CHAPTER 10

Harvesting, Handling and Storage of Horticultural Crops

OBJECTIVES

After studying this chapter, students will be able to:

- Know about importance of safe harvesting, handling and storage of fruits and vegetables.
- Know about the maturity indices of fruits and vegetables.
- Know about different step in handling of produce after harvest.
- Know about different storage conditions for fruits and vegetables.
- To start their own business of handling and storage of fruits and vegetables.
- To market their produce more efficiently.

INTRODUCTION

Farmers spend months working in the fields, and then they have a bountiful harvest of beautiful fruits and vegetables. They want to ensure that their customers would also enjoy this healthy harvest. How can they best maintain the quality and safety of fruits and vegetables as it travels from the field to the table? How can produce be stored so that it does not need to be sold immediately? High-quality, disease-free produce with a good shelf life is a result of sound production practices,proper handling during harvest, and appropriate postharvest handling and storage. All fresh horticultural crops are perishable in nature due to high in water content and are subjected to desiccation (wilting, shriveling) and to mechanical injury. Various authorities have estimated that 20-30 percent of fresh horticultural produce is lost after harvest and these losses can assume considerable economic and social importance. These perishable commodities need very careful handling at every stage so that deterioration of produce is restricted as much as possible during the period between harvest and consumption. Postharvest rots are more prevalent in fruits and vegetables that are bruised or otherwise damaged. Mechanical damage also increases moisture loss. The rate of moisture loss may be increased by as much as 400% by a single bad bruise on an apple, and skinned potatoes may lose three to four times as much weight as non-skinned potatoes. Damage can be prevented by training harvest labour to handle the crop gently; harvesting at proper maturity; harvesting dry whenever possible;handling each fruit or vegetable no more than necessary (field pack if possible); installing padding inside bulk

bins; and avoiding over orunder-packing of containers. The horticultural produce includes fruits, vegetables, flowers and other ornamental plants, plantation crops, aromatic and medicinal plants and spices. However, in this chapter, information on fruits and vegetables is only included.

HARVESTING OF FRUITS AND VEGETABLES

Quality cannot be improved after harvest,only maintained; therefore it is important to harvest fruits and vegetables at the proper stage and size and at peak quality. Immature or over-mature produce may not last as long in storage as that picked at proper maturity. Harvest should be completed during the coolest time of the day, which is usually in the early morning, and produce should be kept shaded in the field. Fruits harvested too early may lack flavour and may not ripe properly, while produce harvested too late may be fibrous or have very limited market life. Similarly, vegetables are harvested over a wide range of physiological stages, depending upon which part of the plant is used as food. For example, small or immature vegetables possess better texture and quality than mature or over-mature vegetables. Therefore harvesting of fruits and vegetables at proper stage of maturity is of paramount importance for attaining desirable quality. The level of maturity actually helps in selection of storage methods, estimation of shelf life, selection of processing operations for value addition etc. The maturity has been divided into two categories i.e. physiological maturity and horticultural maturity.

Physiological maturity: *It is the stage when a fruit is capable of further development or ripening when it is harvested*

Horticultural maturity: *It refers to the stage of development when plant and plant part possesses the pre-requisites for use by consumers for a particular purpose*

Physiological maturity: It is the stage when a fruit is capable of further development or ripening when it is harvested i.e. ready for eating or processing.

Horticultural maturity: It refers to the stage of development when plant and plant part possesses the pre-requisites for use by consumers for a particular purpose i.e. ready for harvest.

