Post-harvest Management and Value Addition of Fruits and Vegetables

- **Content Revisor:** Dr. C. Indu Rani, Tamil Nadu Agricultural University, Coimbatore
- **Course Reviewer:** Dr. Pritom Kumar Borthakur, University of Agricultural Sciences, Bangalore

Lesson Number	Topic
Lesson 1	Importance of Post-Harvest Processing of Fruits and Vegetables
Lesson 2	Extent and Possible Causes of Postharvest Losses
Lesson 3	Pre-Harvest Factors Affecting Postharvest Quality
Lesson 4	Maturity, Ripening and Changes Occurring During Ripening; Respiration and Factors Affecting Respiration Rate
Lesson 5	Harvesting and Field Handling; Storage (ZECC, Cold Storage, CA, MA, and Hypobaric)
Lesson 6	Value Addition Concept; Principles and Methods of Preservation
Lesson 7	Intermediate Moisture Food - Jam, Jelly, Marmalade, Preserve, Candy - Concepts and Standards
Lesson 8	Tomato Products - Concepts and Standards; Drying/Dehydration of Fruits and Vegetables
Lesson 9	Canning – Concepts and Standards, Packaging of Products

Course Name	**Post-Harvest Management And Value Addition Of Fruits And Vegetables**
Lesson 1	**Importance Of Post-Harvest Processing Of Fruits And Vegetables**
Course Revisor	**Dr. C. Indu Rani**
University/College	**Tamil Nadu Agricultural University, Coimbatore**
Course Reviewer	**Dr. Pritom Kumar Borthakur**
University/College	**University of Agricultural Sciences, Bangalore**

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

Objectives of the lecture

- To impart knowledge on post-harvest handling of fruits and vegetables
- To impart knowledge on Importance of post-harvest processing

Glossary of terms

	Post-harvest shelf life	-	appearance, taste, flavor, and texture of the commodity.
	Spoilage	-	involvement of microorganism, infestation of pest and invasion of pathogens
	Post-harvest handling	-	cooling, cleaning, sorting and packing.
	Preservation	-	the techniques of extending the storage life of the produce
	Processing	-	the application of techniques to prevent losses through preservation, processing, packaging, storage and distribution.

1. Scope and Importance of postharvest technology of fruits and vegetables

The Indian total production during the year 2020-21 was of the order of 103.23 mill. ton fruits and 193.61 mill. ton vegetables and total horticultural produce was 326.58 mill. ton. During 2020-21, India exported fruits and vegetables worth Rs. 9,940.95 crores/ 1,342.14 million USD which comprised of fruits worth Rs. 4,971.22 crores/ 674.53 million USD and vegetables worth Rs. 4,969.73 crores/ 667.61 million USD. According to FAO (2019), India is the largest producer of ginger and okra amongst vegetables and ranks second in production of potatoes, onions, cauliflowers, brinjal, Cabbages, etc. Amongst fruits, the country ranks first in production of Bananas (26.08%), Papayas (44.05%) and Mangoes (including mangosteens and guavas) (45.89%).

Fruits, vegetables and flowers are harvested at optimum maturity. They are living biological entities; they will deteriorate due to transpiration and respiration. Once harvested, produce subject to the active process of senescence. Biochemical processes continuously change the original composition of the produce until it becomes unmarketable. The period during which consumption is considered acceptable is defined as the time of "post-harvest shelf life".

Post-harvest shelf life is typically determined by appearance, taste, flavour, and texture of the commodity. The technique of extending the storage life of the produce without deteriorating its edible quality for further use is known as preservation.

Spoilage is initiated by enzymes present inside the produce, involvement of micro-organism, infestation of pest and invasion of pathogens. By controlling above factors, food products can be stored for longer period.

2. Postharvest handling

Post-harvest handling is the stage of crop production immediately following harvest, including cooling, cleaning, sorting and packing. The instant a crop is removed from the ground, or separated from its parent plant, it begins to deteriorate. Postharvest treatment largely determines final quality, whether a crop is sold for fresh consumption, or used as an ingredient in a processed food product. Effective handling decreases post-harvest losses.

2.1 Goals of post-harvest handling

1. Keeping the product cool, to avoid moisture loss and slow down undesirable chemical changes
2. Avoiding physical damage such as bruising, delay spoilage.

Implementing Good Agricultural Practices (GAP) in production and harvest; Good Manufacturing Practices (GMP) especially during postharvest and Quality and Safety Assurance Systems, such as HACCP (Hazard Analysis Critical Control Point), throughout the food chain to avoid and to control hazards are of the key factors for the flourishing nature of the post-harvest industries.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

3. Postharvest technology

Post-harvest technology is inter-disciplinary "science and technique" applied to horticultural/agricultural produce after harvest for its protection, conservation, processing, packaging, distribution, marketing, and utilization to meet the food and nutritional requirements of the people in relation to their needs. The field of study that adds to and uses this knowledge in order to develop affordable and effective technologies that minimizes the rate of deterioration is known as postharvest technology.

Pre cooling, waxing, cleaning/washing, chemical treatments, trimming/sorting, packaging, curing, transportation, grading, storage, ripening and distribution There is a general series of steps in post-harvest handling systems that are often followed.

- Harvesting and preparation for market
- Curing root, tuber and bulb crops
- Packinghouse operations
- Packing and packaging materials
- Decay and insect control
- Temperature and relative humidity control
- Storage of horticultural crops
- Transportation of horticultural crops
- Handling at destination
- Packing and packaging practices

3.1 Role of post-harvest technologist

1. To provide quality, nutritious and safe food
2. To develop new product and technologies. Biotechnology has been used to extend the storage life in tomato and developed variety called FLAVR SAVR using technology to reduce the activity of the enzyme endo polygalacturonase, which involved in the cell wall breakdown during ripening and fruit will remain firmer during ripening on and off the plant.
3. To develop new equipment and determine their efficiency.

4. Importance of post-harvest technology in horticultural crops

Ripening of fruits can be delayed and thus their storage prolonged, by reducing fruit respiration. The respiration can be reduced by postharvest storage techniques such as cold storage, gaseous storage and waxy skin coatings.

1. Postharvest loss reduction
2. Value addition
3. Contribution to the economy
4. Making availability of fruits and vegetables during off seasons
5. Tools for export earnings
6. Employment generation
7. Adding variety in taste and nutrition
8. Waste utilization
9. Home scale preservation
10. Supply of food to the defence forces
11. Special canned fruits for infants and children
12. Food supplier to the Astronauts

Course Name	**Post-Harvest Management And Value Addition Of Fruits And Vegetables**
Lesson 2	**Extent and Possible causes of Postharvest losses**
Course Revisor	**Dr. C. Indu Rani**
University/College	**Tamil Nadu Agricultural University, Coimbatore**
Course Reviewer	**Dr. Pritom Kumar Borthakur**
University/College	**University of Agricultural Sciences, Bangalore**

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

Objectives of the lecture

- To impart knowledge on post-harvest losses
- To impart knowledge on factors responsible for deterioration of horticultural produce

Glossary of terms

1.	Post-harvest losses	-	The deterioration in harvested fresh produce occurs both quantitatively and qualitatively
2.	Respiration rate	-	being living entities fruits, vegetables respire actively after harvest
3.	Ethylene production	-	ethylene plays a vital role in postharvest produce
4.	Transpiration	-	a physical process in which high amount of water is lost from the produce
5.	Maturity stage	-	less matured fruits lose more moisture then matured fruits/vegetables

1. Introduction:

It is well known fact that fruits, vegetables and flowers are living commodities even after harvest and continue to respire, transpire and carryout other biochemical activities. Therefore, they are more perishable when compared to other agricultural commodities. The deterioration in harvested fresh produce occurs both quantitatively and qualitatively. The losses that occur from the time of harvesting of fresh produce till they reach the consumer are referred as post-harvest losses. Post-harvest losses are estimated to be 30 - 40 percent.

2. Postharvest losses:

i. **Quantitative loss** - referring to the reduction in weight due to moisture loss and loss of dry matter by respiration

ii. **Qualitative loss** - referring to freshness deterioration leading to loss of consumer appeal and nutritional loss including loss in vitamins, minerals, sugars, etc.

The postharvest losses could be minimized to a large extent by following proper pre-harvest treatments, harvesting at right maturity stage and adopting proper postharvest treatments, handling, packing, transportation and storage techniques.

3. Factors responsible for deterioration of horticultural produce:

I. Biological factors

II. Environmental factors

3.1 Biological factors

Following biological factors are responsible for deterioration of horticultural produce

3.1.1 Respiration rate - being living entities fruits, vegetables, flowers respire actively after harvest.

3.1.2 Ethylene production - ethylene plays a vital role in postharvest produce.

3.1.3 Compositional changes

Many pigment changes also take place even after harvest in some commodities.

These changes are

a. Loss of chlorophyll (green colour) - Vegetables

b. Loss of carotenoids (yellow and orange colour) - Apricot, peaches, citrus, tomato

c. Loss of anthocyanins (red and blue colour) - Apples, cherries, strawberries

d. Change in carbohydrates

i. Starch to sugar conversion - Potato

ii. Sugar to starch conversion - Peas, sweet corn

e. Breakdown of pectin and other polysaccharides causes softening of fruit
f. Change in organic acids, proteins, amino acids and lipids can influence flavour
g. Loss in vitamins effects nutritional quality

3.1.4 Growth and development

In some commodity growth and development continue even after harvest which accelerates deterioration. For example

- Sprouting of potato, onion and garlic
- Fresh rooting of onions
- Harvested corps continues to grows even after harvest but is very much evident in Asparagus
- Increase of volume in lettuce

3.1.5 Transpiration

Most fresh produce contain 80-90 % of water when harvested. Transpiration is a physical process in which high amount of water is lost from the produce, which is the main cause of deterioration. This exchange of water vapour in produce is carried through the cuticle, epidermis cells, stomata and hairs of the produce. Produce stored at high temperature will have high transpiration rate.

When the harvested produce loses 5 % or more of its fresh weight, it begins to wilt and soon becomes unusable. Water loss also causes loss in quality, such as reduced crispness and other undesirable changes in colour, palatability and loss of nutritional quality.

3.1.5.1 Factors influencing the transpiration rate in various commodities:

- Surface of the commodity - commodities having greater surface area in relation to their weight will lose water more rapidly. It is clearly visible in leafy vegetables where the water loss is much faster than a fruit as they have more surface area to volume ratio.
- Surface injuries - Mechanical damages accelerate the rate of water loss from the harvested produce. Bruising and abrasion injuries will damage

the protective surface layer and directly expose the underlying tissues to the atmosphere allowing greater transpiration.

- Maturity stage - less matured fruits lose more moisture then matured fruits/vegetables
- Skin texture - Fresh produce having thin skin with many more spores lose water quickly than those having thick skin with fewer pores.
- Temperature - Water loss is high with increase in storage temperature. The loss will be further enhanced when high temperature is combined with low relative humidity
- Relative humidity - The rate at which water is lost from fresh produce also depends on the water vapour pressure difference between the produce and the surrounding air. So, water loss from fresh produce will be low when the relative humidity i.e., moisture content of the air is high**.** Further, the faster the surrounding air moves over fresh produce the quicker will be the water loss.
- Transpiration results in following type of deterioration:
- Loss in weight
- Loss in appearance (wilting and shrivelling)
- Textural quality softening, loss of crispiness and juiciness)

3.1.6 Physiological breakdown

When produce is exposed to an undesirable temperature physiological breakdown takes place. Following physiological breakdowns are common in various commodities:

- Freezing injury - when commodity stored at below their freezing temperature
- Chilling injury - when commodity stored at below their desired storage temperature
- Heat injury - when commodity exposed to direct sunlight or at excessively high temperature. It causes defects like sunburn, bleaching, scalding, uneven ripening and excessive softening.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

- Very low O2 (<1%) and high CO2 (>20%) atmosphere during storage can cause physiological problems
- Loss of texture, structure and microbial damage

3.1.7 Physical damage

Various types of physical damages responsible for deterioration are

- Mechanical injury/cut - during harvesting, handling, storage, transportation *etc*.
- Bruising due to vibration (during transportation), impact (dropping) and compression (overfilling)

3.1.8 Pathological breakdown

This is the most common symptom of deterioration where it is mainly caused by the activities of bacteria and fungi (yeast and mould). Succulent nature of fruits and vegetables make them easily invaded by these organisms. The common pathogens causing rots in fruits and vegetables are fungi such as Alternaria, Botrytis, Diplodia, Phomopsis, Rhizopus, Penicillium and Fusarium and among bacteria, Eriwina and Pseudomonas cause extensive damage

Microorganisms usually directly consume small amounts of the food but they damage the produce to the point that it becomes unacceptable because of rotting or other defects. Losses from post-harvest disease in fresh produce can be both quantitative and qualitative. Loss in quantity occurs where deep penetration of decay makes the infected produce unusable. Loss in quality occurs when the disease affects only the surface of produce causing skin blemishes that can lower the value of a commercial crop.

