Harvesting and handling of fruits and vegetables

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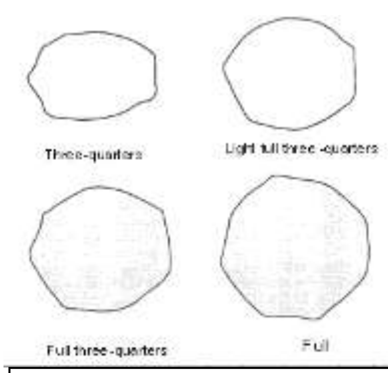
ı postharvest handling of fruits and vegetables, harvesting of fruits at right stage of maturity and right time is of utmost importance. Fruits harvested too early may lack flavour and may not pen properly, while produce harvested too late may be fibrous or have very limited market life. imilarly, vegetables are harvested over a wide range of physiological stages, depending upon hich part of the plant is used as food. For example, small or immature vegetables possess better xture and quality than mature or over-mature vegetables. Therefore harvesting of fruits and egetables at proper stage of maturity is of paramount importance for attaining desirable quality. he level of maturity actually helps in selection of storage methods, estimation of shelf life, election of processing operations for value addition etc. The maturity has been divided into two ıtegories i.e. physiological maturity and horticultural maturity.

hysiological maturity: The stage at which a plant or a plant part continues ontogeny even if etached from its parent plant or the point of origin.

orticultural maturity: It may be defined as the stage at which a plant or a plant part possesses all e pre-requisites for utilization by the ultimate consumer for a particular purpose. For example, orticultural maturity stage of tomato if harvested for long distance transportation would be the ., rning stage of peel 'from green to red' while the optimum stage of harvesting of the same crop ır home use or local markets would be 'when the fruits have attained full red colour'.

Iaturity indices



Cross-section of banana finger showing changes in angularity

The indicators which dictate at which stage of maturity a fruit or vegetable should be harvested for fresh consumption, storage or marketing. If a fruit or vegetable is harvested at an immature stage, it is likely that it may not develop attractive size, colour, and flavor and have poor eating quality and low storage life. As a result, it will fetch very low price in the market. Hence, a commodity should be harvested at an appropriate stage of maturity. In general, a single maturity index is not considered to be reliable. In most of the crops, more than one or two indices should be made use of while determining the exact stage of optimum maturity. Experience of growing, harvesting and marketing a particular crop along with critical observations would be the est for determination of the optimum maturity. A beginner should seek the help of a local xperienced person in determination of maturity of a crop till he himself gains experience and onfidence. Some typical maturity indices are described below:

Iaturity indices for horticultural crops

Visual

Size and shape*:* Maturity of fruits can be assessed by their final shape and size at the time of ırvest. Fruit shape may be used in some instances to decide maturity. For example, the fullness of ıeeks adjacent to pedicel may be used as a guide to ıaturity of mango and some stone fruits. Size is ɛnerally of limited value as a maturity index in fruit, ough it is widely used for many vegetables, especially ose marketed early in their development. With these

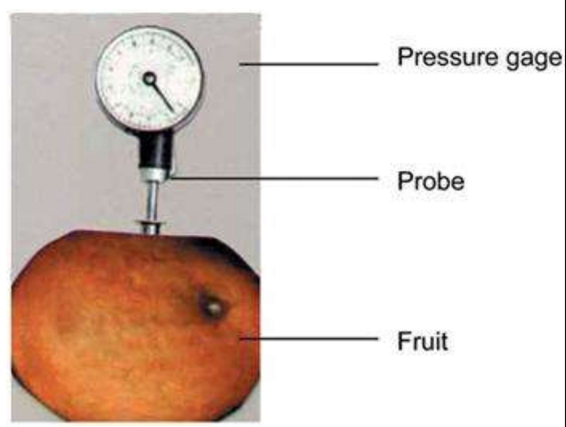
Judging mango harvest maturity by shape of shoulder

oduce, size is often specified as a quality standard, with rge size generally indicating commercial over-maturity ıd under-sized produce indicating an immature state. The assumption, however, is not always a liable guide for all-purpose. The appearance of the product is the most critical factor in the initial ırchase, while subsequent purchase may be more related to texture and flavour.

i) Colour: The loss of green colour of many fruits is a valuable guide to maturity. There is nitially a gradual loss in intensity of colour from deep green to lighter green and with many ommodities, a complete loss of green colour with the development of yellow, red or purple ıigments. Ground colour as measured by colour charts, is useful index of maturity for apple, pear ınd stone fruits, but is not entirely reliable as it is influenced by factors other than maturity. For ome fruits, as they mature on the tree, development of blush colour, can be a good indicator of ıaturity. Examples are red or red-streaked apple cultivars and red blush on some cultivars of ıeach.