MATURITY INDICES OF FRUITS AND VEGETABLES

The principles dictating at which stage of maturity a fruit or vegetable should be harvested are crucial to its subsequent storage and marketable life and quality. Post-harvest physiologists distinguish three stages in the life span of fruits and vegetables: maturation, ripening, and senescence. Maturation is indicative of the fruit being ready for harvest. At this point, the edible part of the fruit or vegetable is fully developed in size, although it may not be ready for immediate

Maturity indices: *Visual, physical and chemical parameters indicating maturity of horticultural produce*

consumption. Ripening follows or overlaps maturation, rendering the produce edible, as indicated by taste. Senescence is the last stage, characterized by natural degradation of the fruit or vegetable, as in loss of texture, flavour, etc. (senescence ends at the death of the tissue of the fruit). The importance of maturity indices are to ensure sensory quality (flavour, colour, aroma, texture) and nutritional quality, to ensure an adequate post harvest shelf life, to facilitate scheduling of harvest and packing operations and to facilitate marketing over the phone or through internet.

TYPES OF MATURITY INDICES

i) **Visual appearance:** The visual appearance of fruit and vegetable is the most important quality factor, which decides its price in the market. The consumer (wholesaler or retailer) observes the quality of fresh fruits and vegetables with their visual or external appearance. The produce should attain proper shape and size. Medium size produce is always preferred by the consumers, because they tend to view large fruits as more mature. The appearance of the product is the most critical factor in the initial purchase, while subsequent purchase may be more related to texture and flavour.

Size and shape: Maturity of fruits can be assessed by their final shape and size at the time of harvest. Fruit shape may be used in some instances to decide maturity. For example, the fullness of cheeks adjacent to pedicel may be used as a guide to maturity of mango and some stone fruits. Some cultivars of banana become less angular in cross section as development and maturation progress. Size is generally of limited value as a maturity index in fruit, though it is widely used for many vegetables, especially those marketed early in their development.

Colour: The loss of green colour of many fruits is a valuable guide to maturity. There is initially a gradual loss in intensity of colour from deep green to lighter green and with many commodities, a complete loss of green colour with the development of yellow, red or purple pigments. Ground colour as measured by colour charts, is useful index of maturity for apple, pear and stone fruits, but is not entirely reliable as it is influenced by factors other than maturity. For some fruits, as they mature on the tree, development of blush colour, that is additional colour superimposed on the ground colour, can be a good indicator of maturity. Examples are red or red-streaked apple cultivars and red blush on some cultivars of mango and peach.

C olur changes in mango during maturity and ripening

ii) Physical indices

Firmness: As fruit mature and ripen they soften by dissolution of the middle lamella of the cell walls. The degree of firmness can be estimated subjectively by finger or thumb pressure, but more precise objective measurement is possible with pressure tester or penetrometer. In many fruits such as apple, pear, peach, plum, guava, kinnow etc. firmness can be used to determine harvest maturity. Penetrometer measures the pressure necessary to force a plunger of specified size into the pulp of the fruit. Such pressure is measured in pounds and kilograms force.

Specific gravity: As fruit mature, their specific gravity increases. This parameter is rarely used in practice to determine when to harvest a crop but it could be where it is possible to develop a suitable sampling technique. It is used, however, to grade crops into different maturities. To do this the fruit or vegetable is placed in a tank of water; those that float will be less mature that those that sink. To give greater flexibility to the test and make it more precise, a salt or sugar solution can be used in place of water. This changes the density of the liquid, resulting in fruits or vegetables that would have sunk in water floating in the salt or sugar solution.

iii) Chemical measurement

Measurement of chemical characteristics of produce is an obvious approach to the problem of maturity determination. The conversion of starch to sugars during maturation is a simple test for the maturity of some apple cultivars. It is based on the reaction between starch and iodine to produce a blue or purple colour. The intensity of the colour indicates the amount of starch remaining in the fruit. The total soluble solids of the fruit can be measured with refractometer, which indicate the harvest maturity of fruits. Acidity is readily determined on a sample of extracted juice by titration with 0.1 N NaOH. The sugar acid or TSS acid ratio is often better related to palatability of fruit than either sugar or acid level alone. Soluble solid content (SSC) also called total soluble solids (TSS), can be determined in a small sample of fruit juice using hand refractometer.Titratable acidity (TA) can be determined by titrating a know volume of juice with 0.1N NaOH to end point of pink colour as indicated by phenolphethalin indicator.

iv) Calculated indices

Calendar date: For perennial fruit crops grown in seasonal climate which are more or less uniform from year to year, calendar date for harvest is a reliable guide to commercial maturity. Time of flowering is largely dependent as temperature and the variation in number of days from flowering to harvest can be calculated for some commodities by use of degree-day concept. Such harvesting criteria can be developed by the growers based on their experiences.

