

PRINCIPLES OF FOOD GRAIN STORAGE

Abstract

Food grain production has been steadily increasing due to advancement in production technology but improper storage results in high losses in grains. The extent of losses occurring after harvest and particularly during storage has been the subject of considerable speculation because of the difficulties of reaching accurate assessments of the amount being lost. Inadequate storage and conditioning facilities or their complete absence contribute to substantial losses every year. The management objective during the storage period is to reduce the metabolic activity to such a low level that the grain mass is sufficiently stable with minimum deterioration. The main aim of grain storage is to prevent the spoilage of grain. In this chapter, we shall discuss various principles that are widely employed for food grains.

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I. INTRODUCTION

Food grains being an essential part of the human diet have gained huge attention in these years as they contain a very good amount of nutrients. The production of grains has been rapidly increasing but several storage factors pose great hurdles in its pathway. The increase in human population, several climatic changes results in several qualitative and quantitative losses that compel us to find some solutions to utilize these resources in effective way. Grains are small, hard, dry seeds (with or without attached hulls) harvested for human food or animal feed and they have a shelf life just like any other food product. Shelf life is the length of time that foods, beverages and many other perishable items are given before they are considered unsuitable for sale, use, or consumption. Shelf life is primarily determined by its moisture content and temperature. It is normally used through the time before use, and each operation or storage regime consumes a portion of the life. The basic objective of good and effective storage is to create the suitable environmental conditions which provide sufficient protection to the product to maintain its quality and its quantity thereby reducing the product and financial loss.

II. IMPORTANCE OF STORAGE

Good storage facilities play a very important role in the life of farmers so as to get required price of their produce. Moreover, this factor is important from the food security point of view. The storage methods and equipments vary with the type of grain and purpose. Grain stored on farms for seed or livestock feed is an important part of the farm income and protecting the grain from insect attack is an exercise in income protection. But considerable losses are noticed during grain storage. The extent of losses after harvesting and storage need to be considered a special care. But actual judgement of these losses is very difficult in context with rural and developed countries. If these losses are uncontrollable, they result in decreasing the product quality, storage time and ultimately storage costs etc. Therefore, grain storage is extremely important as far as product quality is concerned which otherwise results in both qualitative and quantitative losses.

This has been observed that quantitative and qualitative losses in stored food grains may occur due to physical (abiotic), biological (biotic), chemical (breakdown of produce and pesticides) and engineering (structural and mechanical, aspects) factors. Grain temperature and moisture are the two important factors which affect the normal behavior, metabolism rate, growth and reproduction of stored grain insects etc. Within this scope, storing grains in appropriate conditions for a required amount of time will contribute remarkably to the world economy in context of efficiency. Following are the losses observed due to inappropriate grain storage.

1. Quantitative Losses: A physical loss which results in reduction in volume is known as quantitative loss. This loss can be assessed and valued as weight loss results in several malpractices like food adulteration with stones, water etc. so as to fill up the deficiency. In several cases, weight loss is not judged and undetected which gives profit to the trader. These types of losses occur due to various factors.

- It may be due to reduced moisture content easily recognized by a shrinkage factor.

- Losses created by insects, rodents, etc. results in weight loss as they feed on the product but these weight losses are not always apparent.

On average, losses due to insects are reported to be in the range of 10-20% of stored grains, but at times may be as high as 30%. The damage and losses created by insects greatly affect the farmers as their grain may lose value for marketing and consumption. In fact, insects result in the highest loss of grain.

2. Qualitative Loss: Nutritional loss and loss of seed are both aspects of quality losses. Qualitative loss is most difficult to calculate and is possibly identified by comparing with well-defined standards. Losses of this category can be nutritional, chemical, through contamination with foreign matter, molds etc.

