



STORAGE AND WAREHOUSING

*Notes*

Do you know that saving and serving food is a service to humanity. A significant part of the human population in the world does not have enough food to meet their daily needs. Countries like China, United States of America, India, Australia, Canada etc. are producing enough foods to meet their people's needs, but many countries depend on imports from food-surplus nations. Besides, some states in India like Punjab and Haryana produce huge quantities of food grains. These food grains are harvested during specific crop seasons such as *Kharif* and *Rabi* in India; however, their demand remains year-round. So, it becomes necessary to store food grains not only to ensure year-round domestic supplies but also to meet export obligations to other needy countries. Similarly, perishable commodities such as seasonal fruits (apple, oranges) and vegetables (potato, onion, garden peas, carrots) also need proper storage for regular supplies in local and export markets. Proper storage ensures a steady supply and regulates market prices, which are essential for healthy market situation. However, despite the importance of food storage for domestic and export markets, there is not enough attention given to creating and maintaining proper storage facilities. As a result, post-harvest loss of food products is very common in India. It is estimated that around one-third of the food produced in India is wasted due to improper storage. In this lesson, you will learn about various methods to store food for longer period of time.



LEARNING OUTCOMES

After studying this lesson, the learner:

- defines the storage and its importance;
- explains the important factors of food storage;
- indicates several precautions for prolonged storage of foods;

Post-harvest
Management

Notes

- identifies the difference between traditional and modern storage structures; and
- describes warehouse and its system of food storage.

14.1 IMPORTANCE OF STORAGE

Food is a perishable commodity, and it must be kept in a favorable environment after harvesting to avoid post-harvest losses. Post-harvest losses refer to the loss in quality or physical attributes that occurs after harvesting the crop until its consumption. This situation is more serious in developing countries, where on one side, people are facing severe hunger and malnutrition, and on the other, the produced food is being spoiled due to lack of infrastructure and inadequate technology for storage. If the harvested products are stored properly, both the farmer and consumer can benefit in following ways:

- Reduction in the fluctuations of market price of the commodity
- Availability of a wide range of food products in the market
- Consumers can enjoy seasonal products throughout the year, mainly during the off-season
- Better economic return to the farmers or producers

14.2 FACTORS OF STORAGE

Several factors influence the storage life of food produce. These are:

A. Temperature

Optimal temperature after harvesting greatly increases the shelf life of the produce. Usually, lower temperatures are preferred for long-term storage of food. The optimum temperature of storage varies with the type of food stored. Some food items are more perishable and require refrigeration temperature, while others need temperature above refrigeration to keep them well. Reduction in the rate of spoilage during low-temperature storage is attributed to lower respiration rates of fruits and vegetables and reduced microbial activity. It is essential to keep in mind that very low temperatures during storage can harm the produce and cause 'chilling injury'.

**B. Humidity**

An optimum level of humidity is required in the surroundings for stored food items for maximizing their storage life. Fruits and vegetables should be kept at 80-95% humidity to maintain their freshness for a long period of time. High temperature coupled with high humidity is the most ideal condition for microbial attack. Therefore, both factors should be monitored to maximize longevity.

C. Moisture

All fresh foods have a certain amount of moisture present inside them. It varies greatly depending on the type of food. Fruits and vegetables are usually high in moisture, while grains contain less moisture. A general rule is that the lower the moisture content of the food item, the longer is the storage life. Therefore, drying of food items to a certain level of moisture content is done prior to storage, which enhances their storage life.

D. Length of storage

Many food items are seasonal in nature. There is a fixed period in a year during which they are available. To relish them throughout the year, they need to be stored for a much longer period of time which requires special conditions to sustain them. For long storage periods, usually cold storage is done. It maintains temperatures around 0°C.

E. Other factors

Post-harvest disease, damage caused due to pressure of overfilling packages, package failure causing collapse of bottom layers due to excessive stacking, and moist cartons boxes are all factors that affect how long crops can be stored.

