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Review Article

ADVANCEMENT IN HARVESTING, PRECOOLING, AND GRADING OF FRUITS

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ABSTRACT

Generally, quality grading includes outer parameters (size, color intensity, color homogeneity, bruises, shape, stem identification surface texture, and mass), inner parameters (sweetness, acidity, or inner diseases) and freshness. All horticultural crops are high in water content and are subjected to desiccation and to mechanical injury. That is why 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. Horticultural maturity is the stage of development when plant and plant part possesses the prerequisites for use by consumers for a particular purpose, i.e., ready to harvest. Postharvest handling is the final stage in the process of producing high quality fresh produce. Being able to maintain a level of freshness from the field to the dinner table presents many challenges. A grower who can meet these challenges will be able to expand his/her marketing opportunities and be better able to compete in the market place.

Keywords: Quality, Ripening, Maturity, Harvesting.

INTRODUCTION

The ultimate objective of production, handling and distribution of fresh fruits is to satisfy consumers. It is generally agreed that consumer satisfaction is related to product quality. Quality implies the degree of excellence endowed with sensory and hidden nutritional attributes [1]. Any mistakes made at harvest will be reflected and magnified down the line. Once an item is harvested, its quality cannot be improved, only maintained at the best. Fruit harvesting at proper stage of maturity has direct effect on quality and market value of the produce [2]. Stage of harvesting also influences the postharvest enzymatic activities of the horticultural produce, which determines the level of different sugar, acids, flavors, vitamins, pigments in fruits. Horticultural maturity is defined as the stage of development when a plant or plant part possesses the prerequisites for utilization by consumer for a particular purpose [3]. Ripening is a process that occurs in fruits after they have reached the physiological maturity.

The produce harvested too early, i.e., immature or tender stage will shrivel and may not develop characteristic flavor and color of the commodity, while over mature produce have very limited market life and higher rate of spoilage. Since the horticultural crops comes from diverse morphologically, anatomically, and biochemical origins and are intended for different uses, some prefer still very immature and tender while other when fully developed either, for fresh use or processing.

Maturity indices

Fruits harvested too early may lack flavor and may not ripen properly, while produce harvested too late may be fibrous or have very limited market life. However, pickers can be trained in methods of identifying produce that is ready to be harvested for various markets.

Type of maturity

1. Physiological maturity: It is the stage when a fruit is capable of further development or ripening, when it is harvested
2. Horticultural maturity: It refers to the stage of development when plant and plant part possesses the prerequisites for use by consumers for a particular purpose.

Importance of maturity indices

1. Ensure sensory quality (flavor, color, aroma, texture) and nutritional quality
2. Ensure an adequate postharvest shelf life
3. Facilitate scheduling of harvest and packing operations
4. Facilitate marketing over the phone or through internet.

HARVEST CRITERIA

Visual

Skin color

Predominant color is commonly referred as the skin color. It is most obvious indicator of ripeness in many fruits. However, it is a crude method of approximating the fruit ripeness.

Ground color

It is inconspicuous on most fruits, but it is fairly good indicator of properly mature fruit. For example, on red apple varieties, the ground color is visible between red strips and quite often shows through around the stem and blossom end.

Seed color

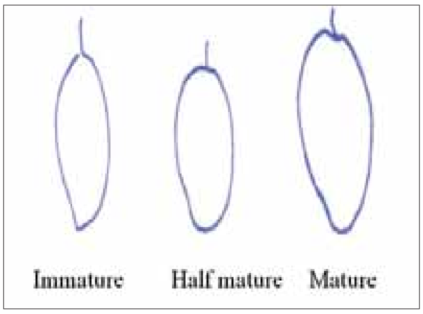
In papaya, apple, and pears, one can judge ripeness by the seed color. This involves cutting of fruits to expose the seeds, which are located in the center or core. If the seed coat color has turned completely dark brown the fruit is usually ripe enough to harvest.