- Foreign matter in the form of earth, stones, glass, insect fragments, excreta etc. results in quality loss.
- Normally, quality is judged and food products are categorized on the basis of several factors like size, shape and appearance, etc. but smell and flavour are sometimes included.
- There are several reasons of general contamination. This may be due to dust and several materials that enter the food product through human mishandling, insect fragments, rodent hair etc.
- Pests that selectively eat a part of the foods will affect the food value as a whole. Moreover, sunlight and temperature results in loss of vitamins in food grains.
- Chemical changes are very prevalent in fat and oil-based foods which results in development of rancidity.

III. STORAGE REQUIREMENTS FOR FOOD GRAINS

Almost all grains are stored before they are finally processed and consumed. The storage life of grains may be few weeks, months, years or more. Adequate storage conditions are essential which otherwise result in qualitative and quantitative losses.

- Moisture content of grains are very important from storage aspects. This may vary as moisture content required for storage and harvesting should be less than 9% (wb). Although many of the dry regions have monsoon season of high humidity causing an increase in moisture in stored grains unless protected from humid air. These conditions if prevalent results in the development of molds and insects as they rely on temperature and moisture content for their growth and survival.
- Safeguarding the stored grains from climatic conditions, insects, birds etc. can be achieved by adequate construction of the storage bins but this does not implement to several other destructive agents except in air tight storage which can be made to exclude insects and mites as well. The activity of these is greatly affected by:
 - ❖ Moisture
 - ❖ Temperature
 - ❖ Oxygen in the stored atmosphere.

- 1. Moisture:** One of the most important parameters that is important from storage aspect is moisture content of grains. As if it did not monitor correctly results in development of molds, insects etc. Reducing the moisture levels for safe storage of grains is essential. Normally, reducing the moisture content to 11-13% in most grains is adequate for all organisms except insects. For insects, the moisture content should be less than 9%. If a cereal grain is to be kept for a longer span, its moisture content should be below 12%.
- 2. Temperature:** Temperature is the next most important parameter after moisture content that holds special place as far as storage of grains is considered.

In context with temperature, the following important points should be kept in mind as far as grain storage is considered:

- Mites do not develop below 5°C and insects below 15°C.
 - Storage fungi do not grow below 0°C.
When the grain temperature approaches around 20°C, it gets easily attacked by insects and microorganisms and at the same time, respiration rate becomes fast with the expense of chemical constituents.
 - If adequate moisture content is present and temperature conditions are appropriate, then grains will germinate. This results in activating both enzymes and microorganisms and the quality of grain becomes degraded due to mold growth. Under such circumstances, this is often followed by development of mycotoxins.
 - Microorganisms are minute living organisms like bacteria, yeasts and molds. Enzymes are special proteins that are built up in the living plant and animal tissue for the purpose of accelerating the chemical reactions necessary to life.
 - Autolysis is the self-decomposition of compounds by the action of enzymes. On the other side, if disintegration is done by combined action of enzymes and microorganisms; it is known as decay.
- 3. Oxygen in the Stored Atmosphere:** Like food grains, oxygen is the prime requirement of insects and microorganisms for their survival. Oxygen and carbon dioxide of inter granular environment influences the respiration of the grain and consequently also the rate of deterioration and heating. Majority of the fungi are storage aerobes. They fail to sporulate, their spores fail to germinate and their mycelium fails to grow when oxygen concentration is below a minimum which is well adequate for yeast growth. Storage of food grains in those areas having low oxygen will affect the growth and development of microorganisms and insects. Therefore, there is need to store these grains in hermetically sealed containers in which oxygen is removed. This is the basic principle of Controlled Air Storage. This type of storage results in retarding the growth of microorganisms. In early days, the level of oxygen was allowed to fall naturally but this method was very slow. But in modern practice, constant monitoring and adjustment of the CO₂ and O₂ levels within gas tight stores or containers is done to inhibit the growth of microorganisms and insects.

IV. PRINCIPLES OF STORAGE

The ultimate goal of storing grains is enhancement of shelf life by destroying the microbes. This may be achieved by controlling various parameters like temperature, moisture

etc. so as to prevent various food losses. Food losses during storage are the result of physical, chemical and biological damage.