**INTEXT QUESTIONS 14.1**

1. Post harvest loss of harvested products is severe in developed countries (True/False).
2. State any two benefits of storage of fruits and vegetables.
3. For long term storage of food, temperature is preferred.

Post-harvest
Management

Notes

4. To maintain freshness, fruit and vegetables are stored at humidity of
 - a. 10 – 20%
 - b. 30- 45%
 - c. 55 – 60%
 - d. 80 – 95%
5. What should be the moisture content of food for long-term storage?

14.3 PRECAUTIONS FOR FRUIT AND VEGETABLE STORAGE**14.3.1 Precautions Before Storage:**

Several precautions need to be taken before final storage of produce in order to enhance the shelf life of products:

- Immediately after harvesting, the perishable agricultural commodity should not be exposed to high temperatures or laid in direct sunlight, which can decrease the storage life of the produce. Vehicles with the produce should not be parked in full sun. To avoid these conditions, transportation during the night or before dawn is practiced for highly perishable commodities. The cold supply chain is best for safe transportation of such produce, which is in the infancy stage in our country.
- There should be a facility of a shed or room near the farm for keeping the freshly harvested produce. Thereafter, the produce should be transferred to the storage facility as soon as possible.
- Fruits and vegetables need to be handled carefully as slight mishandling might damage them, leading to a reduction in quality or complete deterioration due to microbial attack.
- To minimize vibrational damage during transportation, the produce should be packed properly using cushioning materials.
- Avoid using wet packaging materials and packing of wet items (free from surface wetness) in cartons; otherwise, this will deteriorate the product, and collapse the package, and ultimately leads to spoilage of the produce.
- Proper cleaning and drying up of the produce to a safe moisture level before moving it inside the storage area can help check the microbial infestation.



- Sorting of the harvested produce should be done to remove damaged or diseased items; otherwise, they will damage the whole lot. Grading of fruits according to weight, color, size and maturity is also practiced. Pricing of the produce varies widely according to the grade or quality of the product.
- Emerging technologies like modified atmospheric packaging (MAP), where the atmosphere inside the package is modified to reduce the rate of respiration, transpiration, and browning, may be adopted for highly perishable crops. However, it is a costly process and requires careful supervision of other factors.

14.3.2 Precautions During Storage:

- The area for handling and storage of produce should be maintained in a hygienic condition with frequent cleaning and repair.
- Timely fumigation and disinfection should be done to reduce microbial and insect-pest infestation.
- All the holes of storage area should be properly covered to avoid entry of insects, rats and dust particles.
- Humidity control inside the room should be done as frequent changes in the level of humidity could lead to deterioration in the product quality.
- The floor should be cemented or tiled properly to avoid infestation from soil-borne microbes and insects.
- Bags should be placed on wooden or bamboo crates to avoid contact with the floor and to keep away moisture.
- Poison baits and cages should be employed to combat the risk of rodent infestation.
- Old and new stocks should be stored separately. First-in-first-out principle should be used to remove old stock.
- Proper air circulation should be maintained through all the bags.
- Drying in the open space should be avoided as it may lead to contamination.
- Regular checks of stored items are necessary to avoid insect infestation or deterioration.

Post-harvest
Management

Notes

- All the pipes and ducts of the warehouse should have mesh on their openings to avoid the entry of insects and rats.
- Proper lighting should be done to monitor entry of insects and other problems.

**INTEXT QUESTIONS 14.2**

1. What is the main purpose of forming a shed near the farm?
2. Why is exposure to high temperature avoided for freshly harvested farm products?
3. The practice that is performed to reduce microbial infestation
 - a. Cleaning
 - b. Drying
 - c. Fumigation
 - d. All of these
4. Poison bait and cages are employed to reduce the attack of

14.4 CHANGES IN THE FOOD DURING STORAGE

During storage, food undergoes several changes due to internal (e.g. respiration) as well as external factors (e.g. pest attack). These changes can affect both the quality and quantity of the product. These changes may be categorized as:

I. Physical changes

- a. Change in shape and size
- b. Cracking
- c. Formation of clumps

II. Chemical changes

- a. Browning
- b. Dehydration
- c. Absorption of moisture
- d. Degradation of protein, vitamins, or antioxidants