Leaf and peduncle color

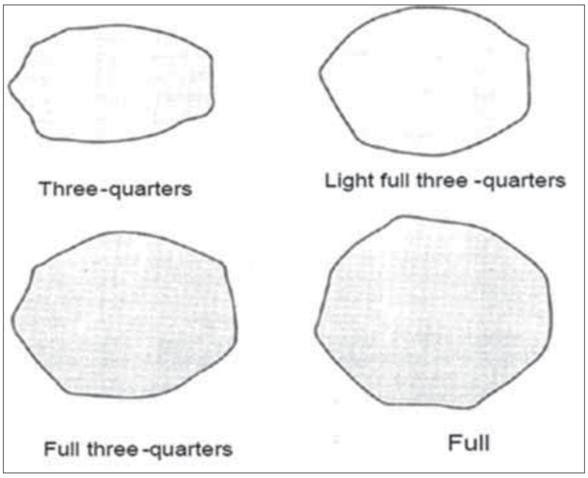
In jackfruit, peduncle and last leaf of peduncle turned yellow at ripening.

Size

Avocado industry is using minimum fruit weight and diameter for each commercial variety in conjunction with picking dates. Fullness of finger with size is a standard practice to determine proper time of harvest in banana. It is an indicator of maturity in many other fruits.



Judging mango harvest maturity by shape of shoulder (Source: Wardlaw and Leonard, 1936) [4]



Cross-section of the middle banana fingers showing the changes in angularity as they mature on the plant (Source: Von Loesecke, 1949) [5].

Shape

Angularity of banana finger, full checks of mango, and compactness of cauliflower, cabbage, and broccoli are the maturity indices for harvesting of crops.

Drying of leaf

In banana leaf, senescence is an indication for harvesting.

PHYSICAL

Dropping of fruits from the tree

The general criteria for the time of harvesting of mango fruit are when a few ripe fruits begin to fall naturally from the tree. This is called as "tapka." The whole crop is considered to be ready for picking.

Fruit firmness

Firmness is a useful way to estimate fruit maturity. The resistance of the flesh of fruits to pressure is tested by several puncture and pressure testers. The force needed to puncture is a measure of firmness. It is expressed in kg/sq. cm. It is very useful for judging the maturity of apple, pear, peach, plum, nectarines, apricot, and other fruits.

Tenderness

In peas and other vegetables are used as maturity index for harvesting.

Specific gravity (SG)

This can be used as a quick method for judging the maturity. Fruits that will float in water has lower total suspended solids (TSS), lower SG and hence immature. Fruits that sink in water have SG more than one, higher TSS, and therefore, are mature. To obtain SG, the weight of a fruit in air is divided by its weight in water. This method has been found useful in judging the maturity of guava, cherries, mango, and ber.

Juice content

Juice content is a general criterion for harvesting of citrus fruits. The international standards organization sets the minimum juice content for citrus fruits are – 30% in sweet orange, 33% in mandarins, 35% in grapefruit, and 25% in limes and lemons.

COMPUTATIONAL

Computation of days

Time harvest for some fruits has been predicted on the basis of counting days from bloom or fruit set to maturity. It is expressed in days/weeks or month. This is very common in apple and pear.

Heat units

The time required for fruits to reach maturity is determined mainly by the total amount of heat received which can be expressed in terms of, temperature – time values called "degree days" or heat units. This method has been found useful in judging the maturity of apple, pear and grape.

The number of heat units required for a growing area can be estimated as follows:

$H=T-TL\times D$

H=Heat units or degree days

T=Mean or average monthly temperature

TL=Baseline temperature

D=Number of days in month

CHEMICAL

Sugar content

The sugar content of the ripe fruit can be measured with a hydrometer or a refractometer. These instruments are generally calibrated in the balling or Brix scale and read directly in percent sugar by weight (g sugar/100 g of solution). This index is used in many fruits such as mango, grape, apple, pear, and stone fruits.

Acid content

The total acid content of the fruit is arbitrarily based on the principal acid of the fruit. The principal acid of citrus, guava, mango, pineapple, pomegranate, strawberry, and fig are citric acid. Malic acid is the principal acid of apple, pear, peach, plum, cherry, banana, and sweet lime. Very few fruits have tartaric acid, for example, grapes and tamarind.

TSS/acid ratio

It is an expression of the relationship between the sugar and acid contents of fruits. It gives a much more dependable and complete measurement of palatability than sugar content or acidity alone. The minimum desirable TSS/acid ratio varies with different varieties of fruits. The ratio can be obtained by dividing the degree brix or TSS by the total acidity. This is indices for many fruits such as grape, mango, papaya, and kiwifruit.