. Physical indices

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

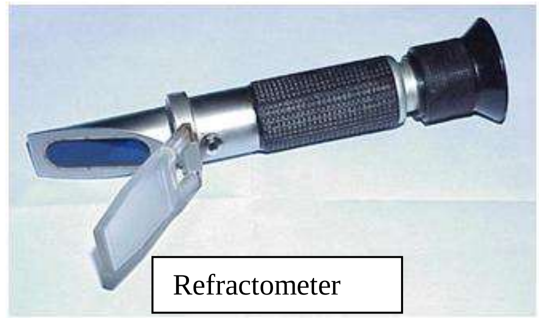


Penetrometer

i) Specific gravity*:* As fruit mature, their specific ɡravity increases. This parameter is rarely used in ıractice to determine when to harvest a crop but it ould be where it is possible to develop a suitable ampling technique. It is used, however, to grade rops into different maturities. To do this the fruit or egetable is placed in a tank of water; those that float vill be less mature that those that sink. To give ɡreater flexibility to the test and make it more precise, ı salt or sugar solution can be used in place of water. This changes the density of the liquid, resulting in fruits or vegetables that vould have sunk in water floating in the salt or sugar solution. Specific ɡravity is used a index for mango and apple.

. Chemical Measurements

Measurement of chemical characteristics of produce is an obvious approach to the problem of maturity determination. The conversion of starch to sugars, called as starch iodine index (SII) (4.5/10) 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.


Refractometer

4. Calculated indices

i) 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. However, it largely depends on grower's experience.

ii) Heat Units: It has been found that a characteristics number of heat unit or degree-days required maturing 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). It is commonly followed in grapes and date palm.

iii) **Days after full bloom:** This is the most important maturity index used for harvesting of temperate fruits (apple, pear, plum, peach). For example, some apple varieties mature in 88±4 days and some in 180±4 days. It has been reported that DFFB do not change in a variety grown under int of climactic conditions.

5. Respiration and ethylene evolution rates: Now, maturity index of fruit or vegetable can also be determined by measuring the rate of respiration or ethylene evolution. This method is primarily used under lab conditions only.

Maturity Indices for selected fruits and vegetables

Fruits/ Vegetables	Maturity indices
Almonds	Splitting of hull, separation of hull from shell, development of abscission zone
Apple	DFFB, Calendar date, Starch Iodine Index (SII), Change in colour, fruit firmness
Asian Pears Pathar Nakh Baggugosha	Peel colour change from green to yellowish green 145 days after fruit set 135 days after fruit set
Banana	Disappearance of angularity in finger
Ber	Colour break stage (when light yellow colour appear)

Cherry	TSS = 14-15%, light red colour
Grapes (table)	Minimum SSC % of 14 to 17.5, depending on cultivars, SSC/TA of 20 or higher.
Guava	Colour break stage (when skin colour changes from dark green to light green)
Lemon	30% or more juice by volume
Lychee/litchi	TSS: total acid ratio of 70, bright red in colour
Kinnow	TSS/acid ratio 12:1 to 14:1
Kiwi fruit	TSS – 6.2%, Firmness = 14 lbs
Mango	*Tapka* (natural faalin of fruits), changes in shape (increase fullness of cheeks or bulge of shoulder), flesh colour yellow to yellowish-orange, specific gravity
Papaya	Skin shows yellowing
Peaches	Ground colour change from green to yellow (varied for different cultivars), DFFB
Plums	Skin colour changes, DFFB
Pomegranate	Metallic sound on tapping, TSS:acid = 70
Strawberries	2/3 of berry surface showing pink or red colour
Beans	Pods are filled, seeds immature.
Brinjal	Immature, glossy skin, 40days from flowering.
Broccoli	Adequate diameter, compact, all florets should be closed.
Cabbage	Firm head
Cantaloup	¾ to full slip under slight pressure, abscission from vine.
Carrot	Immature, roots reached adequate size.
Cauliflower	Mature and atleast 6” in diameter, compact
Cucumber	Immature and glossy skin
Garlic	Well filled bulbs, tops dry down
Ginger	8-9 months after planting
Melon	Ground colour change to white with greenish tint, slightly waxy peel.
Mushroom	Caps well rounded, partial veil completely intact.
Okra	Pod 2-4’’ long, not fibrous, tips of pods pliable.
Onion (dry bulbs)	When 10-20% of tops fall over
Peas	Pods well filled but not faded in colour.
Pepper	Fruit size and colour (depends on colour and intended market)
Potatoes	Harvest before vines die completely, cure to heal surface wounds.
Radish (spring)	20 to 30 days after planting.
Radish (winter)	45 to 70 days after planting.
Tomatoes	Seeds fully developed, gel formation advanced in atleast one locule.
Watermelon	Flesh colour 75% red, TSS = 10%

ethods of harvesting

Hand harvesting

rvesting by hand is being practiced in all the horticultural crops since time immemorial. In India, nd harvesting is still the most common method used in horticultural commodities due to dequate mechanization, small land holding and diversity of crops being grown by a small farmer. me harvesting aids can be used for increasing the efficiency of labour.