- e. Oxidation of lipids

III. Biochemical changes

- a. Alteration in flavor and colour
- b. Textural changes

14.4.1 Cause of Changes in Grain During Storage:

- **Respiration:** The freshly harvested produce respire and releases carbon dioxide along with water and heat energy. This causes grains to clump together, leading to quality deterioration, handling challenges and economic loss. Moreover, the release of moisture favors the growth of pests and microorganisms, leading to a reduction in food quality. This moisture can also condense on the roof of the storage bin, causing localized grain spoilage.
- **Microbial attack:** Abiotic factors like moisture and temperature play an important role in the microbial infection of stored foods. Fungal spores enter the storage area through the air, along with foods, contaminated bags or equipments and manual mishandlings of the stored food. They are able to flourish on the surface of the food when appropriate conditions are provided.
- **Insects:** Beetles and moths are the most common insects encountered in the stored food produce. They can flourish when optimum conditions are provided. Infestation by the insects may result in:
 - ❖ Development of an unpleasant odor and taste due to contamination with their excreta.
 - ❖ Increase in temperature and moisture content of the produce.
 - ❖ Discoloration, pitting, and powdering of grains, leading to an overall deterioration in quality.
 - ❖ Reduced nutritional quality of produce.

14.4.2 Losses in Food:

Food losses are mainly of two types:

1. **Direct losses:** Direct losses refer to the immediate and tangible reduction in the quantity of food due to various factors. Direct losses include spillage, pest infestation, spoilage and damage, etc.



Notes

Post-harvest
Management

Notes

2. **Indirect losses:** Indirect losses refer to the reduction in the quality and usability of food, which are quite significant, and vary greatly depending upon several factors, including consumer preferences and perceptions. Indirect losses include nutritional degradation, textural changes, flavour deterioration, appearance changes and contamination.



INTEXT QUESTIONS 14.3

- Which of the following changes is due to chemical process in food?
 - Cracking
 - Clump formation
 - Change in shape
 - Browning
- What is the reason of clump formation of food products?
- Two main types of losses are and

14.5 STORAGE TECHNIQUES

Storage is a crucial factor in increasing the shelf life of agricultural crops and in controlling transportation and market supply. Storage facilities must provide adequate protection for stored foods against biotic factors such as insects, pests, rodents, birds, and microbes as well as abiotic factors like bad weather, high temperatures, heavy rainfall, etc.

14.5.1 Types of Storage in India:

Storage structures in India may be divided into two types: 1) Traditional and 2) Modern

A. Traditional storage

In India, majority of the grains produced are stored using traditional methods, which do not adequately protect them from biotic and abiotic factors. Moreover, produce cannot be stored for a long period of time in these structures. Examples of traditional storage include **earthen pots, mud bins, underground pits, and maize cribs**. Handmade storage structures made up of mud like earthen pots or mud bins are commonly found in different regions, often with local names.

Other structures such as **baskets** are made from locally available materials like leaves and bamboo. Fruits and vegetables are usually stored in **wooden boxes** and covered with straw to prevent damage from mishandling or sudden shocks.

Farm-level storage facilities with capacities ranging from 100 kg to a few tonnes are created for storing food grains. Other storage structures made from plywood, ferro-cement, metal, and high-molecular weight high-density polyethylene (HMHDPE) are also suitable for storage.