3.1.9 Surface area to volume - grater surface leads to greater weight and respiratory loss

3.1.10 Membrane permeability - fluctuation in storage temperature and physiological injuries like chilling injury leads to membrane damage resulting in electrolyte leakage.

3.2 Environmental factors

Following environmental factors are responsible for deterioration

1. Temperature

2. Relative humidity
3. Atmospheric gas compositions
4. Ethylene
5. Light
6. Other factors

3.2.1 Temperature

Environmental temperature plays very major role in deterioration of produce.

- Every increase of 10°C temperature above optimum increases the deterioration by two times
- Exposure to undesirable temperature results in many physiological disorders like; freezing injury, chilling injury and heat injury *etc*.
- Temperature influence growth rate of fungal spores and other pathogens.
- It affects the respiration and transpiration rate of produce.

3.2.2 Relative humidity

The rate of loss of water from fruit, vegetables and flowers depends upon the vapor pressure deficit between the surrounding ambient air, which is influenced by temperature and relative humidity. The rate of deterioration is a combined factor of temperature and relative humidity and affects the produce in following manner:

- Low Temp. & High Relative Humidity -- Low deterioration
- Low Temp. & Low Relative Humidity -- Moderate deterioration
- High Temperature & High Relative Humidity -- High deterioration
- High Temperature & Low Humidity -- Very high deterioration

3.2.3 Atmospheric gas composition

Build-up of undesirably high carbon dioxide and very low levels of oxygen in the storage facility can lead to many physiological disorders leading to spoilage. E.g., Hollow heart disease in potato is due to faulty oxygen balance in storage or during transportation. Exposure of fresh fruits and vegetable to O_2 levels below the tolerance limits or to CO_2 levels above their tolerance limits in storage rooms may increase anaerobic respiration and the consequent accumulation of ethanol and acetaldehyde, causing off-flavours. The other bad effects of unfavourable gas composition include irregular ripening of certain fruits, soft texture, lack of characteristic aroma, poor skin colour development, etc.

CA storage of Apples (0-1° C with 1-2% CO_2 and 2-3% O_2, RH 90-95%) for 6-12 month.

3.2.4 Ethylene

Effect of ethylene on harvested horticulture commodities may be desirable or undesirable. On one hand ethylene can be used to promote faster and more uniform ripening of fruits. On other hand exposure to ethylene can deteriorate the quality of certain vegetables such as destruction of green colour in leafy and other vegetables, early senescence of flowers, bitterness in carrots, increased toughness, accelerated softening, discoloration and off-flavour, etc.

3.2.5 Light

Exposure of potatoes to light results in greening of the tuber due to formation of chlorophyll and solanine which is toxic to human on consumption.

3.2.6 Other factors

Various kinds of chemicals (e.g., pesticides, growth regulators) applied to the commodities also contribute to deterioration. Many of the chemical constituents present in stored commodities spontaneously react causing loss of colour, flavour, texture and nutritional value. Further there can also be accidental or deliberate contamination of food with harmful chemicals such as pesticides or lubricating oils.

References

- Horticultural Statistics at a Glance. 2018. Horticulture Statistics Division Department of Agriculture, Cooperation & Farmers' Welfare Ministry of Agriculture & Farmers' Welfare Government of India
- Lisa Kitinoja and Adel A. Kader. 2002. Small-Scale Postharvest Handling Practices: A Manual for Horticultural Crops (4th Edition) Postharvest

Course Name	**Post-Harvest Management And Value Addition Of Fruits And Vegetables**
Lesson 3	**Pre-Harvest Factors Affecting Postharvest Quality**
Course Revisor	**Dr. C. Indu Rani**
University/College	**Tamil Nadu Agricultural University, Coimbatore**
Course Reviewer	**Dr. Pritom Kumar Borthakur**
University/College	**University of Agricultural Sciences, Bangalore**

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

Objectives of the lecture

- To impart knowledge on Pre-harvest factors
- To impart knowledge on factors which affecting postharvest quality

Glossary of terms

	Wind damages	-	by causing abrasions due to rubbing against twigs or thorns
	Oleocellosis or oil spotting	-	green spot on the yellow / orange colored citrus fruit after degreening
	Fruit thinning	-	increases fruit size but reduces total yield
	Girdling	-	increases the fruit size and synchronized fruit maturity
	Tissue damage	-	caused by slow wilting and produce ethylene leads to early senescence.

1. PRE – HARVEST FACTORS

1.1 Genetic / variety

Varieties with shorter shelf-lives are generally prone to higher post-harvest losses. Varieties with thick peel, high firmness, low respiration rate and low ethylene production rates would usually have longer storage life. The cultivars that have ability to withstand the rigors of marketing and distribution will have lesser losses after harvest. Varieties with resistance to low temperature disorders and/or decay-causing pathogens can be stored well for longer duration with minimum storage losses. Hence, while growing horticultural crops, one must choose such varieties that inherently have got good quality and storage potential in addition to the high yield and pest resistance potential.

1.2 Light:

Light regulates several physiological processes like chlorophyll synthesis, phototropism, respiration and stomatal opening. The duration, intensity and quality of light affect the quality of fruits and vegetables at harvest. Most of the produce needs high light intensity (3000-8000 Foot-candle). Absorption of red light (625-700 nm) through pigments, phytochrome, is essential for carbohydrates synthesis which determines the shelf life of the produce. The vase life of the carnation and chrysanthemums is longer under high light intensity than low.

Citrus and mango fruits produced in full sun generally had a thinner skin, a lower weight, low juice content and lower acidity but a higher TSS. And citrus fruits grown in the shade may be less susceptible to chilling injury when subsequently stored in cold storage.

In tomatoes, leaf shading of fruits produced a deeper red colour during the ripening than in the case of those exposed to light. The side of the fruit that have been exposed to sun will generally firmer than the non-exposed side. In general, the lower the light intensity the lower the ascorbic acid content of plant tissues. In leafy vegetables, leaves are larger and thinner under condition of low light intensity.

1.3 Temperature:

All type of physiological and biochemical process related to plant growth and yield are influenced by the temperature. The higher temperature during field conditions decreases life and quality of the produce. At high temperature, stored carbohydrates of fruits, vegetables and flowers are quickly depleted during respiration and plant respires at the faster rate. The produce which is having higher amount of stored carbohydrates show longer storage / vase life. For example: High temperature during fruiting season of tomato leads to quick ripening of fruits on and off the plant.

1.4 Humidity

High humidity during growing season results in thin rind and increased size in some horticultural produce and this produce is more prone to high incidence of disease during post-harvest period. Humid atmosphere may cause the development of fungal and bacterial diseases, which damages produce during storage and transport. Damaged produce remove water very quickly and emit a larger concentration of ethylene than healthy ones. Low humidity may cause browning of leaf edge on plants with thin leaves or leaflets. High humidity can maintain the water – borne pollutants in a condition so that they can be more easily absorbed through the cuticles or stomata. Reduced transpiration leads to calcium and other elemental deficiency.

1.5 Rainfall

Rainfall affects water supply to the plant and influences the composition of the harvested plant part. This affects its susceptibility to mechanical damage and decay during subsequent harvesting and handling operations. On the other hand, excess water supply to plants results in cracking of fruits such as cherries, plums, and tomatoes. If root and bulb crops are harvested during heavy rainfall, the storage losses will be higher.

1.6 Wind

Wind damages the produce by causing abrasions due to rubbing against twigs or thorns. These mechanically damaged produce is more prone to spoilage during postharvest period and have shorter postharvest life.

1.7 Mineral nutrition

Balanced application of all nutrient elements is necessary for the maintaining growth and development of the plants. The application of fertilizers to crops influences their postharvest respiration rate. Excess or deficiency of certain elements can affect crop quality and its postharvest life. Numerous physiological disorders are also associated with mineral deficiencies which ultimately lead to post harvest losses.

1.7.1 Nitrogen

High N fertilization reduces while moderate to high K improves postharvest life and quality of anthurium, other cut flowers and many horticultural produces. Application of K in water melon tends to decrease the PH respiration. High levels on N tend to decrease flavour, TSS, firmness and colour of the fruit and in stone fruits it increases physiological disorders and decrease fruit colour.

Generally, crops that have high levels of nitrogen typically have poorer keeping qualities than those with lower levels. High nitrogen increases fruit respiration, faster tissue deterioration thereby reducing their storage life.

1.7.2 Phosphorous

Application of phosphorous minimizes weight loss, sprouting and rotting in bulb crops compared with lesser application. Phosphorous nutrition can alter the post-harvest physiology of some produce by affecting membrane lipid chemistry, membrane integrity and respiratory metabolism. The respiration rate of low-phosphorous fruits will be higher than that of high phosphorous fruits during storage.

1.7.3 Potassium

Potassic fertilizers improves keeping quality, its deficiency can bring about abnormal ripening of fruits and vegetables. Potassium helps in reducing some physiological storage disorders, e.g., superficial rind pitting in oranges.

1.7.4 Calcium

The storage potential of the fruits is largely dependent on the level of Ca and it is associated with produce texture. The higher level of N, P and Mg and low levels of K and Bo lead to the Ca deficiency in fruits and reduce its storage life. Reduction in calcium uptake causes lateral stem breakage of poinsettia. Calcium treatment delays ripening, senescence, reduces susceptibility to chilling injury, increase firmness and reduces decay subsequent to storage in avocados and improves the quality.

Physiological disorders of storage organs related to low Ca content of the tissue are

- Bitter pit in apples
- Cork spot in pears
- Blossom end rot in tomato
- Tip burn in lettuce and hallow heart in potato *etc.*
- Red blotch of lemons

Zn is known to act as vehicle for carrying ions across tissue and increase Ca content of the fruit. Adequate supply of Boron improves the mobility of Ca in the leaves and the fruits and subsequently increases fruit firmness, TSS, organic acids and reduce the incidence of the drought spot, bitter pit and cracking disorders and impart diseases resistance.

1.8 Water relation and irrigation:

Stress due to excessive or inadequate water in the medium reduces the longevity of the produce. Crop like carnation require 850 to 1200 g of water to produce one gram of dry matter. In general, <5 % of water absorbed in the plant system is utilized for the development of different plant components. Moisture stress increases the rate of transpiration over the rate of absorption and irregular irrigation/ moisture regime leads fruits/vegetable cracking (potato and pomegranate cracking). Higher level of moisture stress affects both yield and quality by decreasing cell enlargement.

1.8.1 Quailing

Harvested produce is kept in the basket for few hours in the field before being transported to pack house, this will allow the produce to lose little moisture. Some growers have practice of harvesting lettuce in the late in the morning/ early afternoon because when they are too turgid the leaves are soft and more susceptible to bruising. In green leafy vegetables, too much rain or irrigation can result in the leaves becoming harder and brittle, which can make them more susceptible to damage and decay during handling and transport.

Mango hot water treatment is better if there is delay of 48 hr. between harvest and treatment and resulted better efficiency of hot water in disease control.

Generally, crops that have higher moisture content or low dry matter content have poorer storage characteristics. Keeping quality of bulb crops like onion and garlic will be poor if irrigation is not stopped before three weeks of harvesting.

1.9 Canopy Manipulation

a. Fruit thinning – increases fruit size but reduces total yield. It helps in obtaining better quality produce

b. Fruit position in the tree – Fruits which are exposed to high light environment possesses higher TSS, acidity, fruit size, aroma, and shelf life compared to which lies inside the canopy. Hence better training system should be practiced to circulate optimum light and air.

E.g.: Grapes, Mango, peaches, kiwifruit

c. Girdling - increases the fruit size and advance and synchronized fruit maturity in peach and nectarines. It increases fruitfulness in many fruit tree species.