Mechanical harvesting

rvesting by use of machines is called mechanical harvesting. It is very useful for rapid harvesting a particular crop and at low cost. Special harvesting machines are designed for specific crops. In veloped countries mechanical harvesting is common for most of the crops, but in India it is still ry uncommon. For avoiding spoilage of fruits during harvesting, several institutes have developed rvesters for mango, guava, spaota etc. Similarly, clippers have been developed for harvesting awberry and Kinnow in India.

ecautions to be taken during harvesting

There should be minimum damage to the commodity

Method of harvesting should be less expensive

Less damage to the plant

Should be done at optimum harvesting stage

Some fruits like malta, lemon, orange etc and temperate stone fruits (plum etc) are reported to ve longer shelf life and lesser rotting during storage when harvested alongwith attached pedicel. such fruits should carefully be harvested with attached pedicel.

me of harvesting

though, fruits and vegetables can be harvested at any time of the day but these should be harvested her in the morning or evening hours. If these are harvested at noon or warmer time of the day, y will loose their freshness because of faster rate of respiration and transpiration. In addition, such its or vegetables will require much more precised handling than those harvested in the morning or ening hours.

ools used for harvesting

though, fruits and vegetables are usually harvested manually but now several tools and uipments have also been developed. For example, fruit harvesters have been developed for mango, oota, Kinnow, strawberry etc. Similarly, for potato, digging machine has been developed. Some its need to be clipped or cut from the parent plant for which clippers or knives have been veloped. Varieties of such instruments are available in the market, which allows the picker to rvest without a catching bag and without dropping, fruits. Most of the vegetable crops are rvested manually but root crop vegetables like potato, turnip, radish, beet and carrot etc. are dug t manually or with the help of digging equipment.

e-cooling of produce

reduce the field heat, fruits and vegetables are immediately pre-cooled after harvesting to extend ir life. Several methods of cooling are applied to produce after harvesting to extend shelf life and intain a fresh-like quality. Precooling may be done with cold air, cold water (hydrocooling), ect contact with ice, or by evaporation of water from the product under a partial vacuum (vacuum oling). A combination of cooled air and water in the form of a mist is called as 'hyraircooling' is innovation in cooling of vegetables.

r precooling: Precooling of fruits with cold air is the most common practice. It can be done in rigerator cars, storage rooms, tunnels, or forced air-coolers (air is forced to pass through the ntainer via baffles and pressure differences).

ng: Ice is commonly added to boxes of produce by placing a layer of crushed ice directly on the) of the crop. An ice slurry can be applied in the following proportion: 60% finely crushed ice, % water, and 0.1% sodium chloride to lower the melting point. The water to ice ratio may vary m 1:1 to 1:4.

om cooling:This method involves placing the crop in cold storage. The type of room used may ry, but generally consists of a refrigeration unit in which cold air is passed through a fan. The culation may be such that air is blown across the top of the room and falls through the crop by nvection. The main advantage is cost because no specific facility is required.

d air-cooling: The principle behind this type of precooling is to place the crop into a room where air is directed through the crop after flowing over various refrigerated metal coils or pipes. Forced oling systems blow air at a high velocity leading to desiccation of the crop. To minimize this , various methods of humidifying the cooling air have been designed such as blowing the air gh cold water sprays.

ocooling: The transmission of heat from a solid to a liquid is faster than the transmission of heat a solid to a gas. Therefore, cooling of crops with cooled water can occur quickly and results in loss of weight. To achieve high performance, the crop is submerged in cold water, which is antly circulated through a heat exchanger. When crops are transported around the packhouse in , the transport can incorporate a hydrocooler. This system has the advantage wherein the speed of onveyer can be adjusted to the time required to cool the produce. Hydrocooling has a further tage over other precooling methods in that it can help clean the produce. Chlorinated water can be to avoid spoilage of the crop. Hydrocooling is commonly used for vegetables, such as asparagus, , sweet corn, radishes, and carrots, but it is seldom used for fruits.

um cooling: Cooling in this case is achieved with the latent heat of vaporization rather than ction. At normal air pressure (760 mmHg) water will boil at 100°C. As air pressure is reduced so boiling point of water, and at 4.6 mmHg water boils at 0°C. For every 5 or 6°C reduction in erature, under these conditions, the crop loses about 1% of its weight (Barger, 1961). This weight nay be minimized by spraying the produce with water either before enclosing it in the vacuum ber or towards the end of the vacuum cooling operation (hydrovacuum cooling). The speed and iveness of cooling is related to the ratio between the mass of the crop and its surface area. This od is particularly suitable for leaf crops such as lettuce. Crops like tomatoes having a relatively wax cuticle are not suitable for vacuum cooling.

