UNIT 4 STORAGE

Structure

4.0 OBJECTIVES

By the time you have studied this unit, you should be able to:

- explain the importance of storage;
- understand the type of damages take place during storage;
- identify the traditional and improved storage system being followed; and
- underline the types of losses take place.

4.1 INTRODUCTION

Horticultural crops not only provide us with nutritional and healthy foods, but also generate a cash income to growers. Appropriate production practices, careful harvesting and proper packaging, storage and transport contribute to the good produce quality. Once a crop is harvested it is impossible to improve its quality. The horticultural crops, because of their high moisture content are inherently more liable to deteriorate especially under tropical conditions. Moreover, they are biologically active and carry out transpiration, respiration, ripening and other biochemical activities, which deteriorate the quality of the produce.

Losses during post harvest operations due to improper storage and handling are enormous and can range from 10-40 percent. Post harvest losses can occur in the field, in packing areas, in storage, during transportation and in the wholesale and retail markets. Severe losses occur because of poor facilities, lack of know-how, poor management, market dysfunction or simply the carelessness of farmers. Losses can be reduced if proper storage process is adopted after harvesting.

Storage of fresh fruit and vegetable produce is an important economic aspect as it stabilizes prices, avoids glut in the market, and makes fruits and vegetables available in off season. Storage extends the usefulness and availability of vegetables and fruits since deterioration of the freshness is minimized. Storage also avoids wastage, relieves stress during main season and assures regular supply to the consumers with high quality fruits and vegetables. If not stored, the farmers have to sell the produce soon after harvest at throwaway prices in the market and they suffer great loss. Therefore, creation of storage facilities is essential for proper development of vegetable and fruit industries in the country.

4.2 STORAGE PARAMETERS FOR FRESH PRODUCE

Temperature and humidity management remains the most effective tool for extending the shelf life of fresh horticultural produce. The following table gives approximate storage life and recommended temperature and humidity levels for commercial storage.

Commodity	**Temp (^{0}C)**	**Relative humidity (%)**	**Approximate storage life**	**Highest freezing point**
Apples	-1 to 4	90-95	1-12 months	-1.5
Apricots	-0.5 to 0	90-95	1-3 weeks	-1.0
Bananas, green	13 to 14	90-95	-	-0.7
Blackberries	-0.5 to 0	90-95	2-3 days	-0.7
Blueberries	-0.5 to 0	90-95	2 weeks	-1.2
Cranberries	2 to 4	90-95	2-4 months	-0.8
Currants	-0.5 to 0	90-95	1-4 weeks	-1.0
Dewberries	-0.5 to 0	90-95	2-3 days	-1.2
Elderberries	-0.5 to 0	90-95	1-2 weeks	-
Loganberries	-0.5 to 0	90-95	2-3 days	-1.2
Raspberries	-0.5 to 0	90-95	2-3 days	-1.0
Strawberries	0	90-95	5-7 days	-0.7
Carambola	9 to 10	85-90	3-4 weeks	-
Cherries, sour	0	90-95	3-7 days	-1.7
Cherries, sweet	-1 to -0.5	90-95	2-3 weeks	-1.8
Coconuts	0to 1.5	80-85	1-2 months	-0.9
Dates	-18 or 0	75	6-12 months	-15.7
Figs, fresh	-0.5 to 0	85-90	7-10 days	-2.4
Grapes	-1 to -0.5	90-95	1-6 months	-2.1
Guavas	5 to 10	90	2-3 weeks	-