1.10 Season / Day:

Seasonal fluctuation and time of the day at harvest will greatly affects the postharvest quality of the produce. Synthesis of higher amount of carbohydrates during the day time and its utilization through translocation and respiration in the night is responsible for the variation in the longevity of the cut flowers. Roses and tuberose have been found to show longer keeping quality in the winter season under ambient condition than in the summer seasons.

Generally, produce harvested early in the morning or in the evening hours exhibits longer postharvest life than produce harvested during hot time of the day.

Day length - If long days onion (temperate) grown during short day (tropics) condition it leads to very poor storage quality.

1.11 Carbon dioxide

Quality planting material, early flowering, more flowering, increased yield and rapid crop growth and development at higher level of CO_2 are observed. Production of chrysanthemum under green house at 1000 - 2000 ppm of CO_2 showed an increase in stem length, fresh weight, leaf no. and longevity of cut flowers.

1.12 Use of agro chemicals

Pre-harvest application of chemicals such as BA, IAA, GA_3, growth retardants like B-9, CCC, A-Rest and Phosphon-D have been reported to improve quality and longevity of flowers crops. Application of GA_3 @ 50-100 ppm improves postharvest quality of roses by anthocyanin development and it stimulate the accumulation of N, K, Mg and S. Pre-harvest spray with Alar (1500 ppm), MH (500 ppm), and Cycocel (500 ppm) increased vase life of Aster. Beneficial effect of leaf manure, K and GA_3 is found to enhance the longevity of tuberose flowers.

Use of chemicals on the plants to prevent the pathogen will have direct impact on extending the postharvest life. Generally, if produce has suffered an infection during development its storage or marketable life may be adversely affected. Banana which suffers a severe infection with diseases such as leaf spot may ripen pre maturely or abnormally after harvest and in mango it is rapid postharvest loss. Pre harvest application chemicals like MH on onion field prevent them sprouting during storage.

1.13 Pest and Diseases

Infection by fungi, bacteria, mites and insects reduces the longevity as well as consumer acceptability. Tissue damage caused by them show wilting and produce ethylene leads to early senescence. Vascular diseases/stem rot /root rot of floral corps hinder the transport, affects the post-harvest life and quality. The potato tuber moth may infest tubers during growth if they are exposed above the soil and subsequently in the storage.

References

- Horticultural Statistics at a Glance. 2018. Horticulture Statistics Division Department of Agriculture, Cooperation & Farmers' Welfare Ministry of Agriculture & Farmers' Welfare Government of India
- Lisa Kitinoja and Adel A. Kader. 2002. Small-Scale Postharvest Handling Practices: A Manual for Horticultural Crops (4th Edition) Postharvest Horticulture Series No. 8E. University of California, Davis Postharvest Technology Research and Information Center.
- Thompson A.K. (1996). Post-harvest technology of fruits and vegetables, Blackwell science.

Course Name	**Post-Harvest Management And Value Addition Of Fruits And Vegetables**
Lesson 4	**Maturity, Ripening And Changes Occurring During Ripening; Respiration And Factors Affecting Respiration Rate**
Course Revisor	**Dr. C. Indu Rani**
University/College	**Tamil Nadu Agricultural University, Coimbatore**
Course Reviewer	**Dr. Pritom Kumar Borthakur**
University/College	**University of Agricultural Sciences, Bangalore**

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

Objectives of the lecture

- To impart knowledge on changes occurring during ripening
- To impart knowledge on factors which affecting respiration rate

Glossary of terms:

	Ripening	-	Involving changes in color, texture and taste
	Senescence	-	the period when synthetic (anabolic) biochemical process gives way to degradative (catabolic) process leading to ageing and finally death of the tissue
	Respiratory quotient	-	Oxygen consumed / Carbon dioxide produced
	Chlorophyll degradation	-	leads to development of yellow/orange/red/purple pigments
	Propectin	-	insoluble form of pectic substances binds to calcium and sugars in the cell wall

1. Different Stages of fruits & vegetables:

The life of fruit and vegetables can be conveniently divided into three major physiological stages after germination.

Growth → Maturation → Ripening → Senescence

Developmental phase

1.1 Growth

Growth involves cell division and cell enlargement which accounts for the final size of the produce.

1.2 Maturation

Maturation usually commences before growth ceases and includes different activities in different commodities.

1.3 Ripening

Ripening is a phase of qualitative change which occurs in fruits particularly, after completion of maturation, during which the fruit becomes acceptable for consumption in terms of taste and flavour. Ripening occurs during the later stages of maturation and is the first stage of senescence.

1.4 Senescence

Senescence is defined as the period when synthetic (anabolic) biochemical process gives way to degradative (catabolic) process leading to ageing and finally death of the tissue.

Normally development and maturation processes are completed before harvest. The completion of this stage is referred to as maturity. Mango is harvested after attaining the full stage of maturation to develop the characteristic flavour and taste. But vegetables like Okra, beans, drumstick are harvested before it becomes fibrous and unpalatable. Vegetables are harvested over a wide range from immature stage to commencement of senescence.

2. Physiology and biochemistry

Fruit and vegetables are living entity even after harvest. Transpiration, respiration and ethylene evolution are important physiological processes which greatly influence the post-harvest life of fruits, vegetables and cut flowers. By controlling these physiological processes, shelf life of fruits, vegetables and flowers can be extended.

2.1 Ripening

Ripening is a catabolic process wherein the fruit undergoes a chain of biochemical reactions involving changes in colour, texture and taste.

Table 1. Bio chemical changes that occur during the ripening of fruit

. No	vents	ᒍuality Parameters
1.	Seed maturation	
2.	**Change in pigmentation**	Colour
	Degradation of chlorophyll	
	Unmasking of existing pigments	
	Synthesis of carotenoids	
	Synthesis of anthocyanin	
3.	**Softening**	Texture
	Change in pectin composition	
	Changes in other cell wall composition	
	Hydrolysis of storage materials	
.	**Change in carbohydrates composition**	Flavour
	Starch conversion to sugars	
	Sugar conversion to starch	
5.	Production of aromatic volatiles	
6.	Changes in organic acids	
7.	Fruit abscission	Dropping
8.	Change in repatriation rate	
9.	Change in rate of C2H4 synthesis	Ripening
10.	Change in tissue permeability	Softening
11.	Change in proteins	
	Quantitative	
	Qualitative – enzymes synthesis	
12.	Development of surface waxes	Shining

2.1.1 Colour development in fruit

The change in colour is either due to synthesis of plant pigments or due to unmasking of already existing colour. Change in colour is due to chlorophyll, which is magnesium organic complex. The loss of green colour is due to degradation of chlorophyll structure. Change in colour development is common except avocado, kiwi fruit and Granny Smith Apple. Chlorophyll degradation leads to development of yellow/orange/red/purple pigments.

The principle agents responsible for the degradation are

- Change in pH,
- Oxidation systems or
- Enzymes chlorophyllases

Carotenoids are stable pigments and remain there till senescence. They are either synthesized during developmental process or they are masked by the presence of chlorophyll. This kind of change is seen in case of banana. While in tomato, the colour pigment lycopene is developed simultaneously with degradation of chlorophyll. Other pigments found in fruits and vegetables are anthocyanins. They are red-purple or blue water-soluble phenolic glucosides that are found in vacuoles like in beet root and epidermal cell of apple and grape. They produce strong colour, which often mask carotenoids and chlorophyll. In acidic pH levels the anthocyanins are red in colour and in alkaline pH they tend to become blue. This gives rise to phenomena in roses known as 'blueing', whereas shift from red to blue coloration occur with aging. This is due to depletion of CHO and release of free amino acids resulting in more alkaline pH in the cell sap.

2.1.2 Changes in texture and taste

On ripening of fruits, breakdown of starch to sugars, which affects taste and texture of the produce.

a. Textural changes

The texture of the fruit softens with ripening. This is because of the action of enzymes like hydrolases (Poly galacturonase, pectin methyl esterase and cellulases) which breakdown the pectin, cellulose and hemicellulose.

Propectin is insoluble form of pectic substances binds to calcium and sugars in the cell wall. On maturation and ripening, propectin gradually broken down to lower molecular weight fraction which are more soluble in water. The rate of degradation of pectic substances is directly correlated with rate of softening of the fruit.

b. Change in taste

The primary change in taste is the development of sweetness in fruits after ripening. During ripening the starch break down into simple sugars like glucose, fructose and sucrose which are responsible for sweetness. This change is also mediated through the action of various enzymes like amylase, invertase, phosphorylase, *etc*.

2.1.3 Changes in vegetables

Seeds are consumed as fresh vegetables, for example sweet corn (baby corn) has high levels of metabolic activity, because they are harvested at immature stage. Eating quality is determined by flavour and texture, not by physiological age. Generally, seeds are sweeter and tender at an immature stage. With advancing maturity, the sugars are converted to starch, with a result of loss of sweetness: water content also decreases and amount of fibre material increases.

In edible flower/buds/stems/leaves textures is an often-dominant character that determines the both harvest date and quality, as loss of turgor through water loss causes a loss of texture. The natural flavour is often less important than texture, as many of these vegetables are cooked and seasoned with salt and spices.

Table 2. Conditions for controlled ripening of fruits at RH of 85-90%

Commodities	C_2H_4 (ppm)	Temperature (°C)	Treatment time (hr.)
Avocado	10-100	15-18	12-48
Banana	100-150	15-18	24
Honeydew melon	100-150	20-25	18-24
Kiwifruit	10-100	0-20	12-24
Mango	100-150	20-22	12-24
Stone fruits	10-100	13-25	12-72
Tomato	100-150	20-25	24-48

3. RESPIRATION

Fruits, vegetables and flowers respire by taking up O_2, giving off CO_2 and energy. When fruits, vegetables and flowers attached to plants, losses due to transpiration and respiration are compensated by flow of sap. Once it is detached from the plants, food reserves and moisture content decide the shelf life of fruits and vegetables. Therefore, losses of respiratory substrate and water have to be compensated in order to enhance the shelf life.

Respiration is described as the breakdown of more complex materials such as starch, sugars and organic acids into carbon dioxide, water and production of energy.

$$C_6H_{12}O_6 + 6\ O_2 \longrightarrow 6\ CO_2 + 6\ H_2O + \text{Energy (686 K Cal.)}$$

The respiration rate is an excellent indicator of shelf life of fruits, vegetables and flowers. The rate of deterioration of horticultural commodities is directly proportion to the respiration rate. Anaerobic respiration commences at below 1 % O_2 concentration. Off flavour may results from fermentation.

Respiratory quotient = Oxygen consumed / Carbon dioxide produced

RQ = 1 (Carbohydrates, protein)

RQ < 1 (Fats)

RQ = 1.33 (Organic acids)

3.1 Influence of respiration on the produce

- Reduced food value (energy value) for the consumer
- Reduced flavour due to loss of volatiles
- Reduced sweetness
- Reduce weight
- Important for the commodities desire dehydration

The respiratory pattern also influences the pattern of evolution of ethylene. Based on the respiratory pattern, fruits can be classified into ‘climacteric’ and ‘non-climacteric’. Some fruits exhibit the pronounced increase in the respiration (increase in CO_2 and C_2H_4) coincident with the ripening. Such increase in the respiration is known as respiratory climacteric. This type of fruits is called climacteric fruits.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

Table. 3 Difference between climacteric and non-climacteric fruits

	Climacteric fruits	Non-climacteric fruits
1.	Normally they ripen after harvest	Fruit that does not ripen after harvest. Ripen on the plant itself.
2.	The quality of fruit changes drastically after harvest characterized by softening, change in colour and sweetness. (Except in avocado, which will ripen only after detached from the plant)	The quality does not change significantly after harvest except little softening. Do not change to improve their eating characteristics
3.	Exhibits a peak in respiration	Does not exhibit a peak
4.	More ethylene is produced during ripening	Little / No ethylene production
5.	Significant increase in CO_2 production	No significant increase in CO_2 production
6.	Significant increase in CO_2 production	Slowly
7.	Decrease in internal oxygen concentration	More
8.	Low concentration of ethylene 0.1-1.0 μ l/lit./day is sufficient to hasten ripening	Not much response is seen to exogenous application of ethylene.
9.	Apple, Banana, Avocado, Pears, Kiwifruit etc…	Bell pepper, Blackberry, Blueberry, Cacao, Cashew apple, Cherry, Citrus, Carambola, Cucumber, Eggplant, Grapes, Litchi, Loquat, Okra, Olives, Pea, Pineapple, Pomegranate, Pumpkin, Raspberry, Strawberry,

		Summer squash, Tree tomato, Watermelon

3.2 Factors affecting respiration

3.2.1 Internal factors

1. Stage of the development

   The amount of protoplasm varies with stage of maturity of cells which influence the rate of respiration. The rate of respiration is high in young meristematic cells. In older tissues, rate of respiration is low due to the presence of less amount of protoplasm.
2. Chemical composition

   Concentration of respiratory substrate influences the rate of respiration.
3. Moisture content

   Moisture is essential to activate the respiratory enzymes. Rate of respiration will decrease with decreased amount of water.
4. Surface area to volume of the produce

   Respiration will be high in more surface area
5. Type and size of produce

   The rate of respiration varies with type of tissue viz., leaves, petals, pollen

3.2.2 External factors

1. Temperature

   The optimum temperature for respiration is 30 - 35^{o} C. The rate of respiration is high at high temperature. At low temperature, the rate of respiration is low since respiratory enzymes become inactive.
2. Oxygen

   If sufficient amount of oxygen is available, the rate of respiration increases.
3. Carbon dioxide

   High concentration of carbon dioxide has retarding effect on the rate of respiration.
4. Water

   Water is essential to activate the respiratory enzymes. Rate of respiration will decrease with decreased amount of water.