Heat Units: An objective measure of the time required for the development of the fruit to maturity after flowering can be made by measuring the degree days or heat units in a particular environment. It has been found that a characteristics number of heat unit or degree-days is required to mature a crop under usually warm conditions, maturity will be advanced and under cooler conditions, maturity is delayed. The number of degree days to maturity is determined over a period of several years by obtaining the algebraic sum from the differences, plus or minus, between the daily mean temperatures and a fixed base temperature (commonly the minimum temperature at which growth occurs). The average or characteristic number of degree-days is then used to forecast the probable date of maturity for the current year and as maturity approaches, it can be checked by other means.

Maturity indices for selected fruits and vegetables

Fruits/Vegetables	Maturity indices or characteristics
Apple	
Golden Delicious	12% SSC, 18 lb firmness
Red Delicious	11% SSC, 18 lb firmness
Banana	Disappearance of angularity in a cross section of the finger
Grapes (table)	Minimum TSS 14 to 17.5%, depending on cultivars, TSS/TA ratio 20 or higher.
Guava	Colour break stage (when skin colour changes from dark green to light green)
Kinnow	TSS/acid ratio 12:1 to 14:1
Mango	Changes in shape (increase fullness of cheeks or bulge of shoulder), flesh colour yellow to yellowish-orange
Strawberries	2/3 of berry surface showing pink or red colour
Brinjal	Immature, glossy skin, 40days from flowering.
Carrot	Immature, roots reached adequate size.
Potatoes	Harvest before vines die completely, cure to heal surface wounds.
Tomatoes	Seeds fully developed, gel formation advanced in atleast one locule.
Watermelon	Flesh colour 75% red, TSS = 10%

Harvesting of fruits and vegetables

Fruits and vegetables are living entities and therefore, should be harvested with great care. Harvesting practices should cause as little mechanical damage to produce as possible. The following points should be kept in mind while harvesting the crop:

- Gentle picking and harvesting will help reduce crop losses.
- Wearing cotton gloves, trimming finger nails, and removing jewellary such as rings and bracelets can help reduce mechanical damage during harvest.
- Produce should be harvested during coolest part of the day not wet from dew or rain.
- Empty picking containers with care.
- Keep produce cool after harvest (provide shade).

Picking bag: Cloth bag with openings on both ends can be easily worn over the shoulders with adjustable harnesses. In case metallic buckets are to be used for harvesting, fitting cloth over the opened bottom can reduce damage to crop. Fitting canvas bags with adjustable harnesses, or by simply adding some carrying straps to baskets also helps to reduce handling losses.

Picking poles and catching sacks: These tools can be easily made by hand. A long pole attached to a collection bag, allow the harvester to cut catch produce growing on a tree without climbing on tree. The collection bags can be hand woven from strong cord or sewn from canvas. The hoop used as the collection bag rim and sharp cutting edges can be made from sheet metal, steel tubing or recycled scrap metal.

Clippers and Knives: Some fruits such as citrus, grapes and mangoes, need to be clipped or cut from the plant. Clippers or knives should be kept well sharpened and clean. Peduncles, woody stems or spurs should be trimmed as close as possible to prevent fruit from damaging neighboring fruits during transport. Care should be taken to harvest pears so that the spurs are not damaged. Pruning shears can be used for harvesting fruits and some vegetables.

Tripod ladders: A ladder with three legs is very convenient and more stable than a common ladder. A ladder helps harvesting crops such as mango, kinnow, pears, peaches, plums without damaging tree branches.