Kiwifruit	-0.5 to 0	90-95	3-5 months	-1.6
Lemons	7 to 13	85-90	1-6 months	-1.4
Limes	9 to 10	85-90	6-8 weeks	-1.6
Loquats	0	90	3 weeks	-
Lychees	1.5	90-95	3-5 weeks	-
Mangos	13	85-90	2-3 weeks	-0.9
Nectarines	-0.5 to 0	90-95	2-4 weeks	-0.9
Olives, fresh	5 to 10	85-90	4-6 weeks	-1.4
Papayas	7	85-90	1-3 weeks	-0.9
Passion fruit	7-10	85-90	3-5 weeks	-
Peaches	-0.5-0	90-95	2-4 weeks	-0.9
Pears	-1.5 to -0.5	90-95	2-7 months	-1.5
Persimmons, Japanese	-1	90	3-4 months	-2.1
Pineapples	7 to 13	85-90	2-4 weeks	-1.1
Plums and prunes	-0.5 to 0	90-95	2-5 weeks	-0.8
Pomegranates	5	90-95	2-3 months	-3.0
Quinces	-0.5 to 0	90	2-3 months	-2.0
Artichokes, globe	0	95-100	2-3 weeks	-1.1
Beans, dry	4 to 10	40-50	6-10 months	-
Beans, green or snap	4 to 7	95	7-10 days	-0.7
Beans, lima	3 to 5	95	5-7 days	-0.6
Bean sprouts	0	95-100	7-9 days	-
Beets, bunched	0	98-100	10-14 days	-0.4
Beets, topped	0	98-100	4-6 months	-0.9
Broccoli	0	95-100	10-14 days	-0.6
Brussels sprouts	0	95-100	3-5 weeks	-0.8
Cabbage	0	98-100	3-6 weeks	-0.9
Carrots	0	95-100	2 weeks	-
Carrots, mature	0	98-100	7-9 months	-1.4
Cauliflower	0	95-98	3-4 weeks	-0.8
Celery	0	98-100	2-3 months	-0.5
Corn, sweet	0	95-98	5-8 days	-0.6
Cucumbers	10 to 13	95	10-14 days	-0.5
Eggplants	8 to 12	90-95	1 week	-0.8

Garlic	0	65-70	6-7 months	-0.8
Ginger	13	65	6 months	-
Greens, leafy	0	95-100	10-14 days	-
Horseradish	-1.0 to 0	98-100	10-12 months	-1.8
Lettuce	0	98-100	2-3 weeks	-0.2
Watermelons	10 to 15	90	2-3 weeks	-0.4
Mushrooms	0	95	3-4 days	-0.9
Okra	7 to 10	90-95	7-10 days	-1.8
Onion, green	0	95-100	3-4 weeks	-0.9
Onion, dry	0	65-70	1-8 months	-0.8
Onion sets	0	65-70	6-8 months	-0.8
Parsley	0	95-100	2-2.5 months	-1.1
Parsnips	0	98-100	4-6 months	-0.9
Peppers, chilli (dry)	0 to 10	60-70	6 months	-
Peppers, sweet	7 to 13	90-95	2-3 weeks	-0.7
Potatoes	0	90-95	5-10 months	-0.6
Pumpkins	10 to 13	50-70	2-3 months	-0.8
Radishes	0	95-100	3-4 weeks	-0.7
Spinach	0	95-100	10-14 days	-0.3
Sweet potatoes	13 to 16	85-90	4-7 months	-1.3
Tomatoes, mature-green	13 to 21	90-95	1-3 weeks	-0.6
Tomatoes, firm-ripe	8 to 10	90-95	4-7days	-0.5
Turnips	0	95	4-5 months	-1.0
Turnip greens	0	95-100	10-14 days	-0.2

4.3 DAMAGES DURING STORAGE

Insect/ pests form one of the most important factors responsible for losses in agricultural production at various stages. Living organisms and the environment interact to bring about spoilage of stored products. Living organisms may be plants, insects, pests, man, animal, bacteria, fungi etc. High post-harvest losses are caused by the invasion of fungi, bacteria, insects and other organisms. Micro-organisms attack fresh produce easily and spread quickly, because the produce does not have much of a natural defence mechanism and has plenty of nutrients and moisture to support microbial growth. Control of Post harvest decay is becoming a more difficult task, because the number of pesticides available is falling rapidly as consumer concern for food safety increases.

It is estimated that 5 to 10% of the world food production is damaged by insects during storage. The estimated losses due to insects in India have been estimated to be around 3% of the country's production. Insects feed on the germ and endosperm causing loss in weight as well as nutrients. Besides, they cause contamination with their excreta and dead bodies. The damages can be grouped into, (1) direct damages, and (2) indirect damages.

4.4 DIRECT DAMAGES

i) Few insects consume germ as well as some endosperm and the others eat away both. It causes in loss of weight, loss of nutrients, loss of germination power, loss in gradation and consequently falls in market value.

ii) The contamination may be with the dead bodies, excreta, cast skin, odour.

iii) Structures and containers also get damaged by causing tunneling in wooden parts.