Food spoilage predominates in the prevalent conditions like high temperature, moisture, humidity etc. So, the main aim of grain storage is to reduce the moisture content to safe levels so that microorganisms won't be able to grow.

To control the extent of food grains lost, the environmental conditions in the store requires to be controlled so as to lower the chances of:

- **Physical Damage:** This is caused by crushing, breaking, etc.
- **Chemical Damage:** This may be due to rancidity development and flavour changes, etc.
- **Biological Damage:** This is caused by insects, rodents and micro-organisms. Most of the damage to stored grains is caused by insects and pests that cause grain to heat resulting in a musty odor. The extent of grain damage relies on three factors namely:
 - **Moisture Content:** Most of the insects and micro-organisms did not grow when moisture levels are less than 9%.
 - **Temperature:** Inside storage temperature of grains should be kept low as higher temperature results in the growth of microorganisms.
 - **Oxygen Level:** If air tight conditions are kept prevalent inside the container, it declines the growth of microorganisms, insects etc.

Therefore, effective storage of grains involves controlling various factors like temperature, moisture, light, pests and modification of atmosphere etc.

1. Temperature: This is the most important ecological condition required for grain storage.

Effect on Respiration: Grains respire during storage period as they are biologically active in nature. Heat is generated as the product of respiration. Therefore, by controlling the temperature, one can enhance the shelf life of food grains by eliminating respiration rate.

- It has been noticed that the respiration rate of food grain increases with the temperature until inhibitions of vital process begin. Respiration whether of seeds, moulds or insects depends upon chemical reactions and is, therefore, accelerated by an increase in temperature until it is limited by such factors as the thermal inactivation of enzymes which are involved, exhaustion of the substrate, limitation of oxygen supply or accumulation of inhibitory concentration of carbon dioxide. Inappropriate control of storage temperature can result in biological and chemical damage to the food stuff being stored.
- Appropriate control over temperature results in preventing both physical and chemical damage. Physical damage includes melting of fats in the food products at high temperatures and crystallization of sugars in sweet foods at low temperatures.

- Temperature also regulates chemical damage that relies upon the temperature and the moisture content of foods. A 10°C rise in temperature results in two-fold increase in reaction rate. Therefore, cold storage will reduce such changes like fat oxidation and vitamin loss.
- It is not possible to control direct temperature, thereby reducing the moisture content of the stored produce are necessary to control it.

Effect on Micro-Organisms, Mites and Insect Activity: Temperature has a very prominent effect on the rate of metabolism, growth, development and distribution of pests and micro-organisms. There are many controlled measures by which stored products may become infested. These are mentioned as follows:

- By placing the clean grains in infested storage grains, admixing of clean grain with infested one, use of infested containers, improper storage facilities, infested transportation and distribution facilities etc.
- Infestation is also caused due to natural sources like bird nests and bedding places of animals, etc.

The optimum temperature for most of the insects lies between 29.4-32.20°C. Under Indian conditions some of the mites develop faster if the temperature is between 18-22°C. The micro-organisms differ in their thermal requirements and are commonly classified as Psychrophiles, Mesophiles, and Thermophiles on the basis of thermal classification. Micro-organisms grow faster as soon as temperature approaches their optimum. The required optimum temperatures for growth are:

- ❖ Psychrophiles: 10-20°C
- ❖ Mesophiles: 25-40°C and
- ❖ Thermophiles: 50- 60°C

2. Moisture: Moisture content is one of the dominant and critical factors in successful grain storage.

- High moisture content creates lot of troubles in storage as it favors the growth of microorganisms, germination etc. However, moisture content in the growing crop is naturally high and decreases as the crop reaches maturity and the grains are drying.
- The two main factors upon which chemical change in food products rely are the moisture and temperature. It is appropriate to store food grains at low temperature rather than stored at high temperatures. Moisture is the critical factor that creates deterioration of grains in storage. If the moisture content of grains is 9-10 %, then clean grain can be stored for many years.
- There is direct connection of moisture content and relative humidity in context with food grains. Moisture content equilibrates with the humidity of air. Therefore, fluctuation of moisture relies on temperature and relative humidity of air.

