and smells. The breakdown of edible fats to awfully tasting and evil-smelling fatty acids may render them completely unacceptable to the consumer or unpalatable to animals. The lapses are mostly derived from bacteria e.g. penicillium, pseudomonas and candida; and moulds, which are chiefly responsible for this type of spoilage commonly referred to as rancidity (McDonald, Edwards and Greenhalgh, 1981).

Oxidation of Fats

By insect development, cereals and oilseeds are broken down into smaller particles. Oxidation of fats by lipoxydases is thereby increased and this leads to a higher free fatty acid (f.f.a.) content. The unsaturated fatty acids undergo oxidation to hydroperoxides. The breakdown of the hydroperoxides, results in compounds that confer the so-called "oxidative' or oxidised' taints on fats (McDonald et al,, 1981). Oxidation of saturated fatty acids results in the development of a sweet heavy taste and smell. This condition is known as **'Ketonic rancidity'** and is due to the presence of methyl ketones, as a result of oxidation.

Loss in Nutritive Value

The nutritive value of feeds is usually assessed in terms of energy availability, and the content of protein, minerals and vitamins, and the absence of toxins. In addition to the effects already discussed, oxidation causes the destruction of vitamins, especially vitamins A, D, B_1 (Thaimin), but also B_{12} (Cyanocobalamine) and C. (ascorbic acid) (Coelho, 2008). It also lowers the energy level of feeds.

Change in Colour and Smell

The chemical reactions during the process of biological deterioration or the presence of some metabolites will in general give rise to changes in colour and or smell of the product concerned, away from the normal colour or smell. Thus, colour changes or change in smell are indicated of biological deterioration. Before processed with the exposition on the methods of prevention of the above losses, let us consider the necessary conditions for the safe storage of feedstuff.

Conditions for Safe Storage of Feedstuffs

Losses in feed raw materials can only be prevented when the produce is properly stored. Schulten *et al* (2009) stated that the conditions for safe storage that the conditions for safe storage are:

(1.) *The raw materials must be dry and kept dry; and*

(2.) *The raw materials must be kept as possible and should not be exposed to excessive temperature changes.*

Moisture Content and Safe Storage

Moisture content refers to physically bound water in the produce/product and is related to the relative humidity of the environment (Schulten *et al*, 2009). A high moisture content leads to increased insect and mould development, to bacterial deterioration and chemical changes in the products. If raw materials are stored safely, it is of great importance that they be at a 'safe' moisture content level and free from infestation when they are brought into store. The term 'safe' is generally taken to mean a moisture content at which it is not possible for moulds to grow, but materials with moisture content below the minimum at which mould growth can occur are still liable to attach by insect pests (Coelho, 2008).

According to Schulten *et al* (2009), raw materials should not be stored at moisture contents higher than indicated in moisture contents in the Table 1 below, otherwise, deterioration by moulds and micro-organisms will take place. According to Schulten et al (2009), if one allows a safety of margin to take into account small differences between materials and temperature, maximum moisture content of 13 per cent for materials which are substantially oil free, e.g. cereal and extracted meals, would seem appropriate. This figure should be reduced by about 1 per cent moisture for each 5 per cent of oil contained in the material. Example, the 'safe' moisture content for groundnut cake containing 5 per cent oil would be 12 per cent. Moisture content can also influence the degree to which chemical changes may occur but its greatest effect is on biological spoilages.

It is necessary, therefore, to check the moisture content of all consignments before they are accepted into stores and to inspect them carefully to see if any insect infestation is present. If excessive moisture levels above 13 per cent are detected, the consignment should be either rejected or dried to the 'safe' level for the particular commodity as indicated above.

Table 1: Moisture Contents Levels for Safe Storage

Produce	Moisture Content (%)
Maize (Yellow)	13.0
Maize (White)	13.5
Maize (flour)	11.5
Sorghum	13.5
Millet	15.0
Beans	15.0
Peas	14.0
Cowpeas	15.0
Groundnuts (unshelled)	9.0
Groundnut (shelled)	7.0
Soya beans	11.0
Soyabean oil meal (44% protein)	13.8
Soyabean oil meal (50% protein)	15.4
Sunflower	9.5
Safflower	9.5
Cotton seed	10.0
Cotton seed screw press	11.5
Cotton seed prepress solvent	12.8
Copra	5.8
Palm Kernels	5.7
Cassava chips	12.0 – 13.0
Cassava flour	12.0 – 13.0
Tapioca	12.0
Distillers' dried grains	17.0
Alfalfa stem meal	15.1
Alfalfa leaf meal	14.9

Sources: Schulten et al (2009) and other literature.

Temperature

Temperature also influences changes in quality of feed materials by affecting the level of biological activity and the rate of chemical change (Coelho, 2008). The degree of biological activity is enhanced as temperature rises to an optimum level after which it decreases. According to Schulten et al (2009) (ibid), the optimum range for maximum fungi activity is 35-40^{o}C while insects cannot normally survive at temperatures above 40^{o}C. In the same vien, Schulten et al (2009) stated that the development of storage pests from the tropics and subtropics takes place between 17^{o}C and 35^{o}C. The optimum temperature for most storage pests is around 30^{o}C while the optimum relative humidity is 70 per cent or more. To prevent deterioration of stored raw materials and finished feeds it is essential to keep them as cool and dry as possible and to prevent or minimize infestation by insect and rodent pests by the construction of suitable storage structure as will be discussed later.