4.5 INDIRECT DAMAGES

i) It occurs when heat is created and migration of moisture takes place.

ii) It creates distribution of parasites to man. Few tape worms select stored grain insects as intermediate hosts.

4.6 SOURCES OF INFESTATION

Infestation sources are mainly five types, the field itself, infested bags, infested transport, infested godown and infested stocks.

Field: Insects may attack the crop in the field itself and same is brought to the storage centers where it continues attack. The infestation may be visible or invisible. Fumigation should be done immediately to check the growth of insects.

Infested bags: When new bags are used for packing the newly harvested produce, the insects hiding in the seams of the bags may attack the freshly harvested produce. The gunnies should be fumigated prior to packing the freshly harvested produced.

Infested transport: *DDVP* or Malathion should be sprayed on transport used for carrying the newly harvested produce. If the bullock cart or tractor trolley has been used as the transport for carrying infested stocks on the previous occasion, the left over insects may attack the fresh produce.

Infested godowns: The Godowns *should* be thoroughly cleaned and fumigated as insects present in the cracks and crevices of the wall or that hibernate in the structures, may emerge out and attack the produce.

Infested stocks: In case sound produce/stocks are brought to a storage unit godown where infested stocks are in storage, cross infestation may takes place.

4.7 STORAGE REQUIREMENTS

For successful storage the conditions needed is a better product, optimum required temperature, atmospheric humidity, right stage of maturity for the product to be stored, and freedom from diseases and other injury. There is rapid deterioration in injured or diseased products during storage, particularly under conditions favourable for the development of storage rots. The main storage principles are:

Relative Humidity

Transpiration rates (water loss from produce) are determine by the moisture content of the air, which is usually expressed as relative humidity. At high relative humidity, produce maintains saleable weight; appearance, nutritional quality and flavour, while wilting, softening and juiciness are reduced. Leafy vegetables with high surface-to-volume ratios; injured produce and immature fruits and vegetables have higher transpiration rates. High temperatures, low relative humidity and high air velocity increase transpiration rates.

Relative humidity needs to be monitored and controlled in storage. Control can be achieved by a variety of methods:

1. Operating a humidifier in the storage area.
2. Regulating air movement and ventilation in relation to storage room load.
3. Maintaining refrigeration coil temperature within the storage room.
4. Using moisture barriers in the insulation of the storage room or transport vehicle.
5. Wetting the storage room floor.
6. Using crushed ice to pack produce for shipment.
7. Sprinkling leafy vegetables, cool-season root vegetables and immature fruits and vegetables with water.

Temperature

Respiration and metabolic rates are directly related to room temperatures within a given range. The higher the rate of respiration, the faster the produce deteriorates. Lower temperatures reduce respiration rates and the ripening and senescence processes, which prolong the storage life of fruits and vegetables. Low temperatures also slow the growth of pathogenic fungi, which cause spoilage of fruits and vegetables in storage.

Producers should give special care and attention to proper storage conditions for produce with high to extremely high respiration rates, as these crops will deteriorate much more quickly.

It is impossible to make a single recommendation for cool storage of all fruits and vegetables. Climate of the area where the crop originated, the plant part, the season of harvest and crop maturity at harvest are important factors in determining the optimum temperature. A general rule for vegetables is that cool-season crops should be stored at cooler temperatures (0 to 1.7°C) and warm-season crops should be stored at warmer temperatures (7 to 13°C).

Freezing injury

Temperatures that are too low can be just as damaging as those too high. Freezing will occur in all commodities below 0^oC. Whether injury occurs depends on the commodity. Some can be repeatedly frozen and thawed without damage, while others are ruined by one freezing.

Injury from freezing temperatures can appear in plant tissues as loss of rigidity, softening and water soaking. Injury can be reduced if the produce is allowed to warm up slowly to optimum storage temperatures and if it is not handled during the thawing period. Injured produce should be marketed immediately, as freezing shortens its storage life.

Chilling injury

Fruits and vegetables that require warmer storage temperatures (4.5 to 13°C) can be damaged if they are subjected to near-freezing temperatures (0°C). Cooler temperatures interfere with normal metabolic processes. Injury symptoms are varied and often do not develop until the produce has been returned to warmer temperatures for several days. Besides physical damage, chilled produce is often more susceptible to disease infection.