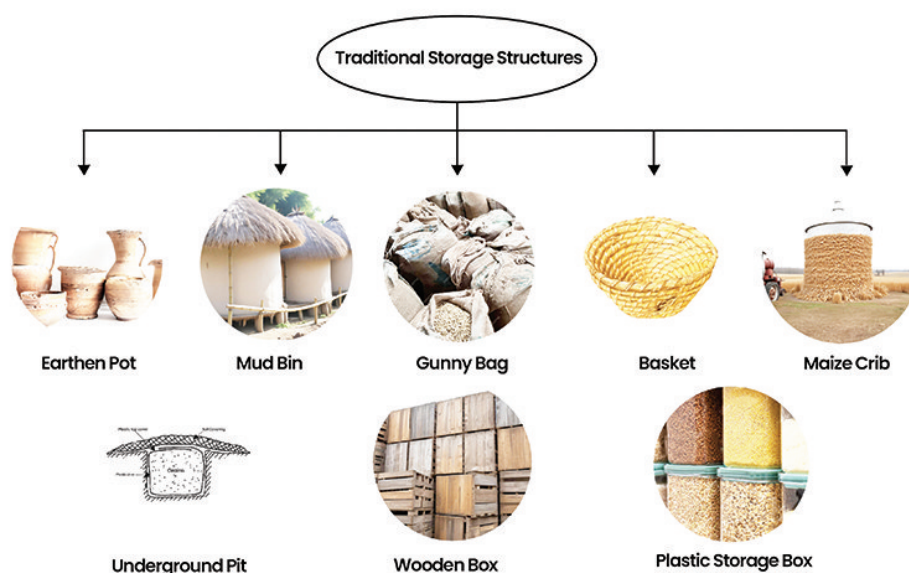


Fig. 14.1: Traditional storage structures

B. Modern storage

- a. **Covered storage:** This is the most common method of storing grains. It involves packing grains in jute bags, which are then piled in warehouses.
- b. **Cover and Plinth method (CAP):** In India, when traditional godowns and silos are full, bag stacks are constructed outside on a raised platform (plinth), and aerated at least once a week by moving the covers to the seventh or eighth layer. Wheat and paddy are currently stored using this method. However, a major disadvantage of the CAP method is that the food grains cannot be efficiently fumigated, and the coverings are susceptible to damage from wind and rain.
- c. **Silos:** These are tall towers specially designed for storing grains. They are considered one of the most efficient methods for storing grains as they require less land and operate round the clock. The most common shape used is the deep silo.



Notes

Post-harvest
Management

Notes

- d. **Silo bag technique:** This technique involves the use of hermetically sealed (airtight) plastic bags. The primary advantage of these bags is that they protect the grain from insects, pests, rain, humidity, sun, and dust.

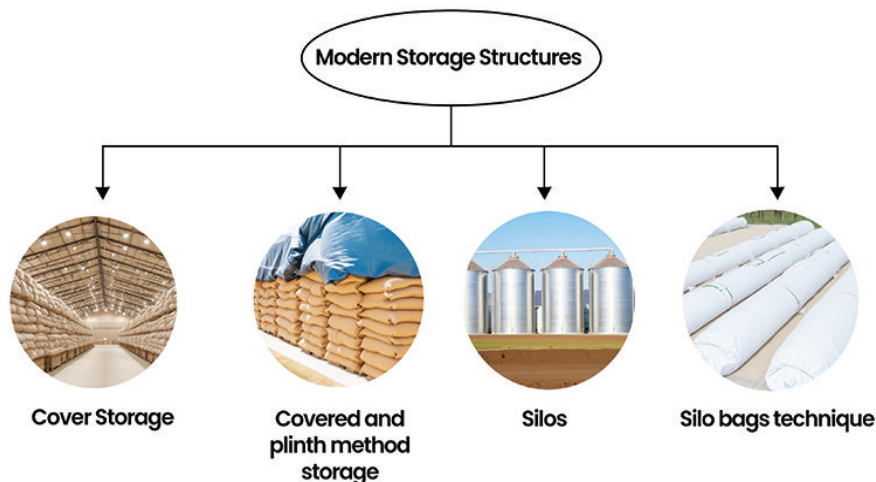


Fig. 14.2: Modern storage structures

Although many other storage options are available, the majority of agricultural produce is typically stored using an air-cooled system. Controlled ventilation and dehumidifiers are sometimes used to manage the humidity of the storage area. Cold storage, also known as refrigerated storage, involves controlled temperature and humidity to extend the shelf life of produce. Zero energy cooling is a well-known low-cost storage structure. Storage under a controlled atmosphere (3-5% O_2 and 2-5% CO_2) reduces peel browning and decreases the loss of soluble solids, acidity, and ascorbic acid.