ding of fruits and vegetables

sorting, the healthy produce should be graded according to size and colour. Different fruits are d in to different grades but usually produce is graded as A, B or C as per size and colour. A grade ce is supplied to class A cities where you will find consumers of such class, and so on. ssified produce can be utilized for making value added products like jam, jelly or pickle etc. ng can be done manually or by machine. In our country apple and Kinnow are primarily graded anically. Several units of apple and Kinnow graders have been established in H.P. and Punjab, ctively. According to size, apple is classified in to 7 different grades in H.P. The smallest sized are called as '*pittoo*', which are usually made into juice by HPMC and sold at premier price by C counters at different cities of India.

king in the field and transport to packinghouse

es picked for the fresh market (except blueberries and cranberries) are often mechanically sted and usually packed into shipping containers. Careful harvesting, handling, and transporting its and vegetables to packinghouses are necessary to preserve product quality. Packing cab done ferent containers.

thylene bags: Clear polyethylene bags are used to pack banana bunches in the field, which are ransported to the packinghouse by means of mechanical cableways running through the banana ation. This technique of packaging and transporting bananas reduces damage to the fruit caused by pper handling.

ic field boxes: These types of boxes are usually made of polyvinyl chloride, polypropylene, or thylene. They are durable and can last many years. Many are designed in such a way that they can nside each other when empty to facilitate transport, and can stack one on top of the other without ing the fruit when full

den field boxes: These boxes are made of thin pieces of wood bound together with wire. They in two sizes: the bushel box with a volume of 2200 in^3 (36052 cm^3) and the half-bushel box. They dvantageous because they can be packed flat and are inexpensive, and thus could be non-able. They have the disadvantage of providing little protection from mechanical damage to the ice during transport. Rigid wooden boxes of different capacities are commonly used to transport ice to the packinghouse or to market.

bins: Bulk bins of 200-500 kg capacity are used for harvesting fresh fruits and vegetables. These re much more economical than the field boxes, both in terms of fruit carried per unit volume and ility, as well as in providing better protection to the product during transport to the packinghouse. are made of wood and plastic materials. Dimensions for these bins in the United States are 48 × , and 120 × 100 cm in metric system countries. Approximate depth of bulk bins depends on the of fruit or vegetable being transported

Packaging of fruits and vegetables

According to Wills et al. (1989), modern packaging must comply with the following requirements:

a) The package must have sufficient mechanical strength to protect the contents during handling, transport, and stacking.

b) The packaging material must be free of chemical substances that could transfer to the produce and become toxic to man.

c) The package must meet handling and marketing requirements in terms of weight, size, and shape.

d) The package should allow rapid cooling of the contents. Furthermore, the permeability of plastic films to respiratory gases could also be important.

e) Mechanical strength of the package should be largely unaffected by moisture content (when wet) or high humidity conditions.

f) The security of the package or ease of opening and closing might be important in some marketing situations.

g) The package must either exclude light or be transparent.

h) The package should be appropriate for retail presentations.

i) The package should be designed for ease of disposal, re-use, or recycling.

j) Cost of the package in relation to value and the extent of contents protection required should be as low as possible.

sification of packaging

ges can be classified as follows:

- Flexible sacks; made of plastic jute, such as bags (small sacks) and nets (made of open mesh)
- Wooden crates
- Cartons (fibreboard boxes)
- Plastic crates
- Pallet boxes and shipping containers
- Baskets made of woven strips of leaves, bamboo, plastic, etc.

Uses for above packages

Nets are only suitable for hard produce such as coconuts and root crops (potatoes, onions, yams).

Wooden crates are typically wire bound crates used for citrus fruits and potatoes, or wooden field crates used for softer produce like tomatoes. Wooden crates are resistant to weather and more efficient for large fruits, such as watermelons and other melons, and generally have good ventilation. Disadvantages are that rough surfaces and splinters can cause damage to the produce, they can retain undesirable odours when painted, and raw wood can easily become contaminated with moulds.

Fibreboard boxes are used for tomato, cucumber, and ginger transport. They are easy to handle, light weight, come in different sizes, and come in a variety of colours that can make produce more attractive to consumers. They have some disadvantages, such as the effect of high humidity, which can weaken the box; neither are they waterproof, so wet products would need to be dried before packaging. These boxes are often of lower strength compared to wooden or plastic crates, although multiple thickness trays are very widely used. They can come flat packed with ventilation holes and grab handles, making a cheap attractive alternative that is very popular. Care should be taken that holes on the surface (top and sides) of the box allow adequate ventilation for the produce and prevent heat generation, which can cause rapid product deterioration.

Plastic crates are expensive but last longer than wooden or carton crates.They are easy to clean due to their smooth surface and are hard in strength, giving protection to products. Plastic crates can be used many times, reducing the cost of transport. They are available in different sizes and colours and are resistant to adverse weather conditions. However, plastic crates can damage some soft produce due to their hard surfaces, thus liners are recommended when using such crates.