METHOD OF HARVESTING OF FRUITS AND VEGETABLES

Harvesting of crops can be done manually or mechanically.

Hand harvesting: Usually done for fruits destined for fresh markets. The primary advantage is harvesting of fruit or vegetable can be done at appropriate maturity and produce will suffer

minimum damage. However, it is a time consuming process and more labour is required during harvesting season.

Mechanical harvesting: Harvesting is carried out with the help of machines. The primary advantage is that the produce can be harvested at a faster rate and less manpower is required as compared to hand harvesting. However, damage can occur to crops and this method is not much suitable for marketing of fresh commodities.

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. The most important goals of post-harvest handling are keeping the product cool, to avoid moisture loss and slow down undesirable chemical changes, and avoiding physical damage such as bruising, to delay spoilage.

Handling operation after harvest

Dumping: The first step of handling is known as dumping. It should be done gently either using water or dry dumping. Wet dumping can be done by immersing the produce in water. It reduces mechanical injury, bruising, abrasions on the fruits, since water is gentle on produce. The dry dumping is done by soft brushes fitted on the sloped ramp or moving conveyor belts. It will help in removing dust and dirt on the fruits.

Pre-sorting: It is done to remove injured, decayed, mis-shapen fruits. It will save energy and money because culls will not be handled, cooled, packed or transported. Removing decaying fruits are especially important, because these will limit the spread of infection to other healthy fruits during handling.

Washing and cleaning: Washing with chlorine solution (100-150 ppm) can also be used to control innoculum build up during pack house operations. For best results, the pH of wash solution should be 6.5-7.5. Mangoes, bananas should be washed to remove latex.

Grading: Grading can be done manually or by automatic grading lines.Size grading can be done subjectively with the use of standard size gauges. Round produce units can be easily graded by using sizing rings. The grading of fruits plays an important role in domestic and export marketing of fruits. Different fruits have different grades on the basis of their size and weight. The grades of some fruits and vegetables suggested by Directorate of Marketing and Inspection (DMI) are as under:

Grapes

Grade	Large berries bunch weight (g)	Small berries bunch weight (g)
Extra class	200	150
Class I	150	100
Class II	100	75

Guava

Size code	Weight (gm)	Diameter (mm)
A	>350	>95
B	251-350	86-95
C	201-250	76-85
D	151-200	66-75
E	101-150	54-65
F	61-100	43-53

Pomegranate

Grade	Fruit weight (g)	Diameter (mm)
A	400	90
B	350	80
C	300	70
D	250	60
E	200	50

Tomato

Size Code	Diameter (in mm)	
	Minimum	Maximum
1	30	34
2	35	39
3	40	46
4	47	56
5	57	66
6	67	81
7	82	101
8	102	above

Pre-cooling of horticulture produce

Pre-cooling of the produce soon after their harvest is one of the important components of the cool chain, which ultimately affect the shelf life of the produce. The main purpose of precooling is to immediately remove the field heat from the produce.

Room cooling: It is low cost and slow method of cooling. In this method, produce is simply loaded into a cool room and cool air is allowed to circulate among the cartons, sacks, bins or bulk load.

Forced-air cooling: Forced air-cooling is mostly used for wide range of horticultural produce. This is the fastest method of pre-cooling. Forced air-cooling pulls or pushes air through the vents/holes in storage containers. In this method uniform cooling of the produce can be achieved if the stacks of pallet bins are properly aligned. Cooling time depends on (i) the airflow, (ii) the temperature difference between the produce and the cold air and (iii) produce diameter.

Hydrocooling: The use of cold water is an old and effective cooling method used for quickly cooling a wide range of fruits and vegetables before packaging. For the packed commodities it is less used because of difficulty in the movement of water through the containers and because of high cost involved in water tolerant containers. This method of cooling not only avoids water loss but may even add water to the commodity. The hydrocooler normally used are of two types i.e., showertype and immersion type.