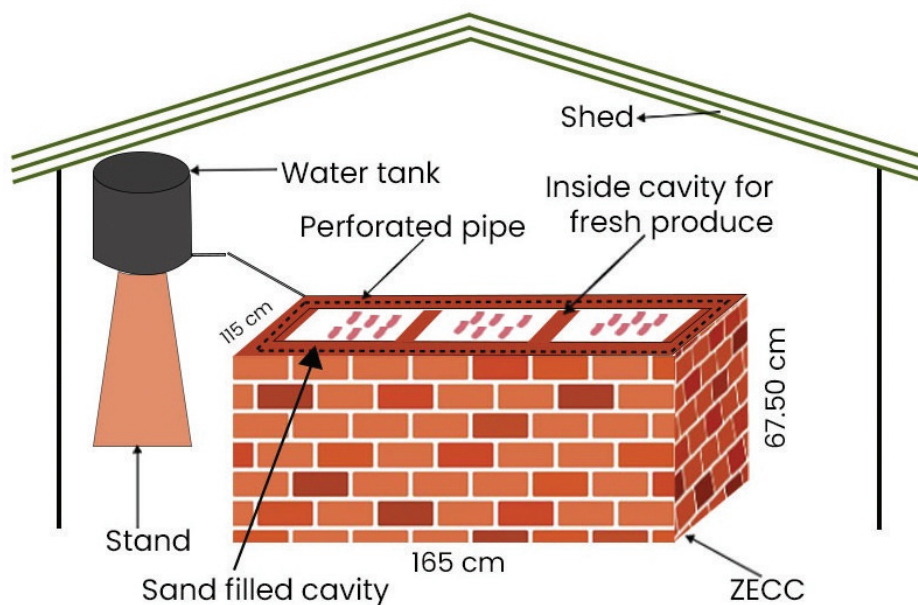


Fig. 14.3: Zero energy cool chamber (ZECC)



Grain storage in typical warehouses is done using gunny bags, polypropylene bags, silos, flat storage facilities, and elevators. The benefits of a bagged storage system include lower initial investment costs and no requirement for complex aeration circulation and fumigant systems. In addition to warehouse storage, other grain storage options exist, such as bulk storage. Bulk storage is carried out in hopper- or flat-bottomed bins, bunkers, and silos with varied capacities, made of brickwork, wood, shatterproof concrete, or metal. However, flat-bottomed bins offer more storage space and are less expensive to build.

Outdoor storage structures are frequently used when:

- There is a shortage of space in permanent storage facilities.
- The cost of constructing new building is too high.
- There is excess production in areas where adequate transportation to relocate the stocks is not available.

14.6 WAREHOUSE

The warehouse building is primarily a single-storey structure with minimal interior walls or partitions, a roof supported by trusses, and the presence of industrial equipment like a crane inside the structure. These warehouses are primarily designed for bulk storage.

A warehouse storage system is a collection of structures specifically designed to optimize space usage and improve organization, ensuring effective use of warehouse space.



Fig. 14.4: Interior of a warehouse

Post-harvest
Management

Notes

14.6.1 Typical Structure of A Warehouse:

1. The most prevalent elements are the vertical long walls with a sloped roof supported by horizontal girts joined to the columns if metal sheathing is used.
2. The building material should be weatherproof, corrosion-resistant, and fireproof.
3. An appropriate bracing system is essential to withstand lateral stresses.
4. Rigid-framed warehouse buildings are typically linear, traditional developments of plane frames that can withstand external loads. Rigid frames can be single-storied or multistoried.

14.6.2 Importance of Warehouse System

- **Improved safety:** Modern warehouse storage systems are safe and well-engineered. These buildings are sturdy and long-lasting enough to hold large quantities at once.
- **Enhanced organization:** The warehouse layout is designed to optimize storage conditions. It allows for alterations in structures to meet specific storage requirements.
- **Maximum space utilization:** All resources and space are utilized effectively for the storage of products.