5. Ethylene
6. Presence of natural coating on the surface
7. Mechanical injury

   Injury stimulates respiration in the tissue. Once the wound is healed, the rate of respiration becomes normal.

Table 4. Classification of horticultural commodities according to their respiration rate

CLASS	Range at 5°C (mg CO_2 / Kg / hr)	COMMODITIES
Very low	< 5	Dates, Dried fruit and vegetables, Nuts, *etc*.
Low	5 - 10	Apple, Beet, Celery, Citrus Fruits, Garlic, Grapes, Kiwi Fruit, Onion, Papaya, Pineapple, Potato (Mature), Sweet Potato, Watermelon *etc*.
Moderate	10 - 20	Apricot, Banana, Cabbage, Carrot (Topped), Cherry, Fig, Lettuce (Head), Mango, Peach, Pear, Plum, Potato (Immature), Radish (Topped), Tomato, Summer squash
High	20 - 40	Avocado. Carrot (with tops), Cauliflower, Leeks, Lettuce (Leaf), Radish (with tops), Raspberry
Very high	40 - 60	Artichoke, Bean Sprouts, Broccoli, Brussels sprouts, Cut flowers, Green Onion, Okra
Extremely high	> 60	Asparagus, Mushroom, Parsley, Peas, Spinach, Sweet corn

3.3 Ways to decrease the respiration

1. To replenish the loss, cut stems should be dipped in preservatives containing sugar
2. Low temperature storage reduces the respiration rate in flowers
3. Modified and controlled atmospheric storage

   Storage of flowers in modified and controlled atmospheric storage where low oxygen and high carbon dioxide concentration is maintained
4. Removal of ethylene in the storage room by proper ventilation

Course Name	**Post-Harvest Management And Value Addition Of Fruits And Vegetables**
Lesson 5	**Harvesting and field handling; Storage (ZECC, cold storage, CA, MA, and hypobaric)**
Course Revisor	**Dr. C. Indu Rani**
University/College	**Tamil Nadu Agricultural University, Coimbatore**
Course Reviewer	**Dr. Pritom Kumar Borthakur**
University/College	**University of Agricultural Sciences, Bangalore**

Objectives of the lecture:

- To impart knowledge on harvesting and field handling
- To impart knowledge on importance of storage

Glossary of terms:

1)	Harvesting	-	gathering of plant parts that are of commercial interest
2)	Packing	-	a protective role against mechanical damage, dust and infection
3)	ZECC	-	(Zero energy cool chamber) On farm storage
4)	MAP	-	(Modified Atmosphere Packaging) a lower degree of control of gas concentration
5)	Hypobaric Storage	-	low pressure storage

1. HARVESTING

Harvesting is the gathering of plant parts that are of commercial interest. Harvesting of fruits, vegetables and flowers generally involves separating them from the vital sources of water, nutrients and growth regulators. Harvesting also bring out wound responses like ethylene production and increased respiration in the tissue. Mature tissue generally shows only small responses to harvesting because it stored carbohydrates reserves and relatively low respiration and transpiration rates, and it's destined for natural separation by abscission any way. Rapidly metabolizing tissue such as leafy vegetables/immature fruits & vegetables exhibit larger responses to harvesting. Harvest the produce when the heat load is low, however around the clock harvesting is done when machinery is used to meet the cost of the machine and factory processing schedule.

1.1 HARVESTING METHODS:

There are two methods of harvesting. They are (1) Hand harvesting and (2) Mechanical harvesting. Several factors are considered in deciding on the appropriate method of harvesting a crop. Some crops offer no choice since machines have not yet been developed for harvesting them. In other cases, the product is so delicate that mechanical harvesting becomes a great challenge and is not cost effective. Where human labour is plentiful and inexpensive, hand picking may be economical.

1.1.1 Hand Harvesting

Harvesting by hand is being practiced in all the horticultural crops since time immemorial. Some of the crops e.g., flowers even today are harvested by hands. But in India hand harvesting is still the most common method used in horticultural commodities. Due to inadequate mechanization, small land holdings and diversity of crops being grown by a small farmer. In developing countries, most produce for internal rural and urban markets is harvested by hand. It predominates for the fresh market and extended harvest period (due to climate, there is accelerated ripening and a need to harvest the crop quickly) particularly the produce which is more susceptible to physical injury and soft fruit like grapes/litchis/ jamun and strawberry and others berries which are borne on low growing plants

1.1.2 Mechanical harvesting

In region where labour cost is high machine harvest is popular for processing crops because it could damage the produce and subsequent faster deterioration. E.g.: Peas for freezing, peaches for canning and grapes for wine making

Likewise, machine harvest is used for robust, low-unit-value ground crop such as potatoes and onions. The main advantages of mechanized harvesting are speed and the reduced costs per ton harvested. However, because of the risk of mechanical damage, it can only be used on crops that require a single harvest

i. Mechanical assistance:

These are the simple machine used to provide assistance to hand pickers with ladder and positioners (tree towers and platforms). Combination of these processes is possible by process by providing bins mounted on trailers moving along the plant rows. 'Flying foxes' (overhead ropeways) are similar systems provided to convey heavy banana bunches into packing house

ii. Harvesting machine: it employs direct harvest by contact methods such as

- Shaking machine

- Picking pole fitted with cutter device - For fruits high on trees like mango, avocados
- The ‘shake and catch’ machine used in apple and citrus to harvest and collect the fruit by shaking the trunk and collection the fallen fruit on the canvas which spread under the tree
- Vibrating digger is used to harvest underground roots/tuber/ rhizomes.
- Use of robotics to harvest mushroom by method of sucker end-effecter.

1.2 Handling of horticultural produce:

- Moment produce is harvested, from that point on quality cannot be improved; only maintained. Remember the suitability of produce for sale begins at harvest. Damage done to produce during harvest is irreparable. No postharvest treatments can improve inferior quality produce resulting from improper handling
- Fruit and vegetables are highly perishable and unless great care is taken in there harvesting, handling and transportation, they soon decay and become unfit for human consumption. The process of decay being accelerated if poorly harvested and handled produce is placed in storage for any length of time

1.2.1 Handling at the Field

As all fruit and vegetables are tender and have soft texture/skin should be handled gently to minimize bruising and breaking/rupturing of the skin. After harvesting, produce is handled at the field for three main activities before dispatch to the market for sale.

i) Washing, cleaning and dressing/trimming

After harvest all underground vegetables and most of the leafy vegetables require washing and cleaning before sorting-grading and packing. While washing and cleaning care should be taken that produce does not get damaged while rubbing to clean the outer surface and only clean water should be used for washing to protect the produce from contamination. Removal of extra water is a must before packing to avoid rotting. E.g., Washing with 100 ppm chlorine solution is better to control microbial growth. Vegetables like Cauliflower, Cabbage, Radish and other leafy items require to be dressed by removing unwanted leaves and stalk before sending them for marketing.

ii) Sorting-grading

All defective produce such as bruised, cut, decayed and insect infested pieces should be discarded while sorting-grading will help to control further deterioration of the produce while in transit. Care should be taken that produce is picked gently and should not be thrown

iii) Weighment and packing

Packing material and package itself play a protective role against mechanical damage, dust and infection. They also diminish the rate of loss of water, or hinder gaseous exchange and thus modify the composition of the atmosphere around the produce. Type of packaging material and pack size for primary and secondary packaging is very important to enhance life of the produce after harvesting. Different types of packs are suitable for different type of produce depending upon the distance of location and transport mode used. Pack should not have inside sharp edges. Proper cushion in the pack helps the produce to sustain jerks/vibrations during transportation. As far as possible, uniformly graded produce should be packed in one type of pack.

Packing must withstand the following:

- Rough handling during loading and unloading
- Compression from the overhead weight of other containers.
- Impact and vibration during transportation.
- High humidity during pre-cooling, transit and storage

After and packing, each pack has to be weighed before sending to the market for sale. Each pack should have some extra quantity to take care about the moisture loss during transit

1.2.2 Tips for handling fruit and vegetables

- Pick all the fruits very gently with thumb and middle finger only
- Never press any fruit and vegetable (Any damage to produce due to bad handling is not visible but damage occurs; however, it develops over a period of time.)
- Do not pick banana from the body; Pick them by stem only
- Do not pick leafy vegetables by the leaf end; Pick them from stem only.
- Do not press citrus fruits; It damage oil cells present on skin and turn brown after some time
- Do not press ripe fruits like sapota, banana and mango etc. to check ripening.

Examples for checking ripeness

Papaya: Punch the body with fine needle, if thick milk secretion comes it is unripe, if watery substance comes out it is ripe

Sapota: Place in your full hand and feel the ripening with slight pressure

Mango: Press the mango from its beak.; if it hard it is unripe, if it takes pressure/smooth, it is ripe

1.2.3 Growers should follow basic principles when handling fresh produce

All labour engaged in handling and transporting fresh produce should be trained

All cut produce, such as cabbage/others should be kept away from being placed in contact with soil

Remove or minimize the effect of all likely damage points from within the handling system

Use methods of padding or cushioning when first filling containers or transport to minimize the risk of bruising or scuffing of produce

Make certain that vegetables being transferred from one point to another during harvesting or grading and sorting, that they suffer the absolute minimum of drop

Protect harvested produce from the debilitating effect of sun, wind and rain each of which cause problems specially to crops destined for long term storage.

2. STORAGE

Many horticultural crops are seasonal in nature and have a relatively short harvesting season. As discussed earlier they are also highly perishable. Hence, proper storage of these produce using appropriate methods would prolong their availability. Storage of fresh produce will also be helpful in checking market glut, providing wide selection of fruits, vegetables and flowers to the consumer through most part of the year i.e., especially during the off season. Storage helps in orderly marketing and increases profit to the producers/farmers. Storage of fresh produce is done to maintain freshness, quality, reduce the spoilage and extend their usefulness. One of the reasons for the huge post-harvest losses of horticultural produce is lack of proper storage facilities. The basic principle of storage is to reduce the rate of physiological processes like respiration, transpiration, ripening and other biochemical changes. Proper storage also aims at controlling disease infection and preserving the commodity in its best quality for consumers.

2.1 Importance of storage

- Slow down biological activity
- Reduce product drying and moisture loss
- Reduce pathogenic infection
- Avoid physiological disorders
- Reduce physical damage

2.2 Factors affecting storage

i. Pre harvest factors
ii. Maturity at harvest
iii. Harvesting and handling practices
iv. Pre-storage treatments
v. Temperature and humidity in storage room
vi. Overall hygiene

2.3 Types of storage:

2.3.1 Zero energy cool chamber

- On farm storage
- Storage chamber, for fresh fruits, vegetables and flowers
- Materials - Brick, sand, bamboo, vetiver/straw, gunny bag

- Keep the temperature 10-15°C cooler than the outside temperature and maintain about 90% relative humidity.

