Journal of Agricultural Science and Research (JASR)
Vol. 4, Issue 2, Dec 2017, 23-38

CHEMICAL CHANGES AND NUTRIENT DETERIORATION IN CROP BYPRODUCTS DUE TO INSECTS AND DISEASES

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ABSTRACT

During storage of agricultural products, a number of physicochemical and physiological changes occur. These changes includes pasting properties, colour, flavour, and composition affect seed quality. A large number of pathogenic fungi, bacteria, viruses and insects infecting and infesting cereals, oil seeds and pulses. They cause spoilage and deterioration of nutritional quality of agricultural products. This review article is about the most important cereals, oil seeds and pulses components, their nutritional value, their nutrient deterioration and proper storage to avoid post harvest losses.

KEYWORDS: physicochemical, viruses and insects & harvest losses

Received: Jul.16, 2017; **Accepted**: Aug 06, 2017; **Published**: Oct 03, 2017; **Paper Id**.: JASRDEC20173

Original Article

INTRODUCTION

Deficiencies of micronutrients such as iron, zinc, and vitamin A (hidden hunger) afflict over three billion people. Wheat and rice are the main source of nutrients for the most of the world population. Over three billion people are currently micronutrient (i.e. Micronutrient elements and vitamins) malnourished.

Vitamins are defined as a diverse group of food-based essential organic substances that are not synthesized by the human body, but by plants and microorganisms.

Micronutrient malnutrition (hidden hunger) now afflicts over 40% of the world's population and is increasing especially in many developing nations. A high risk of tissue hypoxia and heart failure, which can lead to death in young children and pregnant women, is associated with Fe deficiency (Viteri, 1998). Selenium (Se) is an essential micronutrient for humans and animals, with antioxidant, anti-cancer and anti-viral effects.

During storage, a number of physicochemical and physiological changes occur; this is usually termed as ageing. These changes which include pasting properties, colour, flavour, and composition affect seed quality. Meeting the food demand of a rapidly increasing global population is emerging as a big challenge to mankind. The population is expected to grow to 9.1 billion people by the year 2050, and about 70% extra food production will be required to feed them (Godfray *et al.,* 2010; Hodges *et al.,* 2011 and Parfittet *et al.* 2010.

"Food loss" is defined as food that is available for human consumption but goes unconsumed (Aulakh *et al.,* 2013 and Buzby *et al.,* 2015). The solutions to reduce postharvest losses require relatively modest investment and can result in high returns compared to increasing the crop production to meet the food demand.

THE IMPORTANCE OF CEREALS, PULSES AND OIL SEEDS IN HUMAN NUTRITION

The Importance of Cereals in Human Nutrition

The word cereal is derived from ceres, the Roman Goddess of grain. The common cereal crops are rice, wheat, corn, oats and rye.

In almost every country and region, cereals provide the staple food. Cereal grains contain 60% to 70% starch and are excellent energy rich foods for humans. People get a large amount of their dietary energy (20% - 30%) from cereals or foods containing cereal starch. The cereals can easily supply this quantity of protein, but unfortunately they lack the essential amino acid lysine and therefore they must not be used as the sole source of dietary protein. Cereals are an excellent source of fat soluble vitamin E, which is an essential antioxidant. Whole cereal grains contain 20% to 30% of the daily requirements of the minerals selenium, calcium, zinc, and copper. Bran contains substances such as phytic acid, which chelates minerals, preventing them from being easily digested and absorbed. The major fatty acids in cereal grain lipids are linoleic, oleic and palmitic.

Early workers divided the proteins of wheat into four solubility classes called Osborne fractions:

- Albumins- water soluble;
- Globulins- soluble in salt solutions, but insoluble in water;
- Gliadins- soluble in 70-90 percent alcohol;
- Glutenins- insoluble in neutral aqueous solutions, saline, solutions, or alcohol.

Table 1: Proximate Composition of Protein in Cereals

Cereals	Scientific Name	Protein (%)
Rice	*Oryza sativa*	7.3
Sorghum	*Sorghum bicolour*	8.3
Maize	*Zea mays*	9.8
Wheat	*Triticum aestivum*	10.6
Barley	*Hordeum vulgare*	11.0
Pearl Millet	*Pennesetum glaucum*	11.5

Among the Osborne fractions in cereals, the prolamin fraction has been the most studied (Eliasson and Larsson 1993). This fraction is called gliadin in wheat, secalin in rye, hordein in barley, avenin in oats, and zein in maize.