Quality and condition of material

If the fruits are over ripe, they will rot and get spoilt early and quickly. If they are not ripe, the shrinkage can take place and make the product unfit for consumption. The flavour and aroma also changes leading to an appreciable reduction in sugar content and development of acidic (or off-flavour) flavours under storage or transit due to high content of acids. There is also a considerable change in original colour of skin, flesh, firmness, etc, and the product (fruit, root, etc.) becomes soft. The chemical changes continue to take place in immature product (fruits etc) after harvest. The starch content begins to decline and there is increase in sugar content. Also a slow inversion of sucrose to reducing sugars takes place.

Total nitrogen content almost remains the same, but the form of nitrogen is changed, that is, protein and nitrogen decrease compared to soluble nitrogen, fats, oils and waxes increase in storage but oil content increases faster compared to rest. Regarding enzymes the activity of oxidase remains almost constant while catalase activity becomes faster in storage. The mineral constituents also remain constant in the storage. The respiration rate is faster till the fruits are fully mature and finally over mature

Ethylene, a natural hormone produced by some fruits as they ripen, promotes additional ripening of produce exposed to it. The old age saying that one bad apple spoils the whole bushel is true. The damaged or diseased fruits produce high levels of ethylene and stimulate the other apples to ripen too quickly. As the fruits ripen, they become more susceptible to disease. Ethylene "producers" should not be stored with fruits, vegetables, or flowers that are sensitive to it. The result could be loss of quality, reduced shelf life and specific symptoms of injury. Ethylene producers include apples, apricots, avocados, ripening bananas, honeydew melons, papayas, peaches, pears, plums and tomatoes.

Advantages of storage

1. The wastage is avoided.

2. The stress during main season is relieved. It is easy to carry over the produce from periods of high production to periods of low production.

3. Distress selling during glut is offset which ensures remunerative price to the grower.

4. It assures regular supply to the consumer of high quality fresh fruit and vegetables throughout the year at reasonable prices.

5. It is easy to supply and hold regular trade of vegetables from the place of production to the place of consumption.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Why storage of fruit and vegetables are required?

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2. What are the factors responsible for proper storage of fruits and vegetables?

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3. What are the sources of Infestation in storage?

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4. What are various injury occur to fruit and vegetables during storage?

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4.8 STORAGE PROCESS

Most rapidly maturing tropical fruits, soft fruits of all kinds, and leafy vegetables with a large surface area tend to have high respiration rates and normally have short storage lives. In contrast, most temperate fruits, cured potatoes and onions, and vegetable root crops often have lower respiration rates and consequently longer storage lives. Respiration of all produce increases with temperature, which is why all storage techniques aim for a reduction in temperature of the produce.

- Lower storage temperature offers the additional advantage of greatly reduced water loss from the produce with reduced transpiration. High relative humidity slows down water loss and enhances storage life of the produce. Stores should ideally be maintained at the highest relative humidity (RH) that the crop could tolerate.

It is important to retain adequate circulation of the air within a store and around the produce to ensure efficient cooling. However, over-rapid air movement can drastically increase water loss by the produce. Therefore, the choice of the correct storage technique is governed by:

- the type of produce, its temperature from harvest and its respiration rate as well as produce quality;
- the storage temperature and humidity best suited to the produce and intended storage life, with implicating chill damage or unnecessary microbial spoilage;
- appropriateness to the market place and its requirements;
- and above all, the economics of the whole operation.

The different types of storages are (i) ground or pit storage; (ii) natural caves (iii) air-cooled storage; (iv) evaporative cooling (v) ventilated Storages (vi) improved Zero-energy Cool Chamber (vii) refrigerated storages; (viii) controlled atmosphere (CA), modified atmospheres (MA) or Hypo baric storage.

4.9 TRADITIONAL STORAGE STRUCTURES

Ground storage or pit storage

This method of storing vegetables is very commonly followed to the hills, especially in the snow-bound, arid dry template area, deep in the Himalayas. It is always available, simple, cheap, easily made and effective method practiced in some areas. The vegetables like potato, beetroot, carrot, radish, turnip, sweet potato and cabbage are piled in layers in the pit or trenches dug at a higher, well-drained place where water after snow melting does not accumulate. The pits may be pucca or kuchcha and lined with straw or leaves, the produce is then covered with straw followed by a thin layer of soil or prevents severe freezing injury. However, the trenches/ pits are also covered with wooden planks or tree branches and a small hole is kept for proper aeration at each corner.