2.3.1.1 Areas of Application

- Short term storage of fresh vegetables, fruits and flowers
- Growing of white button mushroom
- Ripening of tomato and banana
- Storage of processed fruit products

2.3.1.2 Advantages

- Avoid distress sale of fresh fruits, vegetables and flowers.
- Better marketability of fresh horticultural produce than ambient
- Retain nutritive value
- Environment friendly storage system with no pollution

2.3.2 Low temperature storage (Refrigeration/cold storage)

Low temperature storage is the best known, effective and most widely used method for extending the storage life and long terms storage of fruits, vegetables and flowers. In post-harvest technology, "temperature management is the most important aspect to be looked after to maintain quality, reduce losses and extend the storage life of these perishable commodities. Cold storage is a system with thermal insulation and refrigeration in which perishables commodities can be stored for a set period of time under controlled conditions of temperature and humidity.

2.3.2.1 Purpose of cold storage

- For preservation
- For maintaining nutritional quality
- To increase storage life

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

- To ensure availability of the produce throughout the year for direct consumption as well as processing
- To reduce losses due to wastage
- To preserve the seasonal produce and selling during off season to fetch higher returns

2.3.3 Controlled Atmosphere Storage (CA Storage)

The storage of fruits and vegetables in CA Storage is one of the most advanced methods of storage. It was first suggested by W.R. Philips of Canada. From the construction point of view, controlled atmosphere facilities are similar to refrigeration facilities. However, they should be airtight to allow creation of an atmosphere different from normal. The Oxygen consumption and its replacement by carbon dioxide by respiration, create the atmosphere. When the appropriate combination has been reached, a limited intake of oxygen is required to satisfy the reduced rate of respiration. Accumulation of carbon dioxide is removed by means of different methods.

2.3.3.1 Physiological basis of CA Storage

Air contains about 20.9% O2 78.1 % N2, 0.003 % CO2 and trace number of other gases including Ne, He, CH4 and water vapor. In CA storage, oxygen is reduced and CO_2 is increased and ripening and respiration rates are slowed down.

2.3.3.2 Benefits of CA storage

1. Retardation of senescence and associated biochemical and physiological changes

2. Reduction of produce sensitivity to ethylene action at O_2 levels below 8% and/ or CO_2 levels above 1 %.

3. Useful tool for insect control in some commodities.

2.3.3.3 Limitation of CA storage

1. Causes certain physiological disorders such as black heart in potatoes, brown stain of lettuce.

2. Irregular ripening of produce such as banana, pear, tomato *etc*.

3. Development of off flavors and off odors at very low O_2 concentrations.

4. Timely non availability of gas

5. Costly and technical knowhow is required

2.4 Modified Atmosphere Packaging (MAP)

MA packaging and storage implies a lower degree of control of gas concentration in atmosphere surrounding the commodity. The MA and CA differ only in degree of control, CA is more exact. Advances in the manufacture of polymeric films with wide range of gas permeability have stimulated interest in creating and maintaining modified atmospheres within flexible film packages.

2.4.1 Biochemical and Physiological Basis of MA

The rate of respiration and metabolism doubles for every 10°C rise in temperature. Respiration can be therefore reduced by decreasing the temperature, O_2 level and/or increasing the CO_2 level in the storage atmosphere. Both O_2 and CO_2 levels exert independent effects on respiration. The net effect may be additive or synergistic. When O_2 concentration is reduced below 10%, respiration rate is decreased.

However, when O_2 concentration falls below 2%, anaerobic respiration may set in, thereby leading to the accumulation of ethanol and acetaldehyde. The desirable effect of MA on plant tissues is also attributed to lower pH, due to dissolution of CO_2 in tissues. Ethylene action and biosynthesis are also affected besides water loss and chilling injury

Table.1 Difference between CA and MA Storage CA

CA Storage	MA Storage
High degree of control over gas conc.	Low degree
Longer storage life	Less
More expensive technology	Less
Atmosphere is modified by adding gas	It is created by either actively (addition or removal of gas) or passively(produce generated)
Specific temperature should maintain	May or may not be maintained

Table.2 General Storage Recommendation

The University of California (Thompson *et al*.,1999) recommended three combinations of temperature and relative humidity

Temperature °C	RH %	Crops
0 – 2	90 – 98	leafy vegetables, crucifers, temperate fruits and berries
7 – 10	85 - 95	citrus, subtropical fruits and fruit vegetables

13 - 18	85 – 95	tropical fruits, melons, pumpkins and root vegetables

Low Pressure Storage / Hypobaric Storage

Fruits can be stored under low pressure of 0.2 - 0.5 atmospheric pressure and temperature of 15 - 24°C under airtight chamber. Pressure is reduced by sucking air and creating vacuum.

Table. 3 Comparative storage life (in days) of produce stored in refrigeration and under hypobaric conditions

Commodity	Cold storage	Hypobaric storage
Fruits (fully ripe)		
Pine apple (ripe)	9 - 12	40
Grapefruit	30 - 40	90 - 120
Strawberry	5 - 7	21 - 28
Sweet cherry	14	60 - 90
Fruits (unripe)		
Banana	10 - 14	90 - 150
Avocado	23 - 30	90 - 100
Apple	60 - 90	300
Pear	45 - 60	300
Vegetables		
Green pepper	16 - 18	50
Cucumber	10 - 14	41
Beans	10 - 13	30
Onion (green)	2 - 3	15
Lettuce	14	40 - 50
Tomato (mature green)	14 - 21	60 - 100

Tomato (breaker stage)	10 - 12	28 - 42

References

- Horticultural Statistics at a Glance. 2018. Horticulture Statistics Division Department of Agriculture, Cooperation & Farmers' Welfare Ministry of Agriculture & Farmers' Welfare Government of India
- Lisa Kitinoja and Adel A. Kader. 2002. Small-Scale Postharvest Handling Practices: A Manual for Horticultural Crops (4th Edition) Postharvest Horticulture Series No. 8E. University of California, Davis Postharvest Technology Research and Information Center.
- Thompson A.K. (1996). Post-harvest technology of fruits and vegetables, Blackwell science.
- Verma L.R. and Joshi V.K. (2000). Post-harvest technology of fruits and vegetables. Vol. I & II, Indus Publishing Co. New Delhi
- http://ecoursesonline.iasri.res.in/mod/page/view.php?id=16302

Course Name	**Post-Harvest Management And Value Addition Of Fruits And Vegetables**
Lesson 6	**Value Addition Concept; Principles And Methods Of Preservation**
Course Revisor	**Dr. C. Indu Rani**
University/College	**Tamil Nadu Agricultural University, Coimbatore**
Course Reviewer	**Dr. Pritom Kumar Borthakur**
University/College	**University of Agricultural Sciences, Bangalore**

Objectives of the lecture

- To impart knowledge on value addition concept
- To impart knowledge on preservation methods and principles

Glossary of terms

	Perishable	-	likely to spoil or decay within a short period.
	Irradiation	-	process of using radiation to prevent spoilage
	Anaerobic	-	absence of free oxygen
	Preservation	-	process of treating and handling food to stop or slow down spoilage
	Dehydration	-	loss or removal of water from food material

1. Value Addition

Value addition is the conversion of perishable fruits and vegetables into stable products by various method of preservation.

1.1 Concept of Value Addition

Value is added by changing their form, colour and other such methods to increase the shelf life of perishables raw material. There are various methods of preservation of food including thermal processing, fermentation, pickling, dehydration, freezing etc.

1.2 Need for value addition

- To improve the profitability of farmers.
- To empower the farmers and other weaker sections of society especially women through gainful employment opportunities and revitalize rural communities.
- To provide better quality, safe and branded foods to the consumers.
- To emphasize primary and secondary processing.

- To reduce post-harvest losses.
- Reduction of import and meeting export demands. Way of increased foreign exchange.
- Encourage growth of subsidiary industries.
- Reduce the economic risk of marketing.
- Increase opportunities for smaller farms and companies through the development of markets.
- Diversify the economic base of rural communities

1.3 Importance of Value Addition in Horticulture

- Horticulture deals a large group of crops having great medicinal, nutritional, health promoting values.
- India as second largest producer of fruits and vegetables, only 10 per cent of that horticultural produce is processed, but other developed and developing countries where 40-80 per cent produce is value added.
- Horticultural crops provide varied type of components, which can be effectively and gainfully utilized for value addition like pigment, amino acids, oleoresins, antioxidants, flavors, aroma etc. Post-harvest losses in horticultural produce are 5 to 30 per cent which amounts to more than 8000 crore rupees per annum. If we subject our produce to value addition the losses can be checked.
- Horticultural crops are right material for value addition because they are more profitable, has high degree of process ability and richness in health promoting compounds and higher potential for export.

2. Principles and methods of preservation

The perishable foods like fruits, vegetables deteriorate or decay easily, so considerable amounts of such commodities are wasted in various stages of food supply chain unless special methods are applied for their preservation. Preservation of food involves the processes in which, the perishable food materials are given a suitable physical or chemical treatment to prevent their spoilage and to retain their nutritive value for long periods.

2.1 Principles of Food Preservation

All food preservation methods are based upon the general principle of preventing or retarding the causes of spoilage caused by microbial decomposition, enzymatic and non-enzymatic reaction, chemical or oxidative reactions and damage from mechanical causes, insects and rodents etc. Food preservation operates according to three principles, namely:

2.1.1 Prevention or delay of microbial decomposition brought out by

- Keeping out microorganisms or asepsis
- Removal of microorganisms e.g., washing, filtration etc.
- Hindering the growth and activity of microorganisms by controlling the conditions required for the growth and activity of microorganisms by use of low temperature, drying, maintenance of anaerobic conditions or chemicals
- Killing microorganisms by heat or irradiation

2.1.2 Prevention or delay of self-decomposition of foods by

- Destroying or inactivating food enzymes e.g., blanching, low temperature storage, chemical preservation, drying etc.
- Preventing or delay of chemical reactions e.g., prevention of oxidation with the use of antioxidants as oxygen speeds up decomposition of food and antioxidants deprives food from oxygen.

3.Prevention of damage because of external factors such as insects, rodents, dust, odour, fumes, and mechanical, fire, heat or water damage. E.g., Use of boxes, cartons, and shock absorbing materials, sealed tight, vacuum-packaging etc

2.2 METHODS OF PRESERVATION

The different preservation methods commonly employed are as discussed below

2.2.1 Asepsis

Asepsis is a process of keeping microorganisms out of food. An aseptic environment can be created by

1. Proper packaging of the product, which separates the internal environment from the surroundings.
2. Maintenance of general cleanliness and sanitary conditions while processing and handling the product from raw material to finished stage can help in preventing the entry of microorganisms into the product.

Maintenance of anaerobic conditions/ packaging

Packaging food in a vacuum environment, usually in an air-tight bag or bottle results in anaerobic environment. As bacteria need oxygen for survival, the vacuum environment in the package slows down the spoilage by them.

2.2.2 Drying

Drying is one of the oldest and the simplest method of preserving food. It refers to removal of water from the food. Dried foods are preserved because the available moisture level is so low that the microorganisms cannot grow and the enzyme activity is also controlled. Drying can be accomplished by a number of methods viz. sun drying, mechanical/ artificial drying and freeze drying etc.

1. **Sun drying**: Sun-drying takes heat from sun rays but it is a slow process involving risk of contamination and spoilage.
2. **Mechanical/ artificial drying**: Dehydration process usually implies the use of controlled conditions of heating, with the forced circulation of air or artificial drying (mechanical drier) in contrast to sun drying. Using mechanical driers, fruits and vegetables can all be dried year-round.
3. **Freeze drying**: Freeze-drying is a form of dehydration in which the product is first frozen and then water is removed under vacuum as vapor by sublimation. The principle behind freeze drying is that under certain conditions of low vapor pressure, water in the form ice evaporates as water vapor directly without turning into liquid phase.

4. **Smoking**: Smoking has been used as a method of food preservation from time immemorial. In this method, foods are exposed to smoke by burning some special kinds of wood, which has two main purposes, adding desired flavoring and preserving.

2.2.3 Food concentration

Relatively few liquid foods are preserved by concentration, involving preservative action of reduction in water activity (aw) and development of osmotic pressure, which retard the microbial growth and enzymatic reactions. Concentration of food is usually done for many reasons: reduction in volume and weight; reduction in packaging, storage and transport costs; better microbial stability; and convenience. Examples of food preserved by concentration are tomato paste, fruit juice concentrate, soup and condensed milk. The rate of heating should be controlled to prevent localized burning of the product, particularly when it has become thickened towards the end of boiling.