The baking quality of wheat flour from different varieties is influenced by the glutelin content (Eliasson and Larsson 1993). The gliadin and gluten in fractions of wheat represent 80-85 percent of the wheat endosperm protein and these fractions together make up the gluten.

A large number of pathogenic fungi, bacteria, viruses and insects infecting and infesting maize grain cause combined worldwide annual losses of 9.4% (Verga and Teren, 2005). Fungi affect the quality of grain as a result there will be, increase in fatty acid, reduction in germination, increase its mustiness, production of toxins and finally leading to spoilage of grain in many ways (Dubale, *et al.,* 2014).

The Importance of Pulses in Human Nutrition

Pulses belong to the family *Fabaceae***.** Pulses provide protein, complex carbohydrates, and several vitamins and minerals. Like other plant-based foods, they contain no cholesterol and little fat or sodium. Pulses also provide iron, magnesium, phosphorus, zinc and other minerals, which play a variety of roles in maintaining good health. Pulses are 20 to 25% protein by weight, which is double the protein content of wheat and three times that of rice. While pulses are generally high in protein, and the digestibility of that protein is also high, they are often relatively poor in the essential amino acid methionine. Grains (which are they deficient in lysine) are commonly consumed along with pulses to form a complete diet of protein.

The vitamins present in appreciably quantities in pulses are thiamine, riboflavin, pyridoxine and folic acid; vitamin E and K are also found in pulses. Vitamin K functions primarily in the liver where it is necessary for the formation of blood clothing factors.

Table 2: Proximate Composition of Protein in Pulses

Common Name	Scientific Name	Protein Content (%)
Broad bean	*Vicia faba*	24.0
Chick pea	*Cicer arietinum*	22.2
Common bean	*Phaseolus vulgaris*	23.9
Common pea	*Pistum sativum*	23.1
Cowpea	*Vigna unguiculata*	24.0
Pigeon pea	*Cajanus cajan*	21.0
Groundnut	*Arachis hypogaea*	26.2
Soya bean	*Glycine max*	40.3

The Importance of Oil Seeds in Human Nutrition

Oilseeds, such as soybean, cottonseed, rapeseed (canola), sunflower seed and peanut, are annual plants (O'Brien *et al.* 2000). They are the largest source of vegetable Oils.

Soybeans (*Glycine max)* and soya products have played an important part in world. However, there was little use of soybean oil, because of problems with flavour reversion. It is now the dominant oilseed produced in the world (Wang 2002).

Brassica napus, B. rapa & *B. juncea* are rich in multi saturated fatty acid (MUFA) and alpha linolenic acid (ALNA).

The fatty acid composition of sunflower (*Helianthus annus*) seed oil is dependent on where the crop is grown. Cooler climates produce higher amounts of the *n*-6 polyunsaturated fatty acid (PUFA) linoleic acid (an essential fatty acid, EFA) compared with warmer climates, where the MUFA oleic acid is more dominant.

Peanut (*Arachis hypogaea*) also known as groundnuts. Peanuts are grown for oil (sometimes referred to as Arachis oil) and as a food commodity.

Linseed (*Linum usitatissimum*) is also known as flaxseed and has a very high ALNA content (35– 60%. ALNA is also an EFA (essential fatty acid) and is a member of the *n*-3 family. Linseed oil is used in a variety of industrial applications (*e.g.* resin and plastic, varnish and paint), while the plant's fibre is used in the preparation of high-quality products in the paper and textile industries.

Safflower (*Carthamus tinctorius*) has the highest level of PUFAs (more than 70% as linoleic acid). High oleic oil has also been developed with a 77% oleic acid content.

Sesame seed (*Sesamum indicum*) contains MUFA and PUFA in roughly equal amounts. Sesame seeds can be eaten whole.

Cause of Nutrient Deterioration and Chemical Changes

Storage conditions are important in the ageing process. Off-flavour in cereals and pulses develops due to a decrease in the concentration of compounds responsible for the initial bread flavour and/or an increased concentration of unwanted compounds.