Cellers and caves

The cellers are sophisticated type of below ground storage. These can be part of above ground buildings or underground rooms, where access is easy. The caves are also the natural shelters available under big rocks, which are used for storing vegetables. Good drainage, protection from rains or snowfall and natural hazards are essential. The performance of cellers is improved by providing controlled ventilation, openings for entrance of cold air and exit for warm air by conventional circulation whenever cooling is required. Though optimum temperatures generally cannot be retained. A good, cellar/cave will provide satisfactory storage for hard vegetables.

4.10 IMPROVED STORAGE STRUCTURES

Air-cooled storage

These are simply insulated structures, above ground and partly underground, which are cooled by circulation of colder monoxide air. When the temperature of the produce is of desired level and the temperature of the outside air is comparatively lower, air is circulated at the stock in the store mechanically through bottom inlet vents and top dampers. Fans if fitted are controlled manually or automatically. Air-cooled stores are cheap, easy to install and to operate, which are still widely used for the storage of potato and sweet potato, because both these products need relatively higher storage temperatures to avoid accumulation of sugar and chilling injury, respectively. Potatoes are commonly stored in bulk, piled in stores with air delivery even under the floor or at floor level and with sufficiently spaced air outlets.

Evaporative cooling

This utilizes the evaporation of water using heat of respiration of the vegetables. Water should be near or around the vegetables. Hot, dry air is thus cooled when it flows through a wet surface. The temperature may be reduced 1°-5°C and relative humidity increases by 20-30 percent depending on the prevailing temperature and relative humidity. The hotter and drier the surrounding microclimate, the greater the decrease in temperature and higher the increase in relative humidity. Evaporative cooling is very useful, especially in vegetables which easily wilt, shrivel, or soften because of low relative humidity. A few applications of evaporative cooling can be; (i) sprinkling fresh vegetables with water; (ii) keeping fresh vegetables in moist containers (earthen pots or jars); (iii) keeping vegetables inside drip coolers. There are locally developed structures with sides which could absorb water to be evaporated like jute sack or charcoal held on two sides by wire netting. Water is allowed to drip on the walls continuously

Ventilated Storages

Before the advent of refrigeration, ventilated storage was the only means available for storage of fresh produce and today is still in wide use all over the world for a variety of crops. Ventilated storage is ambient air storage, which makes use of controlled ventilation for cooling of the produce and maintenance of lower temperatures. It requires much lower capital investment and operating costs than refrigerated storage and is perfectly adequate for some crops and conditions where:

- Production is being stored for local use.
- The crops to be stored have a relatively long natural and storage life.
- Regular inspection is possible to remove spoilage centers.
- There is a significant difference between day and night temperatures, for example at altitudes above 1000 meters and most temperate latitudes.
- The need is for relatively short storage periods.

A ventilated store may be used for onions, garlic, yams and sweet potato. However, ambient or ventilated storage for most other commodities is neither a practical nor an economic proposition because spoilage rates are simply too high. Some ventilated storage at the retail point may be an every day reality for small shopkeepers but larger ships and supermarkets, and most importers and wholesalers use refrigerated stores. Hanging onions and garlic are the simplest form of ventilated storage. In low temperature areas, storage houses for potatoes have air inlets at the sides near the floor level and outlets near the ceiling. These storage houses are found ventilated. The entry and exit of fresh air is mechanically controlled by thermostats, which also measure temperature inside and outside the room. Air is allowed to enter when it is cold and to leave when it is hot.

Improved Zero-energy Cool Chamber

A low cost zero-energy cool chamber, developed at IARI, New Delhi, recently is based on the principle of evaporating cooling. Raw material readily available is used for installing the short-term double-walled storage for fresh vegetables and fruits. The inside temperature of the chamber maintained is between 17-18°C (lower than outside) with relative humidity of about 90 percent during the peak summer months and also throughout the year. Such chambers are quite suitable for storage of fresh vegetables for short duration. Moreover, these are cheap, economical and within the reach of an average vegetable grower.

4.11 MODERN STORAGE STRUCTURES

Refrigerated Storage

Refrigerated storage is a well-established technology widely used for storing horticultural crops all over the world and is undoubtly the most effective method of prolonging the storage shelf life of fresh vegetables and reduces post-harvest losses by arresting metabolic breakdown of fungal deterioration of the commodity. Its application is limited only by cost and benefit considerations. Essentially, all crops can benefit by being stored at a suitable low temperature, which extends the storage life and preserves quality.