Prevention of Losses in Stored Feed Materials

The two major approaches to the prevention of losses in stored raw materials are:

- *Hygiene*
- *Use of pesticides*

Hygiene

According to Schulten et al (2009), pesticides in storage are of no use at all if no proper storage hygiene is maintained. Consequently, the first essential for the prevention of losses in stored raw materials is the practice of strict hygiene. This entails the observation of a number of conditions as follows:

1. Warehouses should be designed without ledges, corners or awkward places which are difficult to reach with a broom (or other cleaning devices) to remove dust, grains, flours, etc.
2. Floors should be covered or treated with water-proof material or made of concrete, to avoid water absorption from the ground below.
3. Storage warehouses should be so constructed that micro-climatic variations within them will be significantly reduced compared to ambient conditions. Concrete structures are most suitable-walls and roofs should be moisture proof.
4. Storage warehouses should have a good thermal insulation and entry by pests like rodents, birds, etc, should be prevented.
5. A system for controlled ventilation should be included.
6. Separate areas should be included for raw materials and finished products and these areas should be separated from processing areas; this will help to simplify disinfecting procedures.
7. Bagged raw materials and finished feeds should be stacked on pallets and stacks must stand free of the walls and ceiling. Different materials should always be stacked separately and apart.
8. A raw materials store should be swept at regular intervals, at least every week and the sweeping burnt immediately to destroy insects pests. It is essential to carry out a very thorough cleaning once a year.
9. Tall grasses, weeds and bushes should be removed from the store or silo surroundings.
10. Prevention of losses caused by micro-organisms should be sought by proper drying of the produce.
11. Raw materials may also be bulk stored, either in solos constructed from concrete or steel, or bins formed with partitions in conventional areas.

Uses of Pesticides

Pesticides are preparations for controlling pests of crops or animals, or harvested produce/products. According to Tyler (2009), Pesticides are applied in feed storage and processing premises, or to grains or other raw materials, with the following objectives in mind:

- Prevention, to ensure that an empty structure in which it is intended to keep feed raw materials free of pests.
- Protection, to ensure the safekeeping of feed raw materials stored in warehouse.
- Correction, to combat infestations which have developed. The treatment employed depends upon the type and construction of the premises, the products stored or handled and the nature of the infestation.

Pesticides may be grouped collectively as insecticides, acaricides, fungicides, rodenticides, etc. In this paper, we shall be concerned with the use of insecticides, fungicides and rodenticides.

Insecticides

According to the type of action they exert, insecticides may be grouped as contact insecticides or fumigants.

Contact Insecticides

A substance has contact action if it has the ability to cause, by means of penetration via the epidermis or the cuticle of a living being, temporary or lasting alterations in one or more functions of that living being. Consequently, 'contact' insecticides have been defined as 'solid or liquid formulations which exert their toxic effects only when insects come into direct contact with the pesticide. They cause damage at the point of contact or entry to a plant which is typically the foliage. According to Tyler (2009), contact insecticides are formulated in preparation which enable them to be applied through appropriate applications equipment and which enhance their toxic effects as follows:

- *Dilute dusting powders*
- *Wettable powders (WP) (water dispersible powders, wdp).*
- *Emulsifiable (miscible) concentrate (EC).*
- *Oil solutions*
- *Smoke generators.*

The trade names of some of the main insecticides are: fenitrothion-sumithion, bromophosnexion; tetrachlorvinphos-gardona, chloropyrifos methyl-reldan; primiphos metyl-actellic; dichlorvos-vapona, nuvan, nogos dedevap; lindane-kokotine, gamma HCH (hexachlorocyclohexame) formerly called gamma BHC (benzene hexachloride), gammalin.

Fumigants

Monro (1969) defined a fumigrant as a chemical, which at the required temperature and pressure can exist in the gaseons state in sufficient concentrations to be lethal to a given pest organism. The main objective of control by fumigations, only, is correction of infestation. Any confirmed space, which can be made airtight, may be used for fumigations, e.g. silos, plastic bags, etc. Bagged product is mostly fumigated under gasproof sheets. Methyl bromide and phosphine are two commonly used fumigants. According to Schulten et al (2009), they do not leave residues which may endanger animal health or productivity.

Methyl bromide

Methyl bromide is highly toxic and rather sophisticated equipment such as gas cylinders, piping systems, gas masks and gas detectors are necessary (Schulten et al, 2009). The fumigation has to be carried out by trained personnel. Rates of application under atmospheric pressure are 16-32 g/m^3 for 24 hours depending on temperature, commodity and the insect or mite species to be controlled.