Starch

Starch content is being used for fixing the maturity of various fruits such as banana, mango, apple, and pear.

Fruits	Maturity indices		
	Visual	Physical	Chemical
Mango	Olive color, fullness of cheeks	Specific gravity 1.01-1.02	TSS 12-15%, starch/acid ratio 4
Banana	Fullness of finger	Pulp/peel ratio: 1.2-1.4	Acid 0.25%
Sweet orange	Color break 35%	Juice 40-50%	TSS 10-12%
Mandarins	Color break 40-50%	Juice 50%	TSS about 12-14%
Limes	Color break 50%	Juice 25-40%	
Lemon	Color break 40%	Juice 25-40%	
Grape fruit	Yellow or pink color	Juice 40-45%	TSS 10%
Guava	Light yellow color	Specific gravity 1.01-1.02	TSS 12-14%
Papaya	Trace of yellow color on apex or between ridges	No milk on tapering	TSS 7-11%
Grapes	Appearance of bloom on surface	Sweet taste of berries	TSS/acid ratio 25
Pineapple	Color break 25%	Specific gravity 0.98-1.02	TSS 12% or TSS/acid ratio 21-27
Litchi	Pink color and flatness of tubercles	Pulp/seed ratio: 4.3-6.3 (seeded) 12-28 (seedless)	TSS 17%
Ber	Golden yellow color	Seed/stone ratio: 12-18	TSS 15-18%

(*Contd...*)

Fruits	Maturity indices		
	Visual	Physical	Chemical
Apple	Yellow (Golden delicious)	Deep brown color of seed	TSS 10-13%
Pear	Greenish yellow color	Deep brown color of seed	TSS 12-14%
Peach	Light yellow or red strip	Pulp/stone ratio: 12-16	TSS 12-15%
Plum	Dark blue or purple color	Pulp/stone ratio: 12-25	TSS 12-15%

Mango
The maturity standards have been finalized for most of the commercial mango cultivars. Banganapalle should be harvested with about 8% TSS for air transport [6]. To determine harvest quality, accumulation of starch and dry matter during maturation have been well defined [7,8]. An increase in fruit density, or SG was well correlated with eating quality [9,10]. Ueda *et al*. [8] suggested the use of flesh color or flesh carotenoids as maturity index. Amrapali attains physiological maturity with TSS range from 9 to 11.0 Brix, fruit mass: Volume ratio >0.9, when peel surface appears with prominent lenticels of off-white color [11].

Banana
Banana are harvested before full maturity in a green and hard condition. Fruits destined for distant markets are harvested at a stage known as "three quarters full" when the fingers are still clearly angular. There is no sure way of determining maturity, and growers and exporters rely mainly on fruit diameter and angularity of fingers [12]. When the proportion between starch and sugar is about 20:1, the fruit is unpalatable at that time. The starch and sugar proportion of the tasteful fruit is about 1:20. Standard industry practice in Hawaii is to attach color coded tags or ribbons that identify the harvest dates of banana bunches, so that all bunches of a certain age will be harvested at the same time [13].

Guava
Harvest maturity of guava has been based on visual appearance and destructive tests. Tandon *et al.* [14] found a continuous decrease in SG, with ripe fruit reaching values <1.0. They recommended SG as a maturity index. Silva *et al.* [15] reported that SG and soluble solids concentration are not reliable harvest indices; color was a good harvest index with L*, a*, and Hue values being the best parameters to discriminate among different maturity stages.

Litchi
The number of days from full bloom to harvest is considered to be the best maturity index for litchi fruits. All the varieties arrived at harvest maturity between 55 and 80 days after full bloom [16]. The optimum time for harvesting Bombai litchi under west Bengal conditions was found between 105 and 110 days after an thesis, i.e., second fortnight of May [2].

Sapota
Unlike many other fruits, sapota rarely exhibits any marked changes in external color or texture to indicate maturity [17]. Hence, judging the maturity in sapota is comparatively skill oriented. Farmers are not aware of right maturity stage and about 25-30% immature fruits are passed on for marketing [18]. Sapota takes around 200 days to mature from fruit set. Arrest of latex flow and change in fruit surface color (potato color) are the best maturity indices for sapota fruits.

Ber
Maturity of ber starts from the first week of November in South India and continues up to mid-April in North India [19].