Many horticultural crops have storage life spans ranging from less than one month to several months when refrigerated. Therefore, refrigerated storage can be used continuously only if different crops with different harvesting seasons can share the facility. There are other important reasons why this method is not used in many tropical and sub-tropical countries, where refrigeration is needed most. The initial investment cost is too high and its energy consumption too large for many countries

When this method is to be used on a large-scale, the total value of the commodity should be considered. It may keep the commodity fresh for a long period but if it is not profitable to put in refrigerated store or even to rent a refrigerated room, then it is economical to use other methods of storage. Many tropical and subtropical fruit and vegetables are susceptible to low temperature injury. Due to the lack of money to erect and run cold storages by the individual farmer or farming community, the use of cold storages is limited. However, some well-to-do farmers and government agencies have created these facilities and are making use of them for storing high-priced vegetables. As the commodities have their optimum temperature and relative humidity at which they keep fresh for the longest possible time, therefore the cold room should have the desired temperature and relative humidity

The commodities should be cooled as soon as possible. Root and bulb vegetables should be properly cured before storing for better protection from micro-organisms. For better results, avoid mixing different commodities because most of the fruit & vegetables release ethylene on their ripening, thus leafy vegetables root and bulb vegetables and green fruit vegetables should not be mixed. Only good quality produce should be stored in different chambers. Storing of poor quality produce may not be economical in the long run. The faster the temperature of the vegetable is lowered down to the optimum, the longer is the shelf life of the commodity. Cooling vegetables and fruits immediately after harvesting before storage at the optimum temperature is an effective way to remove both field and product heat leading to slow deterioration. The fast cooling is called pre-cooling and is done by cooling in special pre-cooling chambers or equipment with air (room cooling)- with a much higher capacity to cool than a usual cold room. In lead water (hydro cooler), the vegetable is sprayed or immersed in ice water, here the cooling time is determined by the temperature difference between the water and the vegetable, the nature of the vegetable and type of container used.

4.12 CONTROLLED ATMOSPHERE (CA) AND MODIFIED ATMOSPHERE (MA) OR HYPERBOLIC STORAGE

The fresh horticultural produce consumes oxygen for respiration and releases carbon dioxide and ethylene. The ethylene further enhances ripening. Reducing oxygen and increasing carbon dioxide can increase the shelf life. In CA storage the levels of $CO2$, $O2$ and $N2$ in the storage room are monitored. CA storage combined with refrigeration reduces respiration and delays yellowing and quality changes. However the tolerance of individual varieties of horticultural crops needs to be considered.

Commercial application of CA storage is limited to only a few crops, apples and pears being the most popular ones. It is not used for other crops because the benefit is too slight to cover the cost. The technologies involved are complicated and sophisticated. The cost of building, facilities, and management for CA storage is considerably higher than for refrigerated storage. Therefore it should not be recommended for any crop without a thorough cost and benefit analysis.

While in modified atmosphere (MA), the respiration of the commodity is allowed to reach a desirable low level of O2 and high level of CO2 inside a closed chamber, container, plastic bag or plastic tent and the gases are maintained at those levels. Both the systems are best used with refrigerated storage involving manipulation of CO2, O2 and N2. Other gases such as ethylene, acetylene and propylene are also considered. MA differs from CA only in how precisely the addition of pressures is modified. CA storage is more precise than MA storage without basis or reducing the atmospheric gaseous pressure exerted on the stored valuable vegetables. The CA is seldom used commercially for vegetables, whereas the use of plastic bags to line containers or as retain packages is an example of modified atmosphere. For prevention of accumulation of too much CO2 and decrease of too much O2, a few holes can be made.

Danish cabbage has been reported to be kept better during four to five months at 0˚C in gas mixtures with 2.5 to 5% oxygen and carbon dioxide than it has in air. Mature green tomatoes may keep green for five to six weeks at 13˚C in an atmosphere at 3% oxygen with 97% nitrogen. After removal to air at 18˚ C, these tomatoes ripened normally with acceptable flavour. Mushroom in refrigerated storage has been kept better for short periods in atmosphere with 5 to 10% carbon dioxide than air.