Growth and Activities of Micro-Organisms

Micro-organisms can make both desirable and undesirable changes to the quality of grain s and seeds. The two major groups of micro-organisms found in foods are bacteria and fungi, the latter consisting of yeasts and moulds. Bacteria and fungi are generally the fastest growing, so that in conditions favourable to both of them. Spoilage may also take place when the food products are stored at unusually high temperatures: thermophilic spore-forming bacteria may multiply, causing undesirable changes such as flat sour spoilage. The species of micro-organisms which cause the spoilage of particular foods are influenced by two factors: a) the nature of the foods and b) their surroundings. These factors are referred to as intrinsic and extrinsic parameters. Micro organisms cause damage in field as well as in storage.

Fungi are a major cause of postharvest deterioration of cereals, legumes and oilseeds. The fungi that invade grains are generally grouped into two categories: (1) field fungi which include species of *Alternaria, Cladosporium, Fusarium* and *Helminthosporium*; and (2) storage fungi which are predominantly species of *Aspergillus* and *Penicillium.* This division is based primarily upon moisture requirements.

Many fungi associated with field damage such as *Alternaria, Chladosporium, Aspergillus, Curvularia, Fusarium* and *Helminthosporium.* These fungi required high moisture with 90 % humidity. These fungi cause seed damage, nutrient loss, embryo degradation, shrivelling of seed.

According to Sullivan (1984), groundnut seeds are highly susceptible to diseases because they are rich in nutrients useful for numerous fungi such as *Rhizopusspp, Penicillium sp., Aspergillus Niger* and *A. Flavus.*

The fungal growth also causes discolouration of grain, heating, mustiness, dry matter loss, and production of several secondary metabolites such as mycotoxins, which are potentially dangerous to humans and animals (Christensen and Kaufmann 1969; Williams and McDonald, 1983).

A number of fungal species associated with sorghum belong to the genera *Fusarium*, *Aspergillus* and *Penicillium*, which have been known to produce mycotoxins, that cause mycotoxicosis in animals and humans (Anonymous 2001).

Figure 1: Rice Seed Spoilage due to Fungal Organisms (Photo Courtesy - IRRI)

ACTIVITIES OF NATURAL FOOD ENZYMES

Enzymes which are endogenous to plant tissues can have undesirable or desirable consequences. Examples are involving endogenous enzymes include.1. The post-harvest senescence and spoilage of fruit and vegetables; 2. Oxidation of phenolic substances in plant tissues by phenolase (leading to browning); 3. Sugar - starch conversion in plant tissues by amylases; 4.Post-harvest demethylation of pectic substances in plant tissues (leading to softening of plant tissues during ripening, and firming of plant tissues during processing).

The major factors useful in controlling enzyme activity are: temperature, water activity, pH, chemicals which can inhibit enzyme action, alteration of substrates, alteration of products and pre-processing control.

INSECTS AND RODENTS

Insects are the most diverse species of animals living on earth. The majority of insects are directly important to humans and the environment. Insect pests inflict damage to humans, farm animals and crops. Insect pests inflict damage to humans, farm animals and crops. Insects feed on most feed ingredients and contaminate them with faeces, webbing, body parts, foul odours, and micro-organisms. Beetles and moths are the most destructive of the grain insects, and many are capable of destroying an entire store of feed. High temperatures reduce the efficacy of grain protectants, allowing insects to multiply. Cooling of grain (below 15 degrees C) helps to suppress insect activity. Rats and mice carry disease-producing organisms on their feet and/or in their intestinal tracts and are known to harbour salmonella of serotypes frequently associated with food-borne infections in humans.

Figure 2: Seeds Damaged by Store Grain Pests (Photo Courtesy- Agropedia and Krishisewa)

STORAGE MITES

Storage mites are considered to be detrimental to grain fitness and commonly cause a change in the chemical composition of the stored wheat. The present study showed the changes in nutritional value of the wheat grains of variety

Lasani-08 when subjected to infestation with varying population levels of the acarid mite, *Rhizoglyphus tritici*. The protein contents were lowest (12.66%) after three months of storage with highest level of mite infestation. Also, there was a significant effect of mite population on fat contents.

TEMPERATURE

Warm humid environments promote insect growth, although most insects will not breed if the temperature exceeds about 35 C° or falls below 10 C°. Many fungi and bacteria grow more in warm and humid climate. Humid atmosphere is also a cause for deterioration. All insects attacking stored feedstuffs have an optimum zone of temperature at which populations increase most rapidly. Most of the important insect pests are tropical species with an optimum temperature of about 28°C.