Papaya
Skin color turning stage is attained at 130-135 days and the fruit took 155-160 days to reach eating ripe stage after flowering. The fruits harvested at color break stage attain proper TSS (7-8%), total sugar (5-6%), acidity (0.096%), and sugar/acid ratio 50-55 at ripening [20]. For export, fruits are harvested at color break or between color break and one-quarter yellow color to obtain maximum fruit life and quality [21]. There are other maturity indices such as thermal conductivity of pulp (0.51 W/M°C for ideal ripe fruit) [22], and near infrared transmission spectra.

Aonla
Fruit volume increases up to 75 days after fruit set, outer color changes from green to yellow green or reddish green followed by increment in vitamin C and TSS up to 120 days after fruit set indicating the optimum stage for harvesting [23]. Under Maharashtra conditions, maturity starts from last week of October and lasts up to 25 November [24].

Strawberry
Harvesting is the most crucial operation in strawberry production. Skin color, taste, and TSS:acid ratio are taken into consideration to judge the fruit maturity. For medium distance (400-500 km, 5-6 h transportation duration) and long distance (more than 6 h transportation duration) markets, the fruits are harvested at 75% and 50% scarlet skin color appearance stage [25]. Strawberry fruits at maturity rapidly over-ripe and delayed harvesting may cause severe fruit loss within a day or two. Berries are usually harvested when 3/4th skin develops color [26].

Apple
The relationship between soluble solids content and organic acid concentration is called maturity index and is usually used in industry as a reference parameter of fruit state [27]. Thiault index (TI) is one of the maturity indexes frequently employed in apple fruit; it is related to soluble solids content and malic acid concentration [28].

TI: TI was used as an indicator of apple maturity. The TI is defined by equation [29].

$$TI = Cs + 10 \times Ac$$

where, Cs represents the sugar concentration (g/L) measured by refractometry, Ac represents the NaOH estimated acidity (expressed as g/L).

In apple, if TI is equal to 170, is the minimum to an acceptable fruit quality; if TI is equal to 180, is recommended to harvest the fruit; if TI is more than 180, the fruit quality is excellent [28,30].

Pear
These maturity indices are greatly influenced by prevailing climatic conditions and vary from season to season [31-33]. Quality and ripening potential of pears is closely related to harvest maturity of the fruit [34-36]. An innovative method referred to as the "NSure" has recently been introduced to determine the ripening stage for apples and pears (www.nsure.eu) [37]. This technique is based on measuring the activity profile of fruit genes to determine the ripening stage of the fruit. It is claimed that NSure testing offers reliable prediction of the maturation stage of the fruit, hence helping growers to plan harvest and sales in time.

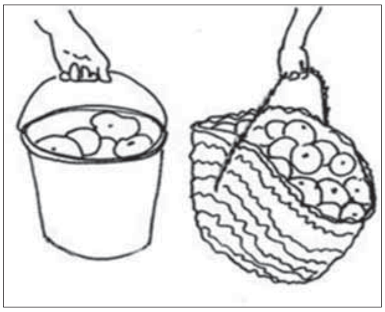
Harvesting of fruits
Majority of fruits are harvested by hands using secateurs, clippers, or diggers. Mechanical harvest in currently used for fresh market crops that is roots, tubers, rhizomes, and nut crops. A number of commodities destined for processing such as wine grapes, prunes, and peaches are harvested with machines because harvest damage dose not significantly affect the quality of processed product as the commodities are processed quickly. The following points should be kept in mind while harvesting the crops:
1. Gentle picking and harvesting will help reduce crop losses
2. Wearing cotton gloves, trimming finger nails, and removing jewellery such as rings and bracelets can help reduce mechanical damage during harvest
3. Produce should be harvested during coolest part of the day, not wet from dew or rain
4. Empty picking containers with care
5. Keep produce cool after harvest (provide shade).

Harvesting tools and containers

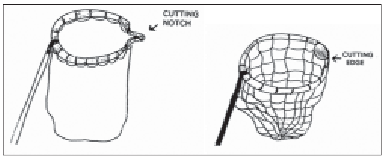
Protect produce quality by using clean harvesting tools and containers. Disinfect tools with one part chlorine bleach: One part clean water solution before use. The use of containers that can be easily filled and carried by workers minimize damage to produce. Use containers that are smooth on the inside, or provide clean, disposable liners made from paper or cardboard.