All types of controlled atmosphere storage require frequent gas analysis to determine when aeration is required to add oxygen or to remove carbon dioxide

Therefore, the fresh fruit and vegetables storage can help in bringing lucrative returns to the vegetable growers and others dealing with the vegetable, trade, and supplying fresh, full of flavour, aroma and attractive vegetables from the different areas, in original state to the consumers. Thus, there is great potentiality of storing vegetables and fruits for both fresh and in processed form.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.

b) Compare your answers with those given at the end of the unit.

1. What is various storage structure required in traditional storage system?

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2. What is various storage structure required in improved storage system?

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4.13 LOSSES IN STORAGE

Fruits, vegetables, root crops, ornamentals collectively called horticulture products are inherently perishable. Losses occur in the period between harvesting and consumption. The loss is generally a result of multiple causes and malpractices along the marketing chain.

About 20% of the damage to produce takes place during harvesting and field handling. The grower should ensure that the produce is harvested well, is kept in good condition till it is treated, kept in safe storage, consumed or sold.

If post harvest treatments are being used, they should start immediately after the produce has been harvested, to ensure that the essential freshness and nutritional values are maintained to the maximum.

Losses during post harvest operations due to improper storage and handling are enormous and can range from 10-40 percent. Post harvest losses can occur in the field, in packing areas, in storage, during transportation and in the wholesale and retail market. Severe losses occur because of poor facilities, lack of know-how, poor management, market dysfunction or simply the carelessness of farmers. Proper storage conditions, temperature and humidity are needed to lengthen the storage life and maintain quality once the crop has been cooled to the optimum storage temperature.

4.14 INDIAN STANDARDS

Various Indian standard are notified by Bureau of Indian Standards, New Delhi, these are given below.

Indian Standards on Storage and Marketing Structures for Agricultural Commodities

IS:

600-1955	Code of practice for construction of BUKHARI type rural food grain storage structure.
601-1955	Code of practice for construction of KOTHARI type food grain storage structure.

602-1955	Code of practice for construction for MORAI type rural food grain storage structure.
603-1960	Code of practice for construction of underground rural food grain storage structure.
607-1965	Code of practice for construction of bagged food grain storage structures suitable for trade and government purposes (revised).
609-1955	Code of practice for improvement of existing structures used oriented to be used for food grain storage.
631-1961	Aluminium food grain storage bins.
1497-1959	Layout for regulated market yards for agricultural commodities.
1787-1961	Layout for regulated market yards for fruits and vegetables.
1788-1961	Layout for regulated market yards for cattle.
2059-1962	Layout for regulated market yards for tobacco.
2821-1964	Thermo-sampler.
3453-1966	Code of practice for construction of hexagonal type concrete-cum-masonary bins for bulk storage of food grains.
5503(PartI)-1969	General requirements for silos for grain storage: Part I Constructional requirements.
5503(PartII)-1969	General requirements for silos for grain storage: Part II Grain handling equipment and accessories.
5606-1970	Steel bins for grain storage.
5826-1970	Constructional requirements for flat storage structures for grain (capacity above 200 tonnes).
6151 (Part I)-1971	Storage management code: Part I Terminology.
6151 (Part II)-1971	Storage management code: Part II General care in handling and storage of agricultural produce and inputs (superseding IS: 610-1955 and IS: 611-1955).
6201-1971	Constructional requirements for flat storage structures for grains (100-200 tonnes capacity).
6663-1972	Method for determination of angle of repose of grains.

Indian Standards on Storage Structures and Storage Management

IS:

607-1971	Code of practice for construction of bagged storage structures (second revision).

3453-1966	Code of practice for construction of hexagonal type concrete-cum-masonry bins bulk storage of food grains.
3503(Part I)-1969	General requirements for silos for grain storage: Part I Constructional requirements.
3503 (Part II)-1969	General requirements for silos for grain storage: Part II Grain handling equipment and accessories.
5606-1970	Steel bins for grain storage.
5826-1970	Constructional requirements for flat storage structures for grain (capacity above 200 tonnes).
6151 (Part I)-1971	Storage management code: Part I Terminology.
6151 (Part II)-1971	Storage management code: Part II General care in handling and storage of agricultural produce and inputs.
6151 (Part III)-1976	Storage management code: Part III Specific care in handling and storage of agriculture produce and inputs.
6201-1971	Constructional requirements for flat storage structures for grains (100 to 200 tonnes capacity).
6883-1972	Method for determination of angle of repose of grains.
7147 (Part I)-1973	Steel bins for domestic storage: Part I GHARELU KOTHI.
7247	Code of practice for fumigation of agricultural produce
7247 (Part I)-1973	Methyl bromide.
7247 (Part II)-1973	Ethylene dibromide.
7247 (Part III)-1973	Aluminium phosphate.
7247 (Part IV)-1975	Ethylene dichloride and carbon tetrachloride mixture.
7715-1975	Methods for testing suitability of bins for safe storage of food grains.
7716-1975	Method for testing efficacy of fumigation for disinfestations of grains in domestic bins.
8455-1977	Code of practice for construction of polyethylene embedded bins for bulk storage of food grains.