2.2.4 Use of high sugar or salt content

1. **Sugaring**- A strong sugar solution (about 68 per cent or more) draws water from the microbial cells and thus, inhibits the growth of microbes. Examples of food preserved by high sugar concentrations are fruits in heavy sugar syrup (preserve or murraba), jams, jellies, marmalades, candies and sweetened condensed milk.
2. **Pickling**- Pickles are the relishing accompaniments in the Indian meals. Microorganisms do not grow well in acidic solutions. And this is the basis of preserving fruits and vegetables by pickling. Pickling uses the salt combined with the acid, such as acetic acid (vinegar). Some of the fruits and vegetables, which are generally pickled, are raw mangoes, limes, Indian gooseberry (aonla), ginger, turmeric and green chillies.
3. **Salting or curing**- Dry salting is used in India for the preparation of preserved tamarind, raw mango, Indian gooseberry (aonla), fish and meat etc.

2.2.5 Use of organic acids

Organic acids are used in food preservation because acid conditions inhibit growth of many spoilage microorganisms. Bacteria are generally pH sensitive. Organic acids penetrate the bacteria cell wall and disrupt its normal physiology and thus preserve the food. Acetic acid, lactic acid, citric acid and malic acid are widely used for preservation in food products.

2.2.6 Fermentation

Fermentation involves multiplication of microorganisms and their metabolic activities are also encouraged, in contrast to other preservation methods. In this, microorganisms break down complex organic compounds into simpler substances either in aerobic or anaerobic conditions. The chemicals produced by the microorganisms such as alcohol or acids cause the preservative effect of fermentation by slowing down spoilage factors. The principal chemicals involved are the acids (especially lactic acid) and alcohol. These inhibit the growth of common pathogenic organisms in foods. Examples of food preserved by fermentation are alcoholic products (e.g., beer, fruit wine) and acid products (e.g., vinegar, pickled vegetables), yogurt, cheese etc. This technique is often combined with pasteurization.

2.2.7 Use of low Temperatures

The metabolism of a living tissue is a function of the temperature of the environment. Low temperature is applied to retard chemical and enzymatic reactions in food. In addition, reducing temperature retards or stops growth and activity of microorganisms in the food. Lower the temperature, the slower will be the rate of above natural activities. Cooling thus slows down or stops the spoilage of foods.

Freezing and refrigeration are among the oldest methods of preservation. Mechanical ammonia refrigeration systems invented during 1875 allowed development of commercial refrigerated warehousing and freezing.

Low temperatures employed can be:

(A) Cellar storage temperature (15°C)

It is usually used for the storage of surplus foods like root crops, potatoes, onions, apples, etc. for limited periods.

(B) Refrigeration/ chilling temperature (0 to 5°C)

Foods kept at this temperature slow down the microbial activities and chemical changes resulting in spoilage. Mechanical refrigerator or cold storage is used for this purpose. Examples of this include meats, poultry, eggs, fish, fresh milk and milk products, fruits, vegetables, etc. which can be preserved for 2-7 days by refrigeration.

(C) Freezing (-18 to -40°C)

In freezing, water in food turns into ice and hence, makes the water unavailable for reactions to occur and for microorganisms to grow. Most perishable foods like poultry, meats, fish, ice-creams, peas, vegetables, juice concentrates, etc. can be preserved for several months at this temperature. In vegetables, enzyme action may still produce undesirable effects on flavour and texture during freezing. Heating, like blanching, therefore, must destroy the enzymes before the vegetables are frozen.

2.2.8 Use of High Temperatures

The process of heating was used centuries ago before its action was understood. Food is heated up or cooked. Heat is used to inactivate organisms or enzymes of spoilage significance in the foods. Microorganisms are killed by heat because the application of heat coagulates the food proteins and inactivates the microbial enzymes and thus results in death of microorganisms. The examples include all forms of cooked food, pasteurization, milk sterilized by UHT (ultra-high temperature), canning etc. One of the most important modern applications of the heat preservation is the pasteurization of milk.

Heat treatment of food may be given in different ways:

(A) Pasteurization (temperature below 100°C)

Pasteurization is a heat treatment involving temperatures below 100°C that kills a part but not all the microorganisms present in food. Milk, for example, is usually heated to 63°C for 30 min or 71°C for 15 seconds or in UHT 138°C for 2-4 seconds. Examples include milk, wine, beer, fruit juices and aerated waters which are routinely pasteurized. The mode of heating can be steam, hot water, dry heat or electric currents. The products are cooled promptly after the heat treatment. Pasteurization is usually supplemented by other methods to prolong shelf-life.

(B) Boiling (temperature at 100°C)

Cooking of rice, vegetables, meat, fish etc. at home is usually done by boiling the food with water and involves a temperature around 100°C.

(C) Canning (temperature above 100°C)

Canning is the process in which the foods are heated in hermetically sealed (airtight) jars or cans to a temperature that destroys microorganisms and inactivates enzymes that could be a health hazard or cause the food to spoil. High-acid foods such as fruits and tomatoes can be processed or "canned" in boiling water, while low-acid vegetables and meats must be processed in a pressure canner at 121°C (15 psi pressure). Tin-coated steel cans are most commonly used followed by glass containers. Nowadays, containers made of aluminium and plastics in the form of pouches or rigid containers are also increasingly used.

2.2.9 Use of Chemical Preservatives

Chemical preservatives are food additives, which are specifically added to prevent the deterioration or decomposition of a food. Chemicals are used to inhibit the factors causing spoilage. These are also used to complement other food preservation techniques. In food preservation, the added chemical preservatives may be grouped into two classes.

Class I preservatives: The first one includes the use of sugar, salt, spices, acetic acid (vinegar) and alcohol, and is referred to as class I preservatives and is considered to be relatively safe to humans.

Class II preservatives: The second group includes the use of benzoic acid, sulphur dioxide, nitrates and nitrites and a variety of neutralizers, firming agents and bleaching agents and referred to as class II preservatives and is considered to be relatively safe to humans, but within the permissible doses prescribed by the food regulatory bodies of the country because higher concentrations can be a health hazard.

2.2.10 Carbonation

Carbonation is the process by which carbon dioxide gas is dissolved in food under pressure. The principle behind this is that by eliminating oxygen, carbon dioxide inhibits bacterial growth. E.g., carbonated beverages (soft drinks), therefore, contain a natural preservative.

2.2.11 Irradiation

Food irradiation is low temperature sterilizing technique as in this case, sterilization can be affected at room temperature. Foods are exposed to high-energy rays called gamma rays or by fast-moving electrons, which kill bacteria, fungi and insects. In some cases, irradiation delays fruit ripening. A major advantage of irradiation is that it can be done after the food is packaged and sealed. It has been used in pasteurizing or sterilizing perishable foods such as meat, fish and fruits and extending their storage lives for long periods. It is also used for sprouting inhibition in onions, potatoes etc. Cobalt-60 or Cesium-137 or electrons producing machines are the principal sources of ionizing radiations used for food irradiation.

References

- Horticultural Statistics at a Glance. 2018. Horticulture Statistics Division Department of Agriculture, Cooperation & Farmers' Welfare Ministry of Agriculture & Farmers' Welfare Government of India
- Lisa Kitinoja and Adel A. Kader. 2002. Small-Scale Postharvest Handling Practices: A Manual for Horticultural Crops (4th Edition) Postharvest Horticulture Series No. 8E. University of California, Davis Postharvest Technology Research and Information Center.
- Thompson A.K. (1996). Post-harvest technology of fruits and vegetables, Blackwell science.
- Verma L.R. and Joshi V.K. (2000). Post-harvest technology of fruits and vegetables. Vol. I & II, Indus Publishing Co. New Delhi
- http://ecoursesonline.iasri.res.in/mod/page/view.php?id=639

Course Name	**Post-Harvest Management And Value Addition Of Fruits And Vegetables**
Lesson 7	**Intermediate Moisture Food- Jam, Jelly, Marmalade, Preserve, Candy-Concepts And Standards**
Course Revisor	**Dr. C. Indu Rani**
University/College	**Tamil Nadu Agricultural University, Coimbatore**
Course Reviewer	**Dr. Pritom Kumar Borthakur**
University/College	**University of Agricultural Sciences, Bangalore**

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

Objectives of the lecture

- To impart knowledge on intermediate moisture foods like jam, jelly, marmalade, preserve and candy
- To impart knowledge on fermented and non-fermented beverages

Glossary of terms

	Sweeteners	-	an artificial substance that can be used in drinks instead of sugar
	Gelatinization	-	convert into gelatinous form or jelly.
	Fermentation	-	chemical process by which molecules such as glucose are broken down anaerobically
	Concentrate	-	form of substance that has had the majority of its base component
	Preservative	-	any chemical additives used to prevent or retard spoilage

1. Fruit Jam

As per FSSA, Jam means the product prepared from sound, ripe, fresh, dehydrated, frozen or previously packed fruits including fruit juices, fruit pulp, fruit juice concentrate or dry fruit by boiling its pieces or pulp or puree with nutritive sweeteners namely sugar, dextrose, invert sugar or liquid glucose to a suitable consistency. It may also contain fruit pieces and any other ingredients suitable to the products. It may be prepared from any of the suitable fruits, singly or in combination. It shall have the flavour of the original fruit(s) and shall be free from burnt or objectionable flavours and crystallization.

The specific requirements for Jam are

- Total soluble solids (m/m) - Min. 68.0 %
- The product shall be manufactured from minimum 45.0% by weight, of original prepared, fruit, exclusive of any added sugar or optional ingredients of finished product

1.1 Judging the end-point of Jam

- Determining the boiling point with thermometer- A 68% solids boil at 104.8°C at sea level.
- Hydrometers- determining the specific gravity
- Refractometer- determine the percentage solids i.e., TSS
- Sheeting or ladle test

a) Cold plate test- A drop of boiling liquid from the pan is placed on a plate and allowed to cool. If the jelly is about to set, it will crinkle when pushed with a finger.

b) Sheet or Flake test- Some portion of a jelly is taken in a large spoon or wooden ladle and cooled slightly. When dropped, if it falls in the form of flake or sheet, the end point is reached. If the jelly drips like syrup, it is required to further concentrate.

2. Fruit Jelly:

As per FSSA, Fruit Jelly means the product prepared by boiling fruit juice or fruit(s) of sound quality, with or without water, expressing and straining the juice, adding nutritive sweeteners, and concentrating to such a consistency that gelatinization takes place on cooling. The product shall not be syrupy, sticky or gummy and shall be clear, sparkling and transparent.

The specific requirements are as shown below:

- Total soluble solids (m/m) - Min. 65.0 %
- The product shall be manufactured from minimum 45.0%, by weight, of original prepared fruit, exclusive of any added sugar or optional ingredients of finished product.

3. Marmalade

As per FSSA, Marmalade means a product prepared by boiling sound fruits with peel, pulp and juice, with or without water, added nutritive sweeteners and concentrating to such a consistency that gelatinization takes place on cooling of the product. It shall not be syrupy, sticky or gummy and shall be clear and transparent.

The specific requirements are as follows:

(i) Total soluble solids (m/m) - Min. 65.0 %

(ii) Fruit content except peel (m/m) - Min. 45.0 %

(iii) Peel in suspension - Min. 5.0 %

4. Preserves

They are whole fruits or large pieces of fruit in thick sugar syrup, often slightly jellied. Preserves are made from practically all fruits including peaches, pears, plums, aonla, strawberries, grapes, muscadines, quinces and tomatoes.

The fruit for preserving should be in a firm-ripe rather than a soft-ripe stage. By using up to 25.0% of firm-ripe fruit, the tartness is increased and less pectin is required in the formula. The fruit should be uniform in size and uniform pieces so as to cook evenly.

5. Candied Fruit

The process is similar to the one employed in preparing fruit preserves, but here the fruit is impregnated with a higher percentage of sugar or glucose; the total sugar content is about 75.0%. A certain amount of invert sugar or glucose is substituted in place of cane sugar.

The fruits suitable for such preparation are those that possess pronounced flavour, such as pineapple, peach, peels of orange, lemon, grapefruit, citrus, cherry, etc. Use of slightly underripe fruit helps in preventing formation of jam-like consistency in the syruping process. The sweeteners used maybe

Confectioner's glucose (corn syrup, crystal syrup or commercial glucose), dextrose, invert sugar, etc.