Pallet boxes are very efficient for transporting produce from the field to the packinghouse or for handling produce in the packinghouse. Pallet boxes have a standard floor size (1200 × 1000 mm) and depending on the commodity have standard heights. Advantages of the pallet box are that it reduces the labour and cost of loading, filling, and unloading; reduces space for storage; and increases speed of mechanical harvest. The major disadvantage is that the return volume of most pallet boxes is the same as the full load. Higher investment is also required for the forklift truck, trailer, and handling systems to empty the boxes. They are not affordable to small producers because of high, initial capital investment.

Ripening of Fruits

Ripening is a dramatic event in the life of a fruit during which structure and composition of unripe fruit is so altered that it becomes acceptable to eat. Ripening marks the completion of development of a fruit and the commencement of senescence and it is normally an irrevesible event. On the basis of ripening behaviour, fruits have been classified as climacteric and non-climacteric fruits.

Climacteric fruits: In several fruits, ripening is associated with a rapid increase in respiration. This sudden upsurge is called as 'climacteric rise' in respiration and the fruits are conventionally called as 'climacteric fruits'. Apple, apricot, blueberry, fig, guava, jackfruit, kiwifruit, mango, muskmelon, nectarine, papaya, passion fruit, peach, pear, persimmon, plantain, plum, sapota, tomato, and watermelon are climacteric fruits

Non-climacteric fruits: Some fruits don't have distinct and well coordinated pattern of ripening as in climacteric fruits. Such fruits show neither rise in respiration nor an associated production of ethylene during ripening process. Thus, the fruits, which do not exhibit respiratory climacteric (pronounced increase in respiration coincident with ripening forming a peak) are known as non climacteric fruits. Coincident with ripening, the non-climacteric fruits produce much lesser amounts of ethylene than climacteric fruits. For example, *ber* (Jujube), blackberry, cashew apple, cherry, cucumber, eggplant, grape, grape fruit, lemon, lime, litchi, loquat, olive, orange, pepper, pineapple, pomegranate, Satsuma mandarin, strawberry, blueberry, cranberry, cacao, rose apple, tamarillo, summer squash, sweet orange, tangerine etc.

Table 2: Difference between climacteric and non-climacteric fruits

Sl. No.	Climacteric fruits	Non-climacteric fruits
1.	Fruits exhibit respiratory climacteric (pronounced increase in respiration	Fruits do not exhibit respiratory climacteric

	coincident with ripening forming a peak	
2.	Coincident with ripening fruits produce much larger amounts of ethylene	No such relationship exists in these fruits
3.	Fruits may ripen on and off the trees	Fruits ripen on the tree only
4.	Important examples are apple, banana, sapota, plum, mango guava, papaya, tomato etc.	Important examples are citrus, pineapple, pomegranate, cashew apple, grape, litchi, loquat, cucumber etc.

pening facilities

Ripening room: Fruit are ripened in specially built rooms that must be gas tight, have systems for ntrolling humidity and concentrations of carbon dioxide and ethylene, and have equipment to ntrol product temperature. Ripening rooms are usually insulated but they typically operate at nperature 15-21 ^{o}C. The ripening process is always done at relative humidity above 85%.

Temperature: Ripening is controlled on the basis of fruit pulp temperature. It should be easured during each cycle with a calibrated pulp thermometer. Simultaneously, room air nperature must also be regularly monitored with calibrated thermometer.

Relative humidity: The refrigeration system must be designed to contain 85-95% RH. Humidity low this range causes excessive product weight loss . Humidifiers are needed to add moisture to e air in rooms. Air humidity should be periodically monitored with a wet and dry bulb ychrometer.

Air flow: Air flow is needed to distribute ethylene gas to the product and to add or remove heat m the product during ripening cycle. Boxes must be stacked with space between them to allow od air flow around each box. Boxes or pallet bins should be vented to allow air flow. If packaging terials are placed in the boxes they should not block vents. Poor venting will cause high fruit nperatures and non-uniform ripening.

Ripening Techniques

Ripening with ethephon/Ethrel: Ethephon (2-choloroethyl-phosphonic acid) is commercially ailable and is registered for pre-harvest use on a variety of crops for controlling developmental ocesses or inducing ripening. This chemical is approved for post-harvest use fruits crops for enhancing ripening. For post-harvest treatments, the known antity of ethephon is diluted in water and fruits are dipped in the solution for specified period. This substance ensures that there is uniform ripening of its. This technique provides a safe and effective method of ripening of fruits mpared to the conventional technique of using calcium carbide.

Ripening with ethylene gas: In this technique, the fruits are exposed to low vel of ethylene gas (10-100ppm) in an air-tight ripening chamber for 24 to 72 urs so as to induce ripening. The most important thing in this technique is nperature and relative humidity control inside the ripening chamber, which ould range between 15-25ºC and 90-95% relative humidity, depending upon e fruit type. Several methods are used to provide proper ethylene ncentration in the ripening room.