MOISTURE AND DRYNESS

High moisture content (13 % or more) renders feed grains soft and susceptible to attack. When storage of grains at high moisture (13 percent or more), it favours the growth of micro-organisms which decrease the nutritional quality. It can occur either as a result of a poor selection of packaging material in the first place, or failure of the package integrity during storage. In general, moisture absorption is associated with increased cohesiveness.

DISEASES

In the field many fungi cause discoloration of developing grains, weaking or death of embryos, blights etc. Species of Alternaira, Curvularia, Drechslera and Cladosporium etc. Many of the field fungi are not directly involved in grain spoilage. However, their presence is responsible for the appearance and quality of the grain.

Black point diseases of wheat (Alternaria tenuis) reduce the commercial value of the grain.

Figure 3: Black Point Diseases of Wheat (Photo Courtesy-Agropedia)

Infection of cereal by *Claviceps sp.* results into formation of sclerotia. Consumption of ergot contaminated grains has been known to develop poisonous symptoms on animal and human.

Figure 4: Ergot Diseases of Bajra

Drechslera oryzae on paddy seeds produce brown to black lesions on infected kernals.

In Alternaria blight of guar decrease in soluble protein, total phenols.

Figure 5: Alternaria Blight of Guar

In loose smut of wheat whole seed convert into black charcoal like powdery mass. These seeds are unfit for sowing and consumption purpose.

Figure 6: Loose Smut of Wheat

In downy mildew of pearl millet (Bajra) whole ear convert into leafy mass. Such ears do not produce seeds. This disease leads in the yield losses.

Figure 7: Green Ear Disease of Bajra

WEEDS

Many weed plants are responsible for cause diseases in humans. Seeds of *Argimone maxicana* (Satyanasi) look like mustard seed. When both types of seeds are mixed, cannot identify easily. Dropsy disease causes due to consumption of contaminated mustard oil.

Nutrient Deterioration and Chemical Changes

Changes in Oil Content

Groundnut seed contains 44-56% oil and 22-30% protein on a dry seed basis and it is a rich source of minerals (phosphorus, calcium, magnesium and potassium) and vitamins (E, K and B group) (Savage and Keenan, 1994). The micro flora causes nutritional and chemical change of groundnut (*Arachis hypogea*), during a storage period. A total number of seven fungal species were identified namely viz., *Aspergillus flavus, Aspergillus Niger, Aspergillus fumigatus, Rhizopus sp., Penicillium sp., Mucor sp.* and *Fusarium sp.*

The importance of presence of moulds in produce lies in the possibility of causing physical and biochemical changes in oil, when stored under conditions favourable for their growth (Ingale and Shrivastava, 2011). Aflatoxin also deteriorated the quality of ground nut seeds and oil content. Aflatoxins are toxic and among the most carcinogenic substances known.

Production of aflatoxin, due to the invasion of the fungus *Aspergillus flavus* to groundnut pod/kernel is a serious problem in the trade of groundnuts in the international market, which has seriously hampered the export business of the developing countries (Nautiyal, 2002).

Figure 8: ***Aspergillus flavus*** **Infected Groundnut Seeds (Photo Courtesy- Agri-Palm.com)**

The deteriorating in sunflower oil due to seed-borne fungi is of a great importance. In the present study ten seed-borne fungi were isolated from abnormal sunflower seeds collected from different locations in Egypt i.e. *Aspergillus flavus, A. Niger, Alternaria alternata, Curvularia lunata,Fusarium moniliforme, F. oxysporum, F. semitectum, Penicillum digitatum, Stemphylium sp., and Trichoderma spp.*

A noticeable variation was recorded in sunflower oil samples, such as chemical properties i.e. saponification number, fatty acid value, iodine number, peroxide value also, physical properties i.e. moisture content, gravity, odour absorbent, absorbance (470 nm) and oil colour, these differences are due to the secondary metabolites produced by storage fungi.

One major problem that besets melon seeds is that, it deteriorates quickly in storage due to fungal infection (Aboaba and Amasike, 1991; Bankole, 1993). The effect of fungal attack on melon seeds include decreased nutritive value, change in colour, and increase in the peroxide value, reduced seed germination and mycotoxin production (Bankole *et al*., 1999; 2004).