The Government of India is emphasizing on building a strong warehousing system in the country for food grains to store as buffer stock. It is essential for meeting contingency situations such as natural calamities that affect production. A robust warehousing system also helps in maintaining market prices.

**INTEXT QUESTIONS 14.4**

1. Give four examples of traditional storage structures.
2. CAP stands for
3. What is the full form of HMHDPE?
4. Tall towers specially constructed for storing grains are termed as
5. What is a warehouse?

**WHAT YOU HAVE LEARNT**

- Food is a perishable commodity; therefore, it must be kept in a favorable environment after harvesting to reduce losses. Proper storage of harvested products is beneficial to both producers and consumers.
- Temperature, moisture, humidity are some of the critical factors affecting the storage of food products. Generally, low temperatures, low moisture levels, and high humidity are preferred for long-term storage.
- In India, traditional storage structures like earthen pots, mud bins, and underground pits are mainly used for storing grains. Fruits and vegetables are usually stored in wooden boxes.
- Modern storage techniques include covered storage, cover and plinth method, silos and silo bag technique, which offer good protection from biotic and abiotic agents.
- Warehouses are large, plain buildings used for bulk storage of food.

**TERMINAL QUESTIONS**

1. Write a short note on storage and warehouse.
2. Discuss the important precautions that need to be taken during storage.
3. What are the types of food loss? Give a brief description of them.
4. What are the different types of modern storage methods?
5. What are the factors affecting the storage life of food?
6. What are the different types of changes that occur during food storage? Explain the reason for such changes.
7. State the conditions when outdoor storage is practiced.
8. Discuss the importance of the warehousing system.

*Notes*

Post-harvest
Management*Notes***ACTIVITY**

Take photographs of various storage facilities and warehouses in your nearby area and describe in your own words the various storage facilities used for different food products.

.....

.....

.....

**ANSWERS TO INTEXT QUESTIONS****14.1**

1. False
2. Reduction in the fluctuations of market price of the commodity and availability of seasonal products in market throughout the year
3. Low
4. 80-95% (option d)
5. Low moisture content

14.2

1. To avoid exposure to direct sunlight to harvested products
2. For increasing storage life of produce
3. All of these (option d)
4. Rats

14.3

1. Browning (option d)
2. Respiration of freshly harvested products
3. Direct and indirect

14.4

1. Earthen pot, mud bin, underground pit, basket
2. Cover and plinth
3. High molecular weight high density polyethylene
4. Silos
5. Warehouse is a large plain building used for bulk storage of foods.



Notes

Post-harvest
Management

Notes

GLOSSARY

Warehouse: The warehouse building is primarily a single-storied structure with minimal interior walls or partitions and a roof supported by trusses. These are primarily created for bulk storage.