Vacuum cooling: Vacuum cooling take place by water evaporation from the product at very low air pressure. In this method, air is pumped out from a larger steel chamber in which the produce is loaded for pre-cooling. Removal of air results in the reduction of pressure of the atmosphere around the produce, which further lowers, the boiling temperature of its water. As the pressure falls, the water boils quickly removing the heat from the produce. Vacuum cooling causes about 1 per cent produce weight loss (mostly water) for each 6oC of cooling.

Package-icing: In some commodities, crushed or flaked ice is packed along with produce for fast cooling. However, as the ice comes in contact with the produce, it melts, and the cooling rate slows considerably. The ice keeps a high relative humidity around the product. Package ice may be finely crushed ice, flake ice or slurry of ice. Liquid icing distributes the ice throughout the container, achieving better contact with the product. Packaged icing can be used only with water tolerant, non-chilling sensitive products and with water tolerant packages (waxed fiberboard, plastic or wood).

PACKAGING OF HORTICULTURE PRODUCE

Packing is a coordinated system of preparing goods for transport, distribution, storage, retailing and end use and a means of ensuring safe delivery to the ultimate consumer in sound

conditions at minimum cost. Packaging helps in safe transportation, storages, marketing and distribution of produce. It protects the produce from pilferage, microorganisms and adverse weather condition and it is also used to advertise the product.

Requirements of a good package

- Should be environment friendly.
- Should have sufficient strength in compression and against impact and vibrations
- Should be stable during the entire distribution chain.
- Should be compatible with the automatic packing/filling, handling machines (mechanical filling systems)
- Should facilitate special treatments like pre-cooling.
- Should have consumer appeal.
- Should be easily printable.
- Should be cost effective.

Materials for packaging

- Wood - boxes, bins, trays, barrels, pallets
- Jute/canvas - sacks
- Paper and card board - liners, boxes, trays
- Plastic - Rigid - crates, pallets, trays
    - Flexible - films (single & multi layered)
    - Polystyrene boxes / trays
- Combined materials - CFB and plastic

CFB has almost replaced wood and jute and is considered as most important package material to be used in combination with other materials.

Some materials used for fresh horticultural produce include:

- Wooden box having CFB liners.
- CFB box with plastic film wraps
- CFB trays with wooden corner supports

- CFB laminated or waxed containers.
- CFB box with plastic retailer packs (strawberry boxes)
- CFB or polystyrene trays/boxes with plastic film wraps.

STORAGE OF FRUITS AND VEGETABLES

`The management of temperature and relative humidity are the most important factors determining storage life of horticultural produce. The natural means like ice, cold water, night temperature have been used for long time for protecting food materials from spoilage and these are still common. However, with the development of innovative technologies, it is possible to achieve optimal environments in the insulated stores.

Objective of storage

- Regulate the market in an orderly manner.
- Avoid glut and distress sale in the market, thus prolonging the market period.
- In long-term storage, making the food available in off-season.

Cold storage: Lowering the temperature to the lowest safe handling temperature is of paramount importance for enhancing the shelf life, reducing the losses and maintaining higher quality during marketing. Always, handle produce gently and never store produce unless, it is of the best quality. Damaged produce will lose water faster and have higher decay rates in storage when compared to undamaged produce.

Recommended temperature and RH conditions

Name of commodity	Temp (^{o}C)	RH (%)	Approximate Shelf-life
Apple	-1-4	90-95	1-12 months
Banana	13-15	90-95	1-4 weeks
Grape	-0.5-0	90-95	2-8 weeks
Guava	6-8	90-95	2-3 weeks
Lychee, Litchi	1-2	90-95	3-5 weeks
Mandarin (Kinnow)	4-5	90-95	2 months
Mango	13	85-90	2-4 weeks
Pomegrante	5	90-95	2-3 months