All micro-organisms require moisture for growth and survival. If the moisture content in a product is low, micro-organisms will be unable to grow, provided that the

moisture inside the storage structure is also kept low. Moisture should therefore be prevented from entering the store.

- **Effect on Insect Activity:** Moisture content of less than 10% is not appropriate for controlling storage insects and pests. With the increase in moisture content, there is increase in insect infestation. Normally, is there is excess of relative humidity (>75%), insect infestation increases. In some cases, it is noticed that pests and insects survive in some products having less moisture content. Although, a definite minimum moisture content is required and this changes markedly for different species. Insects that live in food having low moisture content exhibits a remarkable ability to consume and utilize water and are assuredly well suited for the food products in which they live. It has been familiar that weevils are attracted to moisture. The moisture content has to be more than 12% if rapid multiplication of weevils is required.
- **Effect on Micro-Organisms:** Water contributes to the chemical and physical structures of micro-organisms. Moisture has a great effect on development of fungi, bacteria and yeast etc. Micro-organisms are classified as hydrophytes (minimum requirements is 90% or more relative humidity (RH), mesophytes (minimum requirements is 80 to 90% RH) and xerophytes (less than 80% RH) on the basis of their minimum moisture requirement for growth. Bacteria require higher moisture level for growth in grains and grain products. But if micro-organisms are present in food, then they result in discoloration, loss in viability, heating and induct biochemical changes besides production of various toxins which are very harmful to human beings.

Hence it is essential that food grains must be stored at controlled moisture contents so as to extend their shelf-life. Various storage difficulties are caused by condensation of moisture. Condensation can occur, if the walls of a store are cooled below their dew point by low night temperature. The sitting and the ventilation of the store is of prime importance.

- **Light:** Insect species will behave different with different conditions. Few species will react different to light. Some species will be attracted towards light while others preferred dark conditions for growth. A stack of gunny bags kept in dark places and most concealed parts, are found to be more severely attacked than those which are exposed to light. Therefore, this should be given proper attention to reduce grain spoilage.
- **Insects and Chemical Residues:** Hygiene practices need to be followed while controlling insects in storage grains. Various options for insect control are mentioned as follows:
 - Cooling the grains with aeration
 - Residual chemical treatment for equipments and food grains.
 - Treating infested grain with dichlorvos
 - Fumigation with phosphine gas
 - Controlled atmosphere treatment

Some other factors that need to be kept in mind are as follows:

- Good hygiene practices must be followed for the grains employing aeration facility so to maintain the quality of grains.
- Fumigation with phosphine leaves less residues provided tablet formulations are not admixed with the food grains.
- Investigate with buyers before spraying insecticides over food grains. Spraying with insecticides or fumigating reduces insect problems but leaves chemical residues.
- The existence of residues and their accumulation affects the adequacy of the grains to markets. Some markets prefer grain without residues. Grain buyers will not accept grain treated at rates higher than those specified on the label or within specific withholding period.
- Fumigation of the bin as early as possible the grain is poured in and afterwards 4-5 weeks later this fumigation treatment may be repeated.
- Inspection of grains at least once in a month by collecting samples. Re-fumigation is done if an insect infestation is found.

It is already known that the susceptibility of stored grain insect pests to fumigants is influenced by various factors viz., temperature, carbon-dioxide, oxygen, nutrition, population density, pre-fumigation starvation, post-fumigation starvation, relative humidity, sub-lethal fumigation, repeated fumigation, presence or absence and nature of commodities to be fumigated, effect of age, sex of insects, respiration etc. Hence, the success or failure of fumigation operations depends upon these factors.

Excess amounts of foreign matters and cracked and distorted grains will provide favorable conditions for the growth of microorganisms and fungus beetles. These do not develop readily in clean grain but feed initially on grain dust, broken kernels, moulds, etc. It is very difficult to fumigate the grains which has a high percentage of broken grains and foreign materials.