Production of Mycotoxins

Fungi growing on stored grains produce highly toxic metabolites (mycotoxins). Consumption of food containing mycotoxins can lead to serious physiological disorders in humans and animals. The disease caused by mycotoxins has been grouped under mycotoxicosis. Of the known mycotoxins, the most important are the aflatoxin. Aflatoxins are recognized as the most important mycotoxins. The name was created around 1960 after the discovery that the source of turkey X disease was *Aspergillus flavus* toxins. Aflatoxins are toxic and among the most carcinogenic substances known. Ochratoxin A (OA), fungal growth (glucosamine concentration), changes in the content of starch, lipids and protein, and the amino acid in cereals. In aflatoxin A stands for *Aspergillus,* Fla for *Flavus* and Toxin for Posion.

Aflatoxins are naturally occurring mycotoxins, that are produced by *Aspergillus flavus* and *Aspergillus parasiticus*, species of fungi. Accumulation of aflatoxin during self-heating, the biochemical and baking properties of the grain deteriorated. Aflatoxins have been isolated from all major cereal crops, and from sources as diverse as peanut butter and cannabis. The staple commodities regularly contaminated with aflatoxins include cassava, chillies, corn, cotton seed, millet, peanuts, rice, sorghum, sunflower seeds, tree nuts, wheat, and a variety of spices intended for human or animal consumption.

Table 3: Some Other Mycotoxins are also Found in Grains

SI. No.	Name of toxin	Producer fungi
1.	Rubratoxins	*Penicillium rubrum*
2.	Ochratoxin	*Aspergillus ochraceus* & *P. Viridicatum*
3.	Patulin	*A. Clavatus* & *A. Terreus*
4.	Termortins	*P. Cyclapium* & *A. Flavus*
5.	Zearalenone	*Fusarium oxysporum f.sp. moniliformae*
6.	Citreoviridin	*P. Citreoviridae* & *P. Toxicarium*
7.	Citrinin	*P. Citrinum*
8.	Penecillic acid	*P. Cyclapium*

Figure 9: ***Aspergillus flavus*** **Infected Maize Cob (Photo Courtesy- AMP. Pintrest))**

Enzymatic Activities of Seed

Fungi stimulate the activities of pectic enzyme complex, amylase, invertase and protease in the seed of finger millet. Storage fungi stimulate hydrolysis of starch and protein producing extra cellular amylase and protease besides cellulose and lipase. The *alpha*-amylase and *beta*-amylase activities of rough rice samples decreased significantly during storage. These changes paralleled the decrease in soluble protein in the grain. Peroxidase and catalase activities were lost rapidly during storage of rice.

Reduction and Biochemical Changes in Seed Quality

The fungi and insects deteriorate the seeds both qualitatively and quantatively. They change the starch, fatty acids, reducing sugars, non reducing sugars, insoluble nitrogen, and protein contents of seeds. The level of total conc. of phenolic compounds increases significantly in infected gram seeds during storage (Dwivedi, 1990). As well as their possible health significance, the presence of insects and insect excrete in seeds may render unsaleable, causing considerable economic loss, as well as reduction in nutritional quality, production of off-flavours and acceleration of decay processes due to creation of higher temperatures and moisture levels. Shibuyu *et al* reported that the cell wall structure was decomposed by endo-xylanase during storage which led to the changes in amylo grams of rice. The changes in functionality associated with ageing have focused on the properties of rice components, such as starch, protein, and lipids, during storage. These results probably reflect the increase in water-insolubility of rice starch and protein during ageing, resulting in a slower rate of cooking. Granary weevil *(Sitophilus granarius)* and Rice weevil *(Sitophilus oryzae)* adults feed in and on whole and broken grain. Indian meal moth (*Plodia interpunctella*) attacks oilseeds and cereals. Larvae spin webs on the surface of the grain and consume kernels within the webbing. Rust-red flour beetle (*Tribolium castaneum*) capable of infesting both whole grain and oilseeds, but a more serious problem in stock feed and processed grain (flour).