Gas cylinders: Ethylene is available in large steel cylinders where it is stored under pressure. As s highly flammable, the use of pure gas is discouraged. Therefore, it is usually used diluted with rogen or other inert gases. Typical mixtures are 95 per cent nitrogen and 5 per nt ethylene or 95.5 per cent nitrogen and 4.5 per cent ethylene. The measured antities of ethylene are introduced in ripening room at regular intervals or ntinuously and the flow is regulated through metering devise or flow meter. y piping leading into the ripening room should be grounded to prevent ssible electrostatic ignition of ethylene gas.

Ethylene generator

Shot system: On small scale, commodities can be treated ng shot method with ethylene liberated from ethephon. A culated amount of ethephon in stainless steel bowl is placed und the room. The fruits are stacked in the room and sodium droxide is added to ethephon and all ventilation to the room is n blocked. When sodium hydroxide reacts with ethephon, ylene gas is released that ripens the fruits, Precaution should taken while handling sodium hydroxide and ethephon as these corrosive. Safety glasses and rubber gloves should be used ile their handling.

Health hazard: Workers at a fruit market using calcium carbide to ripen raw mangoes

c) Ethylene generator: This is a device that is portable and placed inside the ripening room. A uid (ethyl alcohol) is filled into the tank fitted with ethylene generator and it is connected to an ctric power source. The ethyl alcohol gets heated in a controlled manner in the presence of a alyst that produces ethylene gas. Gas is maintained inside the ripening room until colour break curs in the fruits.

iii) Calcium carbide: In India and many other developing economies, the banana and mango ripened with the use of calcium carbide, which releases acetylene and ethylene on interaction th moisture coming from fruits. This chemical is harmful to human health and its use for ripening fruits is band in India.

Storage of fruits and vegetables

In temperate countries much of the production of fruits and vegetables is confined to relatively ort growing seasons and thus storage becomes essential for provision of fresh produce out of the rvest season. In tropical countries production is often extended but storage may still be necessary desirable for extended supply to the consumer. As consumer purchasing power increases, the sons for storage may cease to be ones of traditional necessity but of satisfying consumer mand. Consumer demand is likely to include improved quality as well as improved availability d pressure is increasing, and will continue to do so, for improvements in storage techniques.

ice may be stored for a few days or weeks as part of the normal marketing process but some erate produce may also be stored for periods up to 12 weeks. The reasons for storage are:

- Because there is no immediate buyer.
- Because transportation or some other essential facility is not available.
- To extend the marketing period and increase the volume of sales.

- To wait for a price increase.

The marketable life of most fresh vegetables can be extended by prompt storage in an environment that maintains product quality. The desired environment can be obtained in facilities where temperature, air circulation, relative humidity, and sometimes atmosphere composition can be controlled. Storage rooms can be grouped accordingly as those requiring refrigeration and those that do not. Storage rooms and methods not requiring refrigeration include: *in situ*, sand, coir, pits, clamps, windbreaks, cellars, barns, evaporative cooling, and night ventilation:

In situ: This method of storing fruits and vegetables involves delaying the harvest until the crop is required. It can be used in some cases with root crops, such as cassava, but means that the land on which the crop was grown will remain occupied and a new crop cannot be planted. In colder climates, the crop may be exposed to freezing and chilling injury.

Sand or coir: This storage technique is used in countries like India to store potatoes for longer periods of time, which involves covering the commodity under ground with sand.

Pits or trenches: These are dug at the edges of the field where the crop has been grown. Usually pits are placed at the highest point in the field, especially in regions of high rainfall. The pit or trench is lined with straw or other organic material and filled with the crop being stored, then covered with a layer of organic material followed by a layer of soil. Holes are created with straw at the top to allow for air ventilation, as lack of ventilation may cause problems with rotting of the crop.

Clamps: This has been a traditional method for storing potatoes in some parts of the world, such as Great Britain. A common design uses an area of land at the side of the field. The width of the clamp is about 1 to 2.5 m. The dimensions are marked out and the potatoes piled on the ground in an elongated conical heap. Sometimes straw is laid on the soil before the potatoes. The central height of the heap depends on its angle of repose, which is about one third the width of the clump. At the top, straw is bent over the ridge so that rain will tend to run off the structure. Straw thickness should be from 15-25 cm when compressed. After two weeks, the clamp is covered with soil to a depth of 15-20 cm, but this may vary depending on the climate.

Windbreaks: These are constructed by driving wooden stakes into the ground in two parallel rows about 1 m apart. A wooden platform is built between the stakes about 30 cm from the ground, often made from wooden boxes. Chicken wire is affixed between the stakes and across both ends of the windbreak. This method is used in Britain to store.

Cellars: These underground or partly underground rooms are often beneath a house. This location has good insulation, providing cooling in warm ambient conditions and protection from excessively low temperatures in cold climates. Cellars have traditionally been used at domestic scale in Britain to store apples, cabbages, onions, and potatoes during winter.

Barns: A barn is a farm building for sheltering, processing, and storing agricultural products, animals, and implements. Although there is no precise scale or measure for the type or size of the building, the term barn is usually reserved for the largest or most important structure on any particular farm. Smaller or minor agricultural buildings are often labelled sheds or outbuildings and are normally used to house smaller implements or activities.