- **Inspect Grain Frequently During Storage:** Frequent inspection of grains is very important which otherwise results in creating bad odour due to action of mould and insects. Storage problems can be judged by effective aeration system and

By detecting the smell of the air coming through the grain. Any 'hot spots' if detected; must be cooled immediately by aeration. If the trouble is created by insect activity, the grain should be immediately fumigated.

- **Storage Capacity:** Distinct food grains have different features. They vary in their densities, angle of repose and moisture content. Food grains settled during their storage phase. The storage capacity of grains is determined by utilizing flat pads. Angle of repose must be calculated for each food grain while determining the volume of food grains piled on the flat pad. The angle of repose will increase for wet grain and may also vary depending on grain quality and its admixture content.

- **Grain Storage Facilities:** A wide range of grain storage facilities also play predominant role in judging the quality of on-farm grain storage. They all vary in their cost and length of time as per their used for storage. Controlling the stored grains and seed needs varietal methods to guarantee the quality of the product entering the storage facility so that it does not spoil over time. These methods include: sanitation practices, storing clean and dried grains, controlling temperature and aeration, usage of chemical protectants, regular sampling, and the use of fumigation methods.
 - A systematic monitoring facility should be followed until the grain leaves the storage facility.
 - Storage facilities should be checked regularly for any type of spoilage. Proper storage moisture relies on type of seed, length of storage and storage conditions.
 - The storage time plays important role in judging the most suitable storage practice. Therefore, storage can be classified into the following types:

Transit Storage

- A short-term storage where crop rotation is practiced and the grains are transported from one place to another by replacing the old stock with the new one.
- Examples are Government godowns, godowns at seaports and godowns of retailers etc.
- This type of storage has been practiced in a variety of sheds on an emergency basis. In these sheds, bag storage has been followed where the bags are arranged in stacks.

Short-Term Storage

- This type of storage is one of the easiest and most economic methods of grain storage under rural conditions in India. This type of storage is followed by cultivators who stored their grains from harvest to sowing and food grains from harvest to harvest. Examples of this storage category are bukhari, kothar, morai, etc.
- However, the grains are infested with insects in this type of storage. Rats often create trouble in some areas as they easily cut through the mud walls. Grains are also found to be greatly affected by high humidity conditions in some wet regions of the country. As a result, the loss of food grains in storage is often quite considerable.
- Following are some of the short-term storage facilities that are used along with sources of information available as per their construction and usage. Two types of short-term storages are:
 - ❖ Steel mesh silos
 - ❖ Plastic covered bunker storage and ground dumps.

Long-Term Storage

- For this type of storage, careful management and implementation is required by large-scale trade stockist and Government agencies to keep buffer stocks or maintain food banks.

- Moisture content is one of the most important factors prior to the storage of grain. Grains should be thoroughly dried in the sun but it is highly recommended that a suitable dryer be provided for each storage godown.
 - Large-sized structures are constructed on the basis of the Pusa bin will also serve well for long-term storage. Such storage structures housed in storage godowns are permanent means of long-term storage which is quite cheap in the long run.
 - Two types of long-term storage are:
 - ❖ Prefabricated steel silos
 - ❖ Underground pits
 - Sealed air-tight storage is one of the cheap methods of insect pest control. Another advantage is that the moist air cannot enter the silo. But important disadvantage of air-tight storage is that further drying of the produce in the store is impossible. Therefore, the crop needs to be well dried before placing in the store.
- **Harvesting and transportation facilities:** These activities should be appropriate in context with crops as these will affect their storage life resulting in qualitative and quantitative losses. Therefore, harvesting of crops should be done as soon as possible which otherwise be will be easily attacked by insects, molds etc. Following things should be kept in mind:
 - Inspection of grains is very essential before harvesting so that they must be free from any kind of dirt, dust, insects etc.
 - Harvesting and transportation facilities must be cleaned prior to crop harvesting. Harvesting and threshing is important so as to obtain clean and unbroken grains for proper storage.
 - For drying of grains, the grains should be spread over plastic sheets, which otherwise pick moisture from the ground.
 - The threshing yards must be free from insect infestation.
 - The grains should be kept cool and dried between harvesting time and storage.
 - Therefore, in all situations, grain must be harvested in a timely manner before shattering, pre-harvest sprouting and weathering to minimize pre-harvest losses.
 - **Cleaning and Grading:** These are one of the most prominent factors that need to be taken great care of before storing grains. Harvested grain (threshed/shelled/dried) needs further processing to get rid of various types of undesirable matters like inert material, decorticated seeds, damaged seeds etc. Cleaning and grading results in reduced bulk of material, high value products, safe and longer storage, more turn out of better-quality milled products. These practices allow the growers to reduce the level of defects in their grain following harvest. Moreover, they help in enhancing the probability of grain meeting the required specifications and attracting a premium price. Cleaning is normally carried out with the purpose of removal of weeds and other contaminants.