6. FERMENTED AND NON-FERMENTED BEVERAGES

6.1 Fruit beverages

Fruit beverages are easily digestible, highly refreshing, thirst quenching, appetizing and nutritionally far superior to many synthetic and aerated drinks. They can be classified into two groups i.e., Fermented and non-fermented beverages

6.1.1 Fermented beverages

Fruit juices which have undergone alcoholic fermentation by yeasts include wine, champagne port, sherry, tokay, muscatel, perry, orange wine, berry wine, nira and cider.

6.1.1.1 Wine

Wines are made from variety of fruits such as grapes, peach, plum or apricots. However, the most commonly used one is grapes, both green as well as red grapes. The grapes are macerated to release juice which is fermented naturally by wide range of yeasts including *Saccharomyces spp., Pichia spp., Stellata spp*. and certain lactic acid bacteria. The duration of fermentation is also longer as compared to beer and mostly fermented wine is aged (months to year) to develop desirable sensory characteristics.

There are two major types of wines i.e., white wine (made from green grapes) and red wine (from red or blue grapes). The red wine contains anthocyanin (as colouring pigment) and subjected to secondary fermentation termed as **Malolactic fermentation** to mellow the flavour of wine. The alcohol content in wine ranges from 9-16% (v/v).

6.1.1.2 Champagne

It is a sparkling wine made from certain varieties of grapes. Sparkling wines are characterized by effervescence produced by carbon dioxide and clarity

Perry: Wine made from pears is known as perry.

Neera: It is prepared from the juice of the palm tree.

Fenni: This is a fermented wine made from cashew apple in Goa.

Cider: This is made from fermented apples (High tannin content 0.3 – 0.3%).

Fruits such as bael, jamun, and aonla can also be used for preparation of cider.

The technique of preparation is similar to that of grape wine.

Vodka: Made from potatoes, Malted cereals etc. It contains 38-40% alcohol. Popular in Russian federation countries. Two variants available as white and flavoured Vodka.

Brandy: This is made from fruit Juices mainly grapes. It contains 35-60% alcohol. Normally consumed after-dinner, preferred for medicinal purpose. Aged in oak barrels.

6.1.2 non-fermented beverages

Fruit juices which do not undergo alcoholic fermentation are termed as unfermented beverages. They include natural and sweetened juices, RTS, nectar, cordial, squash, crush, syrup, fruit juice concentrate and fruit juice powder. Barley waters and carbonated beverages are also included in this group.

6.1.2.1 Natural fruit juice

It may be defined as pure juice which is extracted from ripe and mature fruits and contain 100 percent fruit content. The juice is extracted by various methods and contains mainly sugars, acids, vitamins, minerals and other minor components. These are preserved by thermal processing and freezing. The commonly available fruit juices are apple, pineapple, citrus, grapes, pomegranate and mango.

6.1.2.2 Sweetened juices

The sweetened juices are beverages which possess at least 85 percent juice and 10 percent TSS. The sugar and acids are added to increase the TSS content and also to balance the acid-to-sugar ratio.

6.1.2.3 Ready-to-Serve (RTS) Beverages

The ready-to-serve beverages as per FSSA specifications should contain at least 10 percent fruit conte nt and not less than 10 percent TSS besides 0.3% acid maximum as citric acid. The levels of permitted preservatives include 70 ppm (maximum) for Sulphur dioxide and 120 ppm (maximum) for benzoic acid. Since these beverages are consumed as such without dilution, hence are termed as Ready-to-serve beverage.

6.1.2.4 Nectar

Nectar is prepared from the tropical fruits pulp such as mango, litchi, guava, papaya, citrus fruits and pineapple by adding sugar, acid and other ingredients. As per FSSA specifications nectar should contain TSS not less than 15^{o} Brix and not less than 20 per cent fruit content, except for pineapple and citrus fruits where fruit content should not be less than 40 percent.

6.1.2.5 Cordial

Fruit juice cordial is a sparkling clear sweetened fruit beverage from which all the pulp and other suspended materials have been completely eliminated. Cordial is prepared by mixing clarified fruit juice, with sugar syrup, acid and other ingredients. As per FSSA specification, cordial should contain not less than 25 percent fruit content and the TSS content should not be less than 30 Brix. The acidity of the cordial should not be more than 3.5 per cent as anhydrous citric acid. The maximum permissible limit of preservative in cordial is 350 ppm of Sulphur dioxide or 600 ppm of benzoic acid. The citrus juices such as lime and lemon are preferred for making cordial.

6.1.2.6 Squashes and crushes

Squash is the product, which is prepared by mixing of calculated quantity of fruit juice or pulp, with sugar, acid and other ingredients. As per FSSA specifications, squash should contain not less than 25 per cent fruit content in finished product and the total soluble solids content should not be less than 40 Brix. The acidity of the squash should not be more than 3.5 per cent as anhydrous citric acid. The maximum permissible limit of preservative in squash is 350 ppm of Sulphur dioxide or 600 ppm of benzoic acid.

There is another category of dilutable beverage called **crush**. As per FSSA guidelines, crush must contain not less than 25 percent fruit content and 55 percent TSS. Mostly, the comminutes of citrus fruits and pineapple are used for crush manufacture.

6.1.2.7 Syrup

Syrup is a type of fruit beverage that contains at least 25 percent fruit juice or pulp and not less than 65 percent TSS. It also contains 1.25-1.5 percent acid and diluted before consumption. The syrups from rose petals, almond, mint, khus, sandal and kewra are quite popular.

6.1.2.8 Fruit juice concentrate

A fruit juice from which water has been mostly removed by heating or freezing is known as concentrate. Carbonated beverages are prepared from this. They contain pure juice with at least 32% TSS.

6.1.2.9 Fruit juice powder

Fruit juice can be converted into a free flowing, highly hygroscopic powder by puff – drying, freeze drying, vacuum drying, spray drying (or) drum drying. Example: Mango, orange, lemon, guava, passion fruit, banana, avocado, tomato, etc.,

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

6.1.2.10 Barley Water

Fruit beverage, which contains 25% fruit juice, 30% TSS, 0.25% barley starch and 1.0% acidity. Barley water is prepared from citrus fruits such as lime, lemon, grapefruit and orange. It is prepared by using about 1.0 litre of fruit juice, 2.0 kg of sugar, 15 gm of barley flour and 1.3 litre of water. Essence and KMS may be added.

References

- Horticultural Statistics at a Glance. 2018. Horticulture Statistics Division Department of Agriculture, Cooperation & Farmers' Welfare Ministry of Agriculture & Farmers' Welfare Government of India
- Lisa Kitinoja and Adel A. Kader. 2002. Small-Scale Postharvest Handling Practices: A Manual for Horticultural Crops (4th Edition) Postharvest Horticulture Series No. 8E. University of California, Davis Postharvest Technology Research and Information Center.
- Thompson A.K. (1996). Post-harvest technology of fruits and vegetables, Blackwell science.
- Verma L.R. and Joshi V.K. (2000). Post-harvest technology of fruits and vegetables. Vol. I & II, Indus Publishing Co. New Delhi
- http://ecoursesonline.iasri.res.in/mod/page/view.php?id=117

Course Name	**Post-Harvest Management And Value Addition Of Fruits And Vegetables**
Lesson 8	**Tomato products- Concepts and Standards; Drying/ Dehydration of fruits and vegetables**
Course Revisor	**Dr. C. Indu Rani**
University/College	**Tamil Nadu Agricultural University, Coimbatore**
Course Reviewer	**Dr. Pritom Kumar Borthakur**
University/College	**University of Agricultural Sciences, Bangalore**

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

Objectives of the lecture

- To impart knowledge on tomato products, their concepts and standards
- To impart knowledge on drying/ dehydration of fruits and vegetables

Glossary of terms

1)	Tangy	-	Sharp acidic flavour/taste
2)	Blanched	-	an item of food having been briefly immersed in boiling water
3)	Puree	-	a smooth cream of liquidized or crushed fruit or vegetables.
4)	Dehydration	-	loss or removal of water
5)	Osmotic	-	movement of a solvent (such as water) through a semipermeable membrane into a solution of higher solute concentration that tends to equalize the concentrations

1. Tomato products

Tomato is one of the most important protective food crops of India. Green tomato is considered as other vegetables whereas ripe tomato is considered as fruit. Tomato is a rich source of vitamins A, C, potassium, minerals and fibres. Tomatoes are used in the preparation of soup, salad, pickles, ketchup, puree, sauces and also consumed as a vegetable in many other ways. In Manipur variety of fruits and vegetables are grown but due to lack of proper storage and processing facilities considerable number of horticultural produces go waste. Farmers are compelled to sell their produce immediately after harvest, which lead to glut in market and resulting into lower return of their produce. Thus, value addition in tomato is one of the scopes for self-employment and income generation.

1.1 Tomato Sauce / Ketchup

Ketchup is a sweet and tangy sauce typically made from tomatoes, sugar, and vinegar, with assorted seasonings and spices. The specific spices and flavours vary, but commonly include onions, allspice, coriander, cloves, cumin, garlic, mustard and sometimes include celery, cinnamon or ginger. It is made from strained tomato juice or pulp and spices, salt, sugar and vinegar, with or without onion and garlic, and contains not less than 12 per cent tomato solids and 25 per cent total solids.

Basically, the difference between tomato ketchup and tomato sauce is that tomato sauce has thinner consistency than ketchup.

1.2 Tomato pickle

Tomato pickle is made using ingredients of vinegar, mustard oil, mustard seeds, red chilli powder fenugreek, cumin, salt, ginger and garlic. The spices are slightly roasted and grinded. After washing the tomatoes thoroughly, it is blanched for 2-3 minutes in boiling water and the water is drained. In oil, ginger garlic paste, spices, salt and tomatoes are added. After pouring vinegar it is filled in clean jars.

1.3 Tomato Paste

For the manufacture of tomato paste, tomato juice or pulp is first concentrated in open steam jacketed kettle to total solid levels in the range of 14-15 percent and subsequent concentration is carried out in vacuum pan. During cooking in open kettle common salt, basil leaf or sweet oil of basil leaf may also be added to prevent the excessive foaming, burning and sticking. In vacuum pan, the water present in pulp or juice starts evaporating at 71˚C. It assists in retention of bright red colour and flavour. The removal of air also checks any oxidative reaction that may adversely affect the nutritional value i.e., vitamin C. For sterilization of the product, vacuum is removed and the temperature is raised to 100˚C and held at that temperature for about 10 min.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

1.4 Tomato Puree

Tomato juice or pulp is strained or filtered to remove portions of skin, seeds and large coarse pieces to get uniform juice or pulp. The juice or pulp is concentrated in open kettle or vacuum kettle to evaporate water and the process of evaporation in case of puree is continued till the volume reduced to equal or one-half of original. The end point is determined by the hand refractometer to measure the total soluble solids and expressed as degree Brix. Alternatively, it can also be determined by using specific gravity bottle or by drying the juice or pulp under vacuum at 70˚C. The puree of desired total soluble solids is then filled into cans (temperature of filling 82-88˚C) and processed in boiling water for 20 min. The processed cans are cooled immediately either by dipping them in cold water or sprinkled with cold water. The cans are then stored in dry and cool place. The tomato juice is concentrated under vacuum to about 9% to 12% total solids so as to get tomato puree.

1.5 Dried tomato slices

Dried tomato slices are versatile ingredient and find its application in various food formulations. Tomatoes of good quality, after through washing are blanched either in plain water or in 2.5% salt solution for 1 min. These blanched tomatoes are dropped in cold water to quickly cool the product. This also helps 1.5 cm thick slices, and excess juice is drained off. Tomato slices are dipped in 2.5% gelatinized starch containing 5% potassium meta-bisulphate for 9 min. They are spread over perforated or aluminum trays. Drying is carried out at 65-70˚C in a tray drier till the moisture reached to 4.5%.

2. DRYING/ DEHYDRATION OF FRUITS AND VEGETABLES:

The practice of drying of foodstuffs, especially fruits and vegetables for preserving them is very old. Drying means the removal of water (75-90%) present in fresh commodity results in reduction in the water activity and ultimately resistance against most of the deteriorative agents. The removal of water is carried out by the application of heat and this heat is usually supplied in the form of solar energy or artificially generated hot air. Removal of moisture and exposure of heat often results in poor textural attributes, loss in nutritive value (vitamins), discoloration and loss of flavoring components.