Table 4: List of Some Store Grain Pests

SI. No.	Common Name	Scientific Name
1.	Weevils	*Sitophilus* sp.
2.	Grain moth	*Sitotroga cerealella*
3.	Flour beetles	*Tribolium sp.*
4.	Saw-tooth grain beetles	*Oryzaephilus sp.*
5.	Flat grain beetles	*Cryptolestes sp.*
6.	Tropical warehouse moth	*Cadra cantella*
7.	Lesser grain borer	*Rhizopertha dominica*
8.	Khapra beetle	*Trogoderma granarium*

Flavour Changes

In fruits, cereals and vegetables, enzymically generated compounds derived from long-chain fatty acids play an extremely important role in the formation of characteristic flavours. In addition, these types of reactions can lead to significant off-flavours. The compound, 2- acetyl-1- pyrroline identified as the most important volatile constituent contributing to the aroma in several aromatic rice varieties. The components of cooked rice flavour change rapidly during ageing. Lipoxygenase-3 (LOX-3) are thought to play an important role in the formation of desirable or undesirable flavour and aroma in many plant products.

Reduction of Seed Germination

If the grain is stored at high humidity, store fungi invade the grain. They slowly kill the embryos of the seeds. Smut disease and some pests also damage the seed embryo. The whole seed lot may be rendered useless for sowing and consumption purposes. At higher moisture levels growth of the fungi and losses in seed germination is more rapid.

Reduction in the Activity of Calvin Cycle Enzymes

Powdery mildew has shown that the activity of some key enzymes of Calvin cycle is progressively reduced due to changes in the concentration of soluble carbohydrates in infected tissues which in turn affects the rate of photosynthetic fixation of carbon dioxide. Bio-tropic fungus *Albugo candida* (causes white rust of mustard), the reductions in the rate of photosynthesis is paralleled by decreases in the amounts of Rubisco (ribulosebiphosphate carboxylase) enzyme present in the host tissues.

Figure 10: White Rust of Mustard

Changes in Nucleic Acid Metabolism

Marked increase in nucleic acid synthesis has been noted in fungal, bacterial, and nematode diseases especially those characterized by outgrowth and gall formation, and in viral diseases. In club root disease of crucifers (*Plasmodiophora brassicae),* the DNA content is 16-fold greater in infected cells in comparison to healthy cells. The higher level of RNA in rust-infected wheat indicates an induced synthesis of proteins in the host. A correlation has been experimentally shown between increased respiration and RNA synthesis in powdery mildew disease of barley and rust diseases of wheat.

Figure 11: Club Root Disease of *crucifers* (Photo Courtesy – Projects. ncsu.edu)

Changes in Transpiration

It is normally observed that the rate of transpiration increases in plant diseases infect the leaves (e.g., leaf rusts, apple scab, powdery mildews, downy mildews). It so happens because these diseases result in destruction of at least part of the protection devices like cuticle, an increase in permeability of leaf cells, and the dysfunction of stomata. These diseases destroy cuticle and epidermis considerably resulting in uncontrolled loss of water and loss of turgor due to which wilting of leaves follows.

Figure 12: Powdery Mildew of Mustard

Figure 13: Tikka (Leaf Spot) Disease of Groundnut

Changes in Photosynthesis Activity

The effect of the pathogen on the overall rate of photosynthesis by plants because the chloroplast, the photosynthesis apparatus, is destroyed or disturbed by pathogens.

Changes in Lipids

Rice lipids are usually stable in the intact spherosomes in the cell. However, when the lipid membrane is destroyed by phospholipase, physical injury or high temperature, lipid hydrolysis is initiated by the action of lipases. For example, the lipid content of brown rice was stable during storage for 12 months at 5 °C but decreased significantly during storage at 35 °C. The absolute amounts of both oleic and linoleic acids in the neutral lipid fraction decreased during the storage period.

Methods of Reducing of Deterioration

- **Proper Harvesting and Threshing:** The seeds should be harvested as soon after maturity as possible. Weathering in the field, mechanical injury during harvesting, threshing and cleaning, damage the seed coat. The storage fungi invade the damaged seeds easily and grow rapidly. Apparently, the harvesting of more and more grain at moisture levels too high for safe storage has contributed to the mycotoxin problem.
- **Drying the Grains:** At high moisture content of stored grains, development of fungi and activities of insects are maximum. For grains the moisture content must be below 12 percent. The optimum moisture content for storage of many seeds against fungal spoilage is 6-8 percent. There are different ways of drying, for example-sun drying, air drying, hot air drying etc.