If the food grains are contaminated with dirt, dust, straw etc., they will affect the quality of food grains during storage. Therefore, food grains must be free from any type of foreign matter and broken grains. It is also very important to remove chaff and weed seeds as they will affect the movement of air within the crops and fill up empty void spaces; creating several storage problems. Therefore, cleaning is of top most priority before storing grains.

- **Good Housekeeping Practices:** This sanitation programme is of utmost importance while preventing grain storage losses. To ensure good grain handling facilities engage in a variety of activities to control the accumulation of grain dust, good housekeeping practices are very essential. Good housekeeping practices include:
 - Calculation of moisture content of food grains is the first factor while considering grain storage. Moisture content should be within permissible limits which otherwise results in spoilage of grains.
 - Don't intermix old grains onto new grains.
 - Thorough cleaning of storage bins is essential prior to filling.
 - Use shovels, brooms etc. to clean out all the grains.
 - Inspect for any leakage inside and under the storage bins.
 - Repair and maintenance of roofs is of prime concern.
 - Bin area should be in good condition and also free from rodents and insects by utilizing rodent traps.

- **HACCP:** HACCP stands for Hazard Analysis Critical Control Point. It is a base of food safety system where food safety is guaranteed. HACCP is implemented at any step of food chain by controlling hazards.

HACCP principles are beneficial for calculating risks in food grain storage. Proper identification and management of hazards is important. Practically, HACCP is not essential for conventional on-farm crop production activities, including food grain storage. The effective practices will help in presuming the proof that food grain storage is technically correct.

- **Controlled Atmosphere Storage (CAS) and Modified Atmosphere Storage (MAS):** Both these techniques are nowadays widely used in grain storage. The technologies involved in CA storage are complicated and sophisticated. In CA storage, continual monitoring of gases like oxygen, nitrogen and carbon dioxide is done. When CA technique is combined with other methods like refrigeration, this tends to reduce the respiration and other quality changes in storage. But the applicability of CA storage is restricted only to few grains. While in MA storage, high levels of carbon dioxide and other gases are maintained inside a closed chamber whereas, low levels of oxygen are allowed by controlling respiration rate of food grains. Both technologies are best when they are combined with refrigeration storage by controlling gases like oxygen, nitrogen and carbon dioxide.
- **Sampling Stored Grain**
 - It is very important to check the quality of the products at the receiving platform of storage centers. Practically, it is not possible to check the quality of all the samples for quality analysis. Thereby, a representative sample is taken whose quality is judged by adequate analysis.
 - To acquire a representative sample for sampling, intermingling of samples is done several times. Afterwards, a sample is pick from the lot whose necessary testing is done.
 - Sampling criteria differs for bag or bulk storage of grains.