2.1 Basic types of drying process:

- Sun drying and solar drying
- Atmospheric drying including batch (kiln, tower and cabinet driers) and continuous (tunnel, belt, belt-trough, fluidized bed, puff, foam-mat, spray, drum and microwave);
- Sub-atmospheric dehydration (vacuum shelf/belt and freeze driers).

Sun and solar drying of fruits and vegetables 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 as the village level provided that the climate is hot, relatively dry and free of rainfall during and immediately after the normal harvesting period.

(A) Sun drying

Drying the food product under natural sunny conditions is called as sun drying. No energy is required for the drying process. To practice sun drying of foods, hot days are desirable with minimum temperatures of 35°C with low humidity. The lower limit of moisture content by this method is approximately 15 per cent.

(B) Solar drying:

Solar drying uses designed structures to collect and enhance solar radiation. Solar driers generate high air temperature and low humidity which results in faster drying. This drier is faster than sun-drying, and also requires less drying area. But it cannot be used on cloudy days. Generally, three types of solar driers are used, as (1) the absorption or hot box type driers in which the product is directly heated by sun, (2) the indirect or convection driers in which the product is exposed to warm air which is heated by means of a solar absorber or heat exchanger and (3) drier, which is combination of first and second type.

(C) Shade drying

Shade drying is carried out for products which can lose their colour and / or turn brown if put in direct sunlight. Therefore, shade drying is carried out under a roof or thatch which has open sides.

2.2 Common driers used for drying / dehydration

a. **Air Convection Driers**

- Kiln drier
- Cabinet, tray and pan driers
- Tunnel and continuous belt driers
- Belt trough drier
- Air lift drier
- Fluidized bed drier
- Spray driers

b. **Drum or Roller Driers**

c. **Vacuum Driers**

- Vacuum shelf driers
- Continuous vacuum belt drier
- Freeze-drying

2.3 Advantages of dehydration

- Dehydration requires less floor area and fewer trays
- Dehydration is done under very hygienic conditions
- The color of dehydrated (or) mechanically dried fruits and vegetables

remains uniform due to uniform drying temperature.

2.4 Osmotic drying

In osmotic dehydration the prepared fresh material is soaked in a heavy (thick liquid sugar solution) and / or a strong salt solution and then the material is sun or solar dried.

Osmotic dehydration is gaining popularity, as the dehydrated product is more stable during storage due to low water activity by solute gain and water loss. The low water activity resulted in fewer rates of chemical reactions avoiding deterioration of the food. Osmotic dehydration in many cases is employed to increase sugar to acid ratio of acidic fruits, thereby to improve the taste, texture and appearance of dried product.

2.5 Factors Affecting Drying Rate

The factors that affect drying rate are external and internal factors.

The external factors are:

- Dry bulb temperature
- Relative humidity
- Air velocity
- Surface heat transfer coefficient

The Internal factors are:

- Surface to volume ratio
- Surface temperature
- Rate of moisture loss
- Composition i.e., moisture, fat

2.6 Steps involved in drying of fruits and vegetables

i. Selection of raw material

Good quality raw material is of prime importance. Immature or over mature fruits and vegetables often result in poor quality product.

ii. **Washing**

Raw materials should be thoroughly washed to remove the adhering dirt, dust and other foreign particles and to remove the traces of pesticides, coloring material and chemicals.

iii. **Peeling, trimming and sizing**

Fruits and vegetables are either dried as whole or undergo size reduction before drying. A number of peeling processes are available on commercial level. Trimming is done to remove unwanted parts. Sizing is done to develop uniform product and it also facilitates subsequent unit operation. Increase in surface area causes faster drying.

iv. **Blanching**

Blanching is mostly done primarily to inactivate the naturally occurring enzymes. Blanching improves the color of dried products, it aids to rapid reconstitution of dried product, it also increases drying rate, it also expels dissolved oxygen and it also improve bacteriological quality of the finished product.

v. **Drying**

Drying of the fruits and vegetables is usually carried out in cabinet dryer. The material is loaded over perforated aluminum trays and dried using hot air. The temperature, velocity and the humidity of the air are important for drying process. It usually varies from commodity to commodity. A lower drying temperature is generally used for fruits, as there may be chances of case hardening. The temperature varies from 55-80^oC. To create perforation initially temperature is maintained towards higher side and them it is reduced. Some vegetables those are light, cylindrical or spherical like peas are dried in fluidized bed dryer. This improves the rehydration characteristic and the nutritive value of the product, as it takes lesser time and more uniform drying.

References

- Horticultural Statistics at a Glance. 2018. Horticulture Statistics Division Department of Agriculture, Cooperation & Farmers' Welfare Ministry of Agriculture & Farmers' Welfare Government of India
- Lisa Kitinoja and Adel A. Kader. 2002. Small-Scale Postharvest Handling Practices: A Manual for Horticultural Crops (4th Edition) Postharvest Horticulture Series No. 8E. University of California, Davis Postharvest Technology Research and Information Center.
- Thompson A.K. (1996). Post-harvest technology of fruits and vegetables, Blackwell science.
- Verma L.R. and Joshi V.K. (2000). Post-harvest technology of fruits and vegetables. Vol. I & II, Indus Publishing Co. New Delhi
- http://ecoursesonline.iasri.res.in/mod/resource/view.php?id=147595
- http://ecoursesonline.iasri.res.in/course/view.php?id=467

Course Name	**Post-Harvest Management And Value Addition Of Fruits And Vegetables**
Lesson 9	**Canning -– Concepts And Standards, Packaging Of Products**
Course Revisor	**Dr. C. Indu Rani**
University/College	**Tamil Nadu Agricultural University, Coimbatore**
Course Reviewer	**Dr. Pritom Kumar Borthakur**
University/College	**University of Agricultural Sciences, Bangalore**

Objectives of the lecture

- To impart knowledge on canning of fruits and vegetables
- To impart knowledge on packaging of products

Glossary of terms

	Head space	-	unfilled space between the food in a jar and the lid of a jar
	Stack-burning	-	deterioration in colour and quality of canned foods
	Stacking	-	arrange (a number of things) in a pile
	Palletization	-	to place (materials) upon pallets for handling or moving
	Crates	-	a slatted wooden case used for transporting goods.

1. CANNING

Canning is the process of applying heat to food that's sealed hermetically in a jar to destroy any microorganism that can cause food spoilage. The food preservation process of canning originated in 1809 when French confectioner Nicolas Appert succeeded in preserving meats in glass bottles that had been kept in boiling water for varying periods of time. In the honour of inventor, canning is also known as "appertization". Canning demonstrates that food can be preserved for quite a longer duration of time when heated and stored in anaerobic condition. Today, the method of canning is one of the most widely used methods for food preservation. In canning the food is placed in containers, heated, and then sealed, usually under vacuum. It is used for products such as fruit juices, syrups, and sauces. Canning process is advantageous in retaining the stable vitamins and colour and flavour of food items.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

1.1 Process of canning

1.1.1. Selection of fruits and vegetables

Fruits and vegetables should be absolutely fresh, ripe, but firm, and uniformly mature. All vegetables except tomatoes should be tender. Fruits and vegetables should be free from dirt. They should be free from blemishes, insect damage or mechanical injury.

1.1.2. Grading

The selected fruits and vegetables are graded according to size and color to obtain uniform quality. This is done by hand or by machines.

1.1.3. Washing

It is important to remove pesticide spray residue and dust from fruits and vegetables. Fruits and vegetables can be washed in different ways.

1.1.4. Peeling

The objective of peeling is to remove the outer layer. Peeling may be done in various ways.

- **Hand peeling**- e.g., mango and papaya
- **Steam peeling**- E.g., peaches, Potatoes and tomatoes
- **Mechanical peeling**-apples, peaches, pineapples and cherries and root vegetables like carrots, turnips and potatoes.
- **Lye peeling**- Fruits and vegetables are peeled by dipping them in 1 to 2 per cent boiling caustic soda solution (lye) for 30 seconds to 2 minutes The peel is then removed easily by hand.
- **Flame peeling-E.g.,** garlic and onion

1.1.5. Cutting- Pieces of the size required for canning are cut. Seed, stone and core are removed.

1.1.6. Blanching

It is also known as scalding, parboiling or precooking. It is usually done in case of vegetables by exposing them to boiling water or steam for 2 to 5 minutes, followed by cooling. Generally, fruits are not blanched.

1.1.7. Cooling

After blanching, the vegetables are dipped in cold water for better handling and keeping them in good condition.

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

1.1.8. Filling

Before filling, cans are washed with hot water and sterilized. After filling, covering with syrup or brine is done and this process is called syruping or brining.

i) Syruping- Syruping is done only for fruits. Strained, hot sugar syrup of concentration 20 to 55˚Brix is poured on the fruit. The syrup should be filled at about 79 to 82˚C, leaving a head space of 0.3 to 0.5 cm.

ii) Brining-Hot brine of salt solution of 1 to 3 per cent concentration is used for covering vegetables and is filled at 79 to 82˚C, leaving a head space of 0.3 to 0.5 cm. After syruping or brining the cans are loosely covered with lids and exhausted.

1.1.9. Exhausting

The process of removal of air from cans is known as exhausting. After filling and lidding or clinching, exhausting is essential.

1.1.10. Sealing

Immediately after exhausting the cans are sealed airtight by means of a can sealer. In case of glass jars a rubber ring should be placed between the mouth of the jar and the lid, so that it can be sealed airtight. During sealing the temperature should not fall below 74 ˚C.

1.1.11. Processing

Heating of foods for preserving is known as processing. Processing time and temperature should be adequate to eliminate all bacterial growth at a temperature of 100˚C, i.e., in boiling water.

1.1.12. Cooling

After processing, the cans are cooled rapidly to about 39˚C to stop the cooking process and to prevent stack-burning.

1.1.13. Storage

After labelling the cans, they should be packed in strong wooden cases or corrugated cardboard cartons and stored in a cool and dry place. Storage of cans at high temperature should be avoided, as it shortens the shelf-life of the product.

2. PACKAGING OF PRODUCTS

2.1 Containers for Packing of Canned Products

Both tin and glass containers are used in the canning industry, but tin containers are preferred.

2.1.1 Tin containers:

Tin cans are made of thin steel plate of low carbon content, lightly coated on both sides with tin metal. It is difficult to coat the steel plate uniformly and during the process of manufacture small microscopic spots are always left uncoated, although the coating may appear perfect to the eye. The contents of the can may react with these uncoated spots resulting in discolouration of the product or corrosion of the tin plate. When the corrosion is severe, black stains of iron sulphide are produced. It is necessary, therefore, to coat the inside of the can with some material (lacquer) which prevents discolouration but does not affect the flavour or wholesomeness of the contents. This process is known as "lacquering". Two types of lacquers are used:

Acid-resistant: Acid-resistant lacquer is golden coloured enamel and cans coated with it are called R enamel or A.R cans. These cans are used for packing acid fruits which are of two kinds:

(a) those whose colouring matter is insoluble in water, e.g., peach, pineapple, apricot, grapefruit,

and (b) those in which it is water-soluble, e.g., raspberry, strawberry, red plum and coloured grape. Fruits of group (a) are packed in plain cans and those of group (b) in lacquered cans.

Sulphur-resistant: This lacquer is also of a golden colour and cans coated with it are called C enamel or S.R. cans. They are meant for non-acid foods only and should not be used for any highly acid product as acid eats into the lacquer. These cans are used for pea, corn, lima bean, red kidney bean, etc. Recently, a midget can has become highly popular for fruit juices, mango nectar, etc.

Tin containers are preferred to glass containers because of certain advantages:

- Ease of fabrication,
- Strength to withstand processing,
- light weight,
- Ease in handling,
- Cheapness, and
- Can be handled by high-speed machines.

References

- Horticultural Statistics at a Glance. 2018. Horticulture Statistics Division Department of Agriculture, Cooperation & Farmers' Welfare Ministry of Agriculture & Farmers' Welfare Government of India
- Lisa Kitinoja and Adel A. Kader. 2002. Small-Scale Postharvest Handling Practices: A Manual for Horticultural Crops (4th Edition) Postharvest Horticulture Series No. 8E. University of California, Davis Postharvest Technology Research and Information Center.
- Thompson A.K. (1996). Post-harvest technology of fruits and vegetables, Blackwell science.
- Verma L.R. and Joshi V.K. (2000). Post-harvest technology of fruits and vegetables. Vol. I & II, Indus Publishing Co. New Delhi
- http://ecoursesonline.iasri.res.in/mod/page/view.php?id=111462