Evaporative cooling: When water evaporates from the liquid phase into the vapour phase energy is required. This principle can be used to cool stores by first passing the air introduced into the storage room through a pad of water. The degree of cooling depends on the original humidity of the air and the efficiency of the evaporating surface. If the ambient air has low humidity and is humidified to around 100% RH, then a large reduction in temperature will be achieved. This can provide cool moist conditions during storage.

Night ventilation: In hot climates, the variation between day and night temperatures can be used to keep stores cool. The storage room should be well insulated when the crop is placed inside. A fan is built into the store room, which is switched on when the outside temperature at night becomes lower than the temperature within. The fan switches off when the temperatures equalize. The fan is controlled by a differential thermostat, which constantly compares the outside air temperature with the internal storage temperature. This method is used to store bulk onions.

Controlled atmospheres: As discussed earlier, controlled atmospheres are made of gastight chambers with insulated walls, ceiling, and floor. They are increasingly common for fruit storage at larger scale. Depending on the species and variety, various blends of O_2, CO_2, and N_2 are required. Low content O_2 atmospheres (0.8 to 1.5%), called ULO (Ultra -Low Oxygen) atmospheres, are used for fruits with long storage lives (e.g., apples).

Refrigerated storage : It is now more than 130 years since the Australian James Harrison designed and built the first effective refrigeration equipment and the first icemaking plant in the world. Over 100 years ago, regular shipments from Australia to England were commenced for the transport of frozen beef, an event soon followed by the operation of the first mechanically refrigerated cool stores for apple and pear. The most modern refrigeration plants available have changed very little in basic design since those times and accordingly consideration will be restricted to the mechanical functions and nomenclature of the equipment. A refrigeration plant, consists of three basic components:

- a compressor in which the refrigerant gas, commonly 'Freon', is compressed and unavoidably heated;
- the condenser, either air-cooled or water-cooled, in which the hot compressed gas is cooled and condensed to a liquid;
- the evaporator coils in which the liquid is permitted to boil and evaporate and so remove heat from its surroundings.

Fans are usually necessary to circulate air over the cooling coils of the evaporator and through the stacks of produce in the store. The compressor and the condenser are always outside the cold store and usually mounted in tandem. The link between the three units is completed by insulated copper-piping. To increase efficiency the evaporator is fitted with metal fins to improve the heat exchange properties. Air-cooled condensers are fitted with similar fins and air is forced through by an electric fan. More detailed information can easily be obtained from any one of a large number of textbooks on the subject.

Too often stores remain in operation at great cost when they are almost empty of produce or when no increase in the selling price of the commodity is expected. A clear appraisal must be made of the commodities planned for storage, which are compatible in storage at specific temperatures and humidities and which commodities are not compatible, the expected storage life of the various commodities and the applicability to the anticipated market situation. Managers should have the confidence and authority to shut-down stores, even, if it means storing some produce at ambient temperature, rather than incur operating losses. The recommended temperature and relative humidity, and approximate storage life for fruits and vegetable crops have been given below.

Fruit/vegetable	Temperature		Relative Humidity (percent)	Approximate storage life
	°C	°F		
Amaranth	0-2	32-36	95-100	10-14 days
Apples	-1-4	30-40	90-95	1-12 months
Apricots	-0.5-0	31-32	90-95	1-3 weeks
Artichokes, globe	0	32	95-100	2-3 weeks
Asian pear	1	34	90-95	5-6 months
Asparagus	0-2	32-35	95-100	2-3 weeks
Atemoya	13	55	85-90	4-6 weeks
Avocados	7	45	85-90	2 weeks
Bananas, green	13-14	56-58	90-95	14 weeks
Barbados cherry	0	32	85-90	7-8 weeks
Bean sprouts	0	32	95-100	7-9 days
Beans, dry	4-10	40-50	40-50	6-10 months
Beans, green or snap	4-7	4045	95	7-10 days
Beans, lima, in pods	5-6	4143	95	5 days
Blackberries	-0.5-0	31-32	90-95	2-3 days
Blood orange	4-7	4044	90-95	3-8 weeks
Blueberries	-0.5-0	31-32	90-95	2 weeks
Breadfruit	13-15	55-60	85-90	2-6 weeks
Broccoli	0	32	95-100	10-14 days
Brussels sprouts	0	32	95-100	3-5 weeks
Cabbage, early	0	32	98-100	3-6 weeks
Cabbage, late	0	32	98-100	5-6 months
Carambola	9-10	48-50	85-90	3-4 weeks