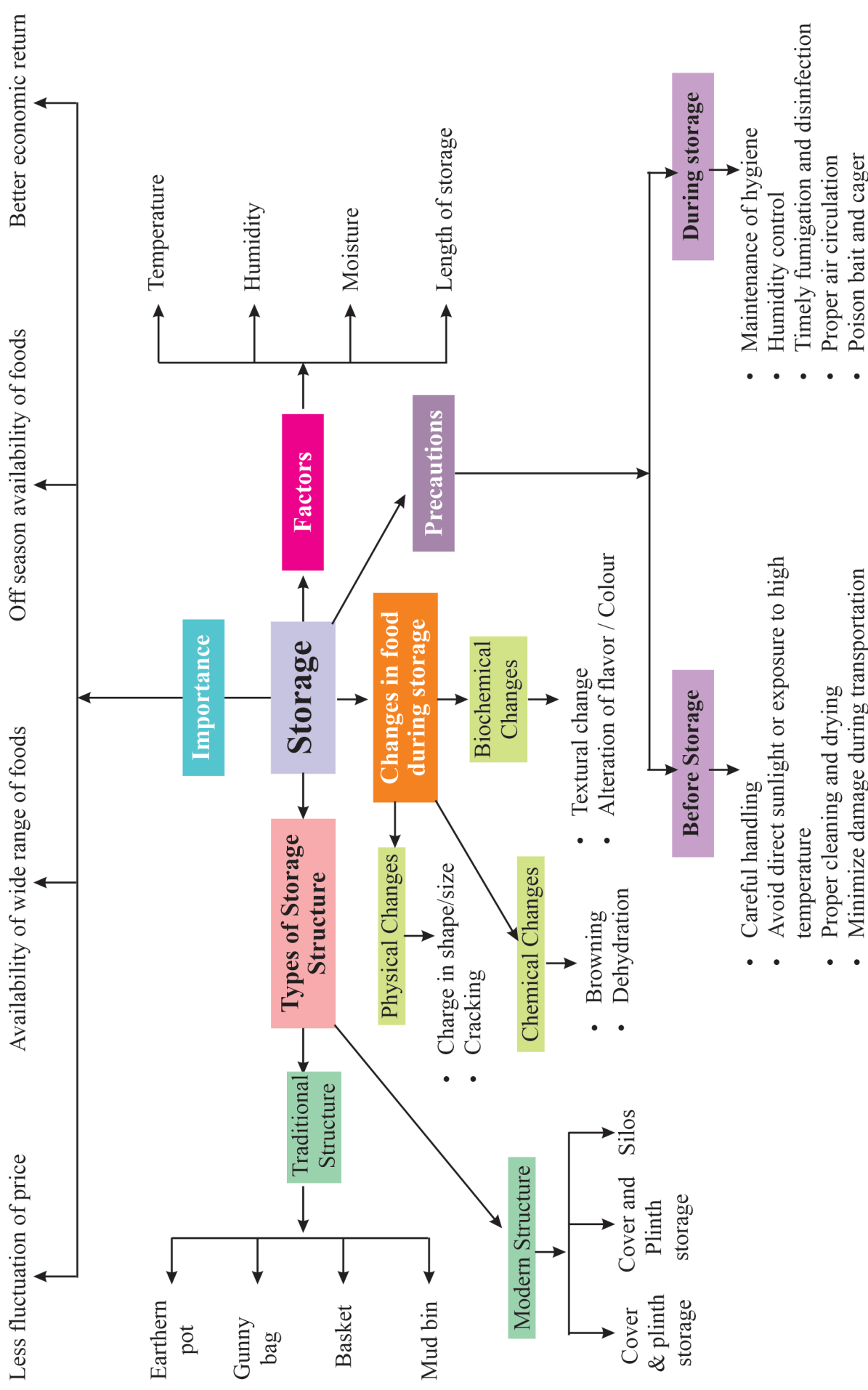
Silos: These are tall towers specifically designed for storing grains. Silos require less land and operate round the clock.

Cover and plinth method (CAP): In this method, stacks of bag are constructed outside on a raised platform (plinth) and covered with some waterproof material.

SUGGESTED READINGS

1. *Agricultural marketing: storage and warehousing*, TNAU Agritech Portal, Tamil Nadu Agricultural University, Coimbatore, India. (https://agritech.tnau.ac.in/agricultural_marketing/agrimark_storage%20and%20ware%20housing.html)
2. *Storage and warehousing: meaning, functions, advantages, kinds*, Accountlearning.com. (<https://accountlearning.com/storage-warehousing-meaning-functions-advantages-kinds/>)
3. *5 types of warehouse storage and their use cases*, Extensiv. (<https://www.extensiv.com/blog/warehouse-storage>)

WHAT YOU HAVE LEARNT



List of Credits

Lesson 1

Fig. 1.4: Severity of the Bengal Famine (1943); Courtesy: <https://t.ly/nOC1q>

Figure Name: Norman Borlaug; Courtesy: <https://t.ly/LxD1q>

Figure Name: M.S. Swaminathan; Courtesy: <https://t.ly/G3EI7>

Figure Name: Verghese Kurien; Courtesy: <https://tinyurl.com/3yu2tj8e>

Fig. 1.7: Imperial Agricultural Research Institute at Bihar; Courtesy: <https://www.iari.res.in/>