Phosphine

Phosphine is available in the form of tablets (pellets or sachets) which are toxic to insects. Rates of applications are ½ - 11/2 tablets per m^3 for bagged products under plastic sheets or 2-5 tablets per tone for grain in silos (Schulten et al, ibid). A fumigation of phosphine takes 5-7 days. After fumigation, reinfestation must be prevented by insecticides or by storing the products in an insect proof silo or container.

Toxicity of fumigants

Wilcox (2005) stated that humans can be poisoned by inhaling the gases of fumigants and by absorption through the skin. The liver and kidney can be damaged by continued intake of these chemicals, whether it be by inhalation, skin contact or other means. The damage is irreversible. To avoid the dangers inherent in the use of fumigants, their application must be entrusted only to trained operators who are fully equipped and understand the hazards involved. Furthermore, all areas, both those fumigated and nearby connected buildings, must be thoroughly ventilated before any person is allowed to enter. Wilcox (ibid) recommended that grain fumigants should not be used on ground materials.

Rodenticides

Rodenticides are pesticides which kill rodents (gnawing animal) e.g. rats, mice, etc. They are mixed with baits which are readily accepted by the rodents. According to Schulten et al (2009), there are two groups of rodenticides: acute poisons and chronic poisons.

Acute Poisons

Small quantities of acute poisons are enough to kill rodents. The disadvantages are the high toxicity (which endangers human life also) and the development of the so-called *'bait shyness'* when a rodent survives a first poisoning. Zinc phosphide is an example of an acute poison.

Chronic Poison

Chronic poisons must be eaten for several days (3-10, depending on the species) and death occurs some days later. They are relatively safe and do not easily lead to *'bait shyness'*. Examples of chronic rodenticides are the anticoagulants warfarin, coumatetralyl. Chlorophacinone and diphacinone. Rodents can develop resistance to warfarin and other rodenticides. Newer anticoagulants which overcome this resistance are difenacoum and bromadiolone.
Great care must be exercised in the use of rodenticides, to avoid contamination of the stored products with these chemicals.

Fungicides

By definition, a fungicide is a substance that kills fungi by chemical action. In the protection of stored feed raw materials, however, it is usual to speak of fungistatric (antifungal agents or mould inhibitors) compounds. These are chemical preservatives employed in the feed industry to retain nutritive factors, prevent product deterioration and protect against decomposition by micro-organisms. Propionate acid or its salts, calcium and sodium propionate, are the most common and least expensive (i.e. with the most favourable cost-efficiency ratio) preservatives available (Tumbiga and McEllhiney, 2006). However, according to Feed International (1991), calcium propionate is the standard formulation.

In order to obtain the best results with the use of mould inhibitors three points should be borne in mind:

- ❖ Mould inhibitors are not a cure- they do not reduce the toxin level that already exists in a feed.
- ❖ When insufficient preservative is applied, tolerant micro-organisms may be selected and become abundant, sometimes at uncharacteristic water activities (Lacey, Hill and Edwards, 1980).
- ❖ An inhibitor cannot be expected to perform under impossible conditions. A heavily mould-infested grain that has not been properly dried and stored is a dubious candidate for production by a mould inhibitor.

Resistance to Pesticides

Resistance to pesticides means that the target pests are no longer controlled by the recommended application rate of a pesticides process. Resistance develops as a result of a selection process. According to Schulten et al (2009), resistance to pesticides is developing fast in storage pests. For example, it is known that *Tribolium castaneum* (rust red flour beetle) has developed resistance to lindane and organo-phosphorus compounds such as malathion and bromophos. Resistance to lindane in pulse beetles is increasing. Also moth pests such as *Ephestia spp.*and *Plodia interpunctella* have developed resistance and causes failure in insect control. The best way to protection if resistance occurs is probably a combination of fumigation with storage in insect proof containers or silos (Schulten et al, 2009).

CONCLUSION

The two conditions for safe storage are that raw materials must be dry and kept dry and that the raw materials must be kept as cool as possible and should not be exposed to excessive temperature changes. Hygiene and the use of pesticides are the major approaches to the prevention of losses in stored raw materials. Pesticides are applied in feed storage with three main objectives in mind: prevention, protection, and correction. They are subdivided into insecticides, fungicides, etc. Insecticides may be contact insecticides or fumigants. Contact insecticides are available powders (water dispersible powders), emulsifiable (miscible) concentrate, oil solutions or smoke generators. The two commonly used fumigants are methyl bromide and phosphine, Fumigants are toxic and great care and skill are imperative to ensure safe usage.

Rodenticides are available either as acute or chronic poisons are relatively safe and do not easily lead to ‘bait shyness, but they must be eaten for several days before death occurs some days later. Contamination of stored products with rodenticides must be avoided. Fungistatric compounds are employed to retain nutritive factors, prevent product deterioration and protect against decomposition by micro-organisms. Propionic acid or its salts, calcium and sodium propionate are the most common and least expensive preservatives available. However, calcium propionate is the standard formulation. Mould inhibitors can be effective only if used as intended and with regard to their limitations. Resistance to pesticides is developing fast in storage pests. A combination of fumigation and storage in insect proof containers or silos have been recommended as the best way of protection if resistance occurs.

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