Carrots, mature	0	32	98-100	7-9 months
Cashew apple	0-2	32-36	85-90	5 weeks
Cauliflower	0	32	95-98	34 weeks
Cherimoya	13	55	90-95	2-4 weeks
Cherries	0	32	90-95	3-7 days
Coconuts	0-1.5	32-35	80-85	1-2 months
Cranberries	2-4	36-40	90-95	24 months
Cucumbers	10-13	50-55	95	10-14 days
Currants	-0.5-0	31-32	90-95	1-4 weeks
Custard apples	5-7	41-45	85-90	4-6 weeks
Dates	-18 or 0	0 or 32	75	6-12 months
Dewberries	-0.5-0	31-32	90-95	2-3 days
Durian	4-6	39-42	85-90	6-8 weeks
Eggplants	12	54	90-95	1 week
Garlic	0	32	65-70	6-7 months
Grapefruit	14-15	58-60	85-90	6-8 weeks
Grapes	-1 to -0.5	30-31	90-95	1-6 months
Guavas	5-10	41-50	90	2-3 weeks
Jackfruit	13	55	85-90	2-6 weeks
Jaffa orange	8-10	46-50	85-90	8-12 weeks
Jerusalem Artichoke	-0.5-0	31-32	90-95	+5 months
Kale	0	32	95-100	2-3 weeks
Kiwifruit	0	32	90-95	3-5 months
Leeks	0	32	95-100	2-3 months
Lemons	10-13	50-55	85-90	1-6 months
Lettuce	0	32	98-100	2-3 weeks
Limes	9-10	48-50	85-90	6-8 weeks
Loganberries	-0.5-0	31-32	90-95	2-3 days
Longan	1.5	35	90-95	3-5 weeks
Loquats	0	32	90	3 weeks
Litchies	1.5	35	90-95	3-5 weeks
Mangoes	13	55	85-90	2-3 weeks
Mangosteen	13	55	85-90	2-4 weeks
Nectarines	-0.5-0	31-32	90-95	2-4 weeks
Okra	7-10	45-50	90-95	7-10 days

Olives, fresh	5-10	41-50	85-90	+6 weeks
Onions, green	0	32	95-100	34 weeks
Onions, dry	0	32	65-70	1-8 months
Onion sets	0	32	65-70	6-8 months
Oranges	3-9	3848	85-90	3-8 weeks
Papayas	7-13	45-55	85-90	1-3 weeks
Passion fruit	7-10	45-50	85-90	3-5 weeks
Parsley	0	32	95-100	2-2.5 months
Parsnips	0	32	95-100	+6 months
Peaches	-0.5-0	31-32	90-95	2-4 weeks
Pears	-1.5 to -0.5	29-31	90-95	2-7 months
Peas, green	0	32	95-98	1-2 weeks
Peas, southern	+5	4041	95	6-8 days
Pepino	4	40	85-90	1 month
Peppers, Chili (dry)	0-10	32-50	60-70	6 months
Peppers, sweet	7-13	45-55	90-95	2-3 weeks
Persimmons, Japanese	-1	30	90	34 months
Pineapples	7-13	45-55	85-90	24 weeks
Plantain	13-14	55-58	90-95	1-5 weeks
Plums and prunes	-0.5-0	31-32	90-95	2-5 weeks
Pomegranates	5	41	90-95	2-3 months
Potatoes, early crop	10-16	50-60	90-95	10-14 days
Potatoes, late crop	4.5-13	40-55	90-95	5-10 months
Pummelo	7-9	4548	85-90	12 weeks
Pumpkins	10-13	50-55	50-70	2-3 months
Radishes, spring	0	32	95-100	34 weeks
Radishes, winter	0	32	95-100	24 months
Rambutan	12	54	90-95	1-3 weeks
Raspberries	-0.5-0	31-32	90-95	2-3 days
Rhubarb	0	32	95-100	24 weeks
Sapodilla	16-20	60-68	85-90	2-3 weeks
Seedless cucumbers	10-13	50-55	85-90	10-14 days
Soursop	13	55	85-90	1-2 weeks
Spinach	0	32	95-100	10-14 days
Squashes, summer	5-10	41-50	95	1-2 weeks

Squashes, winter	10	50	50-70	2-3 months
Strawberries	0	32	90-95	5-7 days
Sugar apples	7	45	85-90	4 weeks
Sweet potatoes	13-15	55-60	85-90	4-7 months
Tamarillos	3-4	37-40	85-95	10 weeks
Tamarinds	7	45	90-95	3-4 weeks
Tangerines, mandarins, and related citrus fruits	4	40	90-95	24 weeks
Taro root	7-10	45-50	85-90	4-5 months
Tomatillos	13-15	55-60	85-90	3 weeks
Tomatoes, mature-green	18-22	65-72	90-95	1-3 weeks
Tomatoes, firm-ripe	13-15	55-60	90-95	4-7 days
Turnips	0	32	95	4-5 months
Turnip greens	0	32	95-100	10-14 days
Water chestnuts	0-2	32-36	98-100	1-2 months
Watermelons	10-15	50-60	90	2-3 weeks
Yams	16	61	70-80	6-7 months

Source: McGregor, B.M. 1989. Tropical Products Transport Handbook. USDA Office of Transportation, Agricultural Handbook 668.

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