Fig. 1.8: Indian Agricultural Research Institute, New Delhi; Courtesy: <https://www.iari.res.in/>

Lesson 4

Fig. 4.2: Tractor-mounted laser land leveller; Courtesy: <https://farmech.dac.gov.in>

Fig. 4.3: Sprinkler irrigation system; Courtesy: <https://shorturl.at/yhchl>

Fig. 4.5: Crops cultivation inside a greenhouse; Courtesy: <https://shorturl.at/AQDJ4>

Fig. 4.7: Application of robotics in agriculture; Courtesy: <https://shorturl.at/GDA8v>

Fig. 4.8: Vegetation monitoring using satellite imagery; Courtesy: Google Earth

Fig. 4.12: Spraying of pesticide through drones; Courtesy: <https://shorturl.at/Ddxwn>

Lesson 5

Fig. 5.1: Components of soil; Courtesy: <https://rb.gy/ifr147>

Fig. 5.3: Textural triangle; Courtesy: <https://rb.gy/mpy1ba>

Lesson 6

Fig. 6.1: *Sesbania* green manuring in field; Courtesy: Dr. Dinesh Kumar, IARI, New Delhi

Fig. 6.2: Intercropping of Coconut with Marigold; Courtesy: <https://rb.gy/63ytom>



Notes



Fig. 6.4: Chisel Plough; Courtesy: <https://shorturl.at/XPTeQ>

Fig. 6.5: Rotavator; Courtesy: <https://rb.gy/kr9v6f>

Fig. 6.7: Earthing up in potato; Courtesy: <https://pxhere.com/en/photo/776945>

Fig. 6.8: Puddling of soil before rice transplanting in field; Courtesy: <https://rb.gy/0xx57c>

Fig. 6.9: Transplanting of rice in puddled field; Courtesy: Dr. Dinesh Kumar, IARI, New Delhi

Fig. 6.10: Rice nursery by wet method; Courtesy: Dr. Dinesh Kumar, IARI, New Delhi

Fig. 6.11: Paddy transplanter for mechanical transplanting; Courtesy: Dr. Dinesh Kumar, IARI

Lesson 7

Fig. 7.4: Furrow irrigation, Courtesy: <https://t.ly/t5uzl>

Lesson 8

Fig. 8.2: Leaf mining and boring by chewing insects, Courtesy: <https://rb.gy/t9j84d>

Fig. 8.3: Sucking of saps from plant tissues by white fly, Courtesy: <https://shorturl.at/BodRK>

Fig. 8.5: Leaf mosaic, Courtesy: <https://shorturl.at/I4qX4>

Fig. 8.5: Leaf curling, Courtesy: <https://t.ly/3koCI>

Lesson 9

Fig. 9.3: Corms; Courtesy: <https://bit.ly/49Kk3Lr>

Lesson 10

Fig. 10.6: Plastic low tunnel for vegetable cultivation, Courtesy: NCPAH (<https://www.ncpahindia.com/low-tunnel>)

Lesson 11

Fig. 11.1: Chrysanthemum loose flower, Courtesy: <https://shorturl.at/I90tH>

Fig. 11.1: Chrysanthemum cut flower, Courtesy: <https://bit.ly/4fB7rrc>

Post-harvest
Management

Notes

Fig. 11.3: Candytuft, Courtesy: <https://bit.ly/41LkYJF>

Fig. 11.4: Arose garden lawn, Courtesy: <https://rb.gy/yv1115>

Fig. 11.5: Bonsai, Courtesy: <https://bit.ly/41IKIpN>

Fig. 11.6: Terrarium, Courtesy: <https://rb.gy/6d8bk5>

Lesson 13

Fig. 13.5: Puffed rice; Courtesy: <https://shorturl.at/Gj7IW>

Fig. 13.6: Flaked rice; Courtesy: <https://tinyurl.com/yu68e46p>

Lesson 14

Fig. 14.4: Interior of a warehouse, Courtesy: <https://tinyurl.com/mt2c98ez>