Strawberry	0	90-95	7-10 weeks
Beans	4-7	90-95	7-10 days
Bitter gourd	10-12	85-90	2-3 weeks
Broccoli	0	95-100	10-14 days
Cabbage	0	90-95	3-6 weeks
Carrots	0	90-95	6-8 months
Cauliflower	0	90-95	3-4 weeks
Eggplant	10-12	90-95	1-2 weeks
Peas	0	90-95	1-2 weeks
Tomato	10-13	90-95	1-3 weeks

Controlled atmosphere (CA) storage

> ***CA storage:*** *Systems where atmospheric control is accurately controlled.*
> ***MA storage:*** *System where degree of atmospheric control is less accurate.*

The term implies the addition or removal of gases resulting in an atmospheric composition different from that of normal air. Thus the levels of carbon dioxide, oxygen, nitrogen, ethylene, and metabolic volatiles in the atmosphere may be manipulated. Controlled atmosphere storage generally refers to keeping produce at decreased oxygen and increased carbon dioxide concentrations and at suitable range of temperature and RH. Systems where atmospheric control is accurately controlled are generally called CA storage and where degree of control "less accurately" monitored are called MA (modified atmosphere) storage. In MAP (modified atmospheric packaging) produce is enclosed in polymeric films and is allowed to generate its own atmsophere (passive MAP) or air of known composition is flushed into the bag (active MAP) and depending upon gas / vapour transmission characteristics of the film on appropriate atmosphere develops in the package to prolong shelf life. MAP is ideally combined with temperature control for maximum benefit.

Benefits of CA storage

- Slow down respiration and ethylene production rates, softening and retard senesence of horticultural produce.
- Reduce fruit sensitivity to ethylene action
- Alleviate certain physiological disorders such as chilling injury of various commodities, russet spotting in lettuce, and some storage disorders including, scald of apples.

Harmful effects of CA storage

- Initiation or aggravation of certain physiological disorders can occur, such as blackheart in potatoes, brown stain on lettuce, and brown heart in apples and pears.
- Irregular ripening of fruits, such as banana, mango, pear and tomato, can result from exposure to O2 levels below 2% or CO2 levels above 5% for more than 2 to 4 weeks.
- Off- flavors and off-odours at very low O2 or very high CO2 concentration may develop as a result of anaerobic respiration and fermentative metabolism.

Recommended CA or MA conditions for selected fruits and vegetables

Commodity	Temperature (°C)	% O2	% CO2
Apple	0-5	1-2	0-3
Banana	12-16	2-5	2-5
Mango	10-15	3-7	5-8
Beans, green	5-10	2-3	4-7
Broccoli	0-5	1-2	5-10
Cabbage	0-5	2-3	3-6
Onions (bulb)	0-5	1-2	0-10
Tomatoes	10-15	3-5	3-5

ACTIVITY/EXERCISE

1. Visit fruit orchard or vegetable garden during harvesting and find out the methods of harvesting used by farmers.
2. Meet fruit and vegetable growers and enquire about the different steps followed by them after harvesting of produce.
3. Visit fruit and vegetable market in your locality and try to know about packaging materials used and storage methods adopted for fruits and vegetables.
4. Visit cold storage or CA storage facility in your locality and enlist the fruits and vegetables stored.

CHECK YOUR PROGRESS

1) Differentiate between physiological and horticultural maturity.

2) Enumerate the types of maturity indices used for adjudging the maturity in fruits and vegetables.

3) What you understand by judging maturity using calendar dates and heat units.

4) Discuss about method of harvesting in fruit crops.

5) Enumerate the handling operation after harvest.

FILL IN THE BLANKS

1) As fruit mature, their specific gravity .....

2) Extra class grapbunches weigh in between ..... to ..... g

3) The hydro-cooler normally used are of two types i.e., ...and .....

4) Packaging material for fruits and vegetables should be ..... and should have sufficient .....

5) ..... has almost replaced wood and jute and is considered as most important package material to be used in combination with other materials.

6) CA storage conditions for apple .....^{o}C, ... O2 and CO2

7) CA storage conditions for tomato ..... ^{o}C, ... O2 and ..... CO2.