Sun and solar drying of grains/seeds is a cheap method of preservation because it uses the natural resource/ source of heat: sunlight. This method can be used on a commercial scale as well at the village level provided that the climate is hot, relatively dry and free of rainfall during and immediately after the normal harvesting period. Grains should keep under sunlight for many (10-11) hours before storage. This process done for removal of excess moisture and decrease microbial activities. Growth of fungi is accelerated by an increase in temperature until such factors as thermal inactivation of enzymes, exhaustion of substrate, oxygen or moisture depletion, or accumulation of carbon dioxide become limiting.

- **Moisture Control:** Seed should only be stored when 'dry', as grain of high moisture causes temperatures to rise and mould to develop. The rate of deterioration of grain in storage increases as grain moisture increases. Mature seeds are hygroscopic and their moisture content will vary with the RH of the atmosphere. Therefore it is necessary to use the following methods to prevent moisture from re-entering the seed.

- **By Ventilation:** Exhaust fans reduce the temp. of the seeds in storage.
- **Moisture Vapour Proofing the Storage:** The moisture as a gas in the air is readily absorbed by the seeds and raise their moisture content. Usually polyethylene sheet, aluminium foil, bitumen are used as moisture vapour proofing materials.
- **Control of the RH:** Usually silica gel used as dehumidifier. The silica gel removes a large part of water vapour and the air flows back into the storage.
- **Moisture Proof Packaging:** Polyethylene sheet, aluminium foil, bitumen are used as moisture proof packaging.
- **Proper Sanitation:** Proper sanitation in food processing and storage areas is the most effective weapon in the fight against rodents, since all packaging materials apart from metal and glass containers can be attacked by rats and mice.
- **Storage in Air Tight Container:** This deprives the storage fungi and insects of oxygen and reduces the metabolism to minimum.
- **Irradiation Treatment:** Different doses of irradiation has been found effective in killing storage fungi and insects.
- **Storage at Low Temp:** Storage of grains at low temp. i.e. 8-10 ^{0}C have been useful.
- **Rat Proofing:** Rodents cause damage field as well as storage. In the field rat population can be checked by flooding, killing, predators (Snake, eagle and cat etc.) and Zinc phosphide. Storage house should be free from rats and other rodents. Storage house should be located at high elevation. Zinc phosphide used as rodenticide.
- **Controlled Atmosphere:** Storage in controlled atmosphere where carbon dioxide and oxygen levels are monitored, increasing concentration of CO_2 and lowering that of oxygen according to fruit species. Application of this combined procedure requires airtight storage rooms. Cold storage can be combined with storage in an environment with added of carbon dioxide, sulphur dioxide, etc. according to the nature of product to be preserved. When the oxygen concentration is reduced within 60 minutes the deterioration is in practice negligible.
- **Seed Treatment:** Treatment of grains with propionic acid at 0.5 %, Acetic acid, iso butyric acid and formaldehyde before storage have been recommended to control fungal spoilage. Use various insecticide, fungicides and Bactericides in field to control the losses. Before storage seeds should be treated with insecticide and fungicides. Both are check the contamination during storage. Seed treatment products contain cypermethrin or triflumuron insecticide. Both insecticides protect against a range of insect pests of stored wheat, barley, oats and other small grains.
- **Fumigation:** Fumigation should be done in ware houses with aluminium phosphide, Sulphur dioxide and sulphites. Aluminum phosphide release phosphine gas. Sulphur dioxide is used as a gas or in the form of its sulphite, bisulphite and meta-bisulphite salts which are powders. The gaseous form is produced either by burning Sulphur or by its release from the compressed liquefied form. The antimicrobial action of sulphur dioxide against

yeasts, moulds and bacteria is selective, with some species being more resistant than other

- **Blanching**: Exposing fruit and vegetable to hot or boiling water - as a pre-treatment before drying has the following advantages- 1. It preserves the natural colour in the dried products; for example, the carotenoid (orange and yellow) pigments dissolve in small intracellular oil drops during blanching and in this way they are protected from oxidative breakdown during drying; 2. Check enzyme activity and 3. Prevent microbial activities.
- **Preservation of Vegetables by Acidification:** Food acidification is a means of preventing their deterioration in so far as a non-favourable medium for micro-organisms development is created. This acidification can be obtained by Lactic acid and organic acids.

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