- Samples should be taken from the areas of general contamination like doors, inlets, emptying points. The general area of contamination of insects in a silo is at the top.
- Sampling once a month is important and for this purpose, at least three samples need to be taken. This must be taken:
 - ❖ At the time of storage.
 - ❖ Approximately halfway through.
 - ❖ About a month before the store is emptied.
- **Monitoring Regularly:** Monitoring the food grains is very essential throughout the storage period. Continuous inspection should be carried out if insects and molds are detected at the early stage. The methods of monitoring will vary with the timings, year, season and initial condition of the grain etc. Normally, food grains should be monitored at least once a month during spring, summer and fall. It is very important to carry out this inspection in summers as this season is favorable in all aspects like temperature and aeration conditions etc. Proper monitoring of actual moisture and temperature is mandatory during each inspection. Bins should be monitored to look for any leaks or condensation on bin roof, condensation on grain surface etc. Any issues that are detected need to be resolved as early as possible. This may include various techniques like dehydration, aeration and fumigation etc.
- **Seed Germination and Testing Germination Rates on Retained Seed:** It is very essential to store the grains at optimum temperature and moisture content so as to avoid the risk of contamination of moulds, insects etc. Inappropriate storage conditions accelerate the deterioration process markedly. Germination test rate on retained seeds helps in keeping seeds at appropriate conditions. This test will be done in a month after harvesting. If germination test is found adequate, utilize that to consult how much extra seed to keep, adding an allowance for all the other factors that will reduce germination and seed establishment.
- **Eliminate spout lines:** Broken kernels and weed seeds are concentrated in the center of the grains where density of stored grains is more, which creates trouble for air to penetrate. These regions are known as spout lines. Therefore, elimination of spoutlines by cleaning the grain prior to binning or using a spreader device is important. High moisture weed seeds commonly collect in spout lines and mold problems often start at these sites. The appropriate method to detect spout lines is to force a probe onto the center of the grains.
- **Use of Storage Structures:** The structures that keep the stored materials for storing their characteristics are known as storage structures. The choice of these structures relies on several factors like climatic conditions, production stage etc. These structures are categorized as traditional and modern storage structures. Traditional storage structures include: ground or pit storage and cellars and caves.
 - The pits storage is generally used that may be shielded with pucca or kuccha and outlined with straw or leaves; the produce is then shielded with straw accompanied by thin layer of soil.
 - The cellars are complicated kind of below ground storage.
 - The caves are the natural shields accessible under big rocks.

Modern storage structures are generally employed for medium or large-scale storage and include: Controlled atmosphere storage system, Refrigeration, Silo/Bin, Cold storage etc.

- Refrigerated storage is a prominent technique widely accepted for storing horticulture crops. Basically, all crops can take advantage by being stored at a appropriate low temperature which improves their shelf life and preserves quality.
- **Proper Sanitation Practices:** Sanitation is an overlooked component of safe and effective grain storage. Various type of microorganisms, insects, molds etc. are responsible for limited shelf life of food grains stored on the farm. Hence, it is very important to follow proper sanitation practices so as to minimize spoilage. These sanitary practices will include:
 - Thorough examination of bin roofs and sides for any rust, cracks etc.
 - To prevent rodent damage, repairing of leaks should be given utmost priority.
 - Remove old grain from grain carts, combines etc. for harvesting, transporting or handling grain.
 - Remove any spilled grain, weeds etc. to reduce insect infestation.
 - Remove all debris from fans, aeration ducts etc.
 - Sanitation of walls is equally important after repairing of storage bins.
- **Dealing with Global Insect Resistance Problem:** In this technique, food grains are treated with insecticides. Insect infestation is prevented by treating grain as it is moved into storage with one of three approved insecticides like Chlorpyrifos-methyl, Malathion and Pirimiphos-methyl. Therefore, controlled dose of insecticidal treatment will control all insects and pests. Moreover, this technique will not permit fastest growth of resistance to insecticides.
- **Use of Technically Trained Hierarchy:** Such persons will be allowed to handle food grains who have keen interest in storage and handling practices. In this prospective, personal hygiene of the person dealing with grain storage is also very important. This involves the concept of GMP (Good Manufacturing Practices) which includes:
 - Personnel
 - Training and supervision
 - Facilities and installation
 - Storage and distribution
 - Pest control
 - Code
 - Control and quality guarantee
 - Production, operation and process
 - Cleaning and Sanitation

The awareness of the persons dealing with grain storage, training and awareness programme will guarantee necessary results.