Picking bag

Cloth bag with opening on both ends (worn over the shoulders with adjustable harnesses). In case of 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.



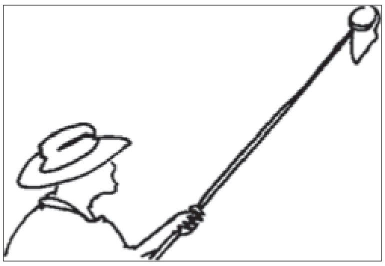
Hand woven collection bag



Canvas collection sack

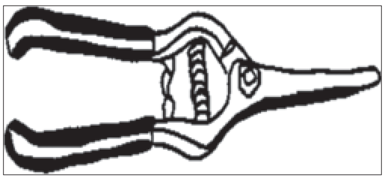
Picking poles and catching sacks

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.

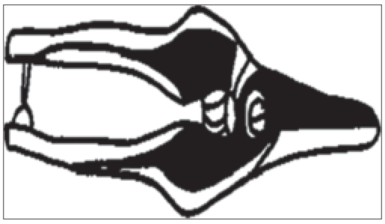


Clippers and knives

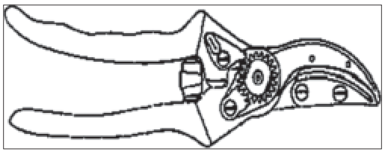
Some fruits such as citrus, grapes, and mangoes need to be clipped or cut from the plant. Clippers or knives should be kept well sharpened and clean. Peduncles, woody stems, or spurs should be trimmed as close as possible to prevent fruit from damaging neighboring fruits during transport. Care should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



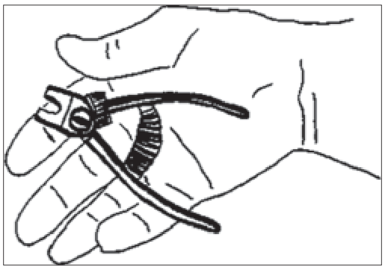
Thin curved blade for grapes and fruits



Straight bladed hand shears for fruits and flowers



Cut and hold hand shears



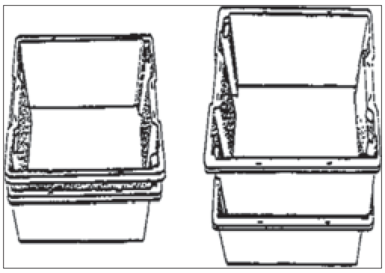
Clipper for citrus fruits

Tripod ladders

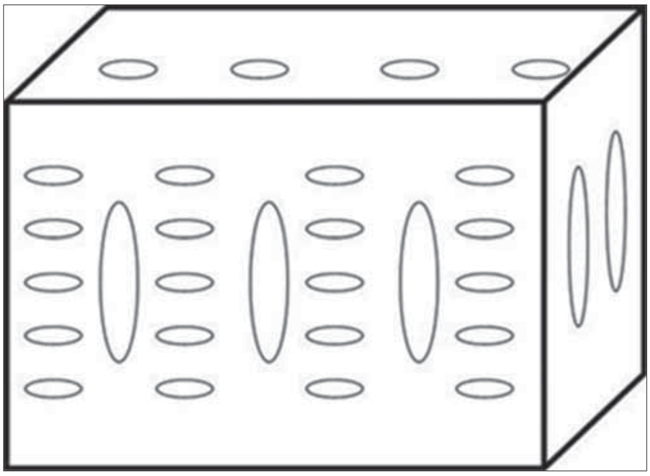
A ladder with three legs is very convenient and more stable than a common ladder. A ladder help harvesting crops such as mango, kinnow, pears, peaches, plums without damaging tree branches.

Harvesting containers

Plastic crates are relatively expensive to purchase, but are reusable and easy to clean. These have required features such as stacking strength, ventilation holes, and long life. These can be used for harvest, storage, cooling, transport, and even for display in retail markets. Various brands and styles are manufactured, but all can be stacked securely if they are not overfilled.



Plastic crates



If plastic crates are well vented along the sides and/or bottom, they can also be used to wash and/or cool produce after harvest

Harvesting
The goals of harvesting systems are as follows:
1. To gather the commodities from the field at proper stage of maturity.
2. With a