Check Your Progress Exercise 3

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What are reason for post harvest losses of fruit and vegetables?

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2. What percentage of losses takes places during storage?

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4.15 LET US SUM UP

Storage of fresh fruits and vegetables produced is an important economic aspect as it tends to stabilize prices to make use of higher production period to low production period, to avoid glut in the market, to make fruits and vegetables available in off season to earn better return. Due to improper storage, infestation takes place in the produce. Proper storage conditions should be maintained during storage. Various parameters such as relative humidity, temperature, etc. are important during storage. Storage can be made in various types of storage structures depending upon capacity and resources available. Important storage methods are Ground storage or pit storage, evaporating cooling, Ventilatated storage, Refrigerated storage, controlled and modified storage.

4.16 KEY WORDS

Temperature : It is the temperature of surroundings of fruits and vegetables stored.

Infestation : It refers to attack of insects and pests on stored product.

Refrigerated storage : In this condition storage temperature ranges from –1C to 10 C. Storage below –1 C is termed as freezer storage.

Airtight storage : Airtight storage refers to storage conditions in which air is minimum (.2% by volume) leading to arrest the insect infestation in dry grains.

4.17 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - Need for storage,
   - Storage conditions for optimum condition,
   - Suitable storage condition for various fruit and vegetables.

2. Your answer should include the following points:

   - various factors,
   - relative humidity,
   - temperature,
   - moisture content.

3. Your answer should include the following points:

   Various types of infestation takes places in storage, it include direct damages and indirect damages, all type of sources for infestation should be noted.

4. Your answer should include the following points:

   Various types of injury like freezing and chilling injury should be mentioned

Check Your Progress Exercise 2

1. Your answer should include the following points:

   - Ground storage or pit storage,
   - Cellers and caves.

2. Your answer should include the following points:

   - Air-cooled storage,
   - Evaporating cooling,
   - Ventilated storage,
   - Improved Zero-energy cool chamber.

Check Your Progress Exercise 3

1. Your answer should include the following points:

   Reasons for post harvest losses and factor effecting losses.

2. Your answer should include the following points:

   Percentage of losses taken place during post harvest operations.

4.18 SOME USEFUL BOOKS

1. Srivastava, S.S. (2000) Horticulture Science, Central Book House, Raipur.

2. Sahay, K.M. and Singh, K.K. (1991) Unit Operations of Agricultural Processing, Vikas Publishing House Pvt. Ltd.

3. Arya, Prem Singh (1997) Vegetable Growing In India, MP Publication Pvt. Ltd.

4. Yadav, P.K. and Singh, Jitendra (2000) Fruit Production and Preservation, Agrobios (India) Jodhpur.

5. Michel, A.M. and Ojha, T.P. (1966) Principle of Agricultural Engineering, Jain Publications, New Delhi.

6. Hardenburg, R.E., Watada, A.E. and Wang, C.Y. (1986) ***The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks.*** U.S. Dept. of Agriculture, Agricultural Handbook No. 66. pp. 130.

7. Kader, A.A. (ed.) (1992) ***Postharvest Technology of Horticultural Crops.*** University of California, Division of Agriculture and Natural Resources. Oakland, California, USA, pp. 296.

8. Janet Bachmann and Richard Earles, NCAT Agriculture Specialists August 2000 ***Postharvest Handling of Fruit & Vegetables*** By ATTRA Ozark Mountains at the University of Arkansas in Fayetteville at P.O. Box 3657, Fayetteville, AR 72702.

9. Fu Wen Liu ***Horticultural Crops Abstract*** Department of Horticulture, National Taiwan University.