- **Phosphine Fumigation Technology:** Phosphine remains the single-most relied upon fumigant to control stored grain pests in Australian grain-production systems but continued misuse is resulting in poor insect control and developing resistance in key pest species. An important new development instigated by Common Wealth Scientific

and Industrial Research Organization, Canberra, Australia is the utilization of Phosphine in gas form. Phosphine is applied in gas cylinders admixed with carbon dioxide acting as carrier. This technology proves to be profitable in grain storage but it is quite expensive.

V. MAINTAINING FOOD GRAIN QUALITY IN STORAGE

Nearly 10 million tonnes of food-grains are lost each year in India by the use of faulty storage techniques. The large stocks of grain in storage pose various problems which are unique and quite different from those of smaller lots. To minimize the storage losses, some practices for large scale storage of food grains has been developed.

1. Moisture

- Food grains with higher moisture content higher than the safe acceptable limit results in losses. Proper control of moisture content is important from storage point of view. Therefore, dry the moist grain before storage because it respire more quickly and gives off more heat and moisture, which favors insect and mould growth. Moisture content should be low to avoid fungal and bacterial growth.
- Aeration is a process of cooling a grain bulk by passing large quantities of untreated air of suitable temperature and humidity, so that the grain in storage remains in an acceptable condition for long periods.
- Aeration reduces grain temperatures to minimize mould growth and insect/mite activity. It maintains the grain quality and provides more uniform grain temperatures to prevent convection air movement and moisture transfer. Fumigants may also be distributed by aeration fans.
- Aeration slow down the rate of spoilage of high moisture grain but if the moisture is more than 2-3% above the limits, it should be dried before long term storage.
- Stored grains have relatively low thermal conductivity. Daily temperature changes have a very small effect upon grain temperatures, and even seasonal changes from summer to winter are likely to cause pronounced grain temperature variation only in most exposed part of a large grain bulk.
- The aeration equalizes the temperature of the grain thus arresting multiplication of insect and mould activities as well as moisture migration. Grain aeration is more properly considered as a preventive rather than a remedial measure.
- Hot air drying is essential to maintain the quality of high moisture grain. However, holding grain at too high a temperature for too long in the dryer will reduce grain quality. Operate the equipment according to specifications of the dryer manufacture. Using higher flow rates is a safer way to speed up drying than increasing temperature.
- Selling grain at a moisture content below that allowed by market results in economic loss. Grain loses approximately 1.2 % of its weight for every 1% of moisture content reduction.

2. Temperature

- Aeration will effectively reduce the grain temperature and minimizes the grain spoilage by maintaining its quality.

- Aeration will also track temperature differences that result in moisture migration from warmer top cooler patches in the grain.
- Insects and moulds affect the quality of grain directly by their feeding and development and indirectly through generation of heat and moisture.
- High temperatures and moisture favor development of insects and moulds. Development of insects is limited by temperatures below 15°C and by moisture below 9% in cereal grains. Development of moulds is limited by temperatures below 10°C and by moisture below 13% in cereal grains.

VI. CONCLUSIONS

Grain production has been rapidly increasing due to progress in production technology but inadequate storage results in high losses in grains. Temperature and moisture are the two most prevalent factors which affect metabolic rate, growth, development and general behavior of stored grain insect pests and fungi and results in qualitative and quantitative losses. The methods and equipments differ for each grain but inappropriate storage solutions cause adequate qualitative and quantitative losses, decreasing product quality and storage time. Grain storage can be enhanced by controlling temperature, moisture, oxygen and by applying various techniques like aeration, drying, use of fumigants, insecticides etc. Therefore, storing grains in adequate conditions for a required amount of time will contribute markedly to the world economy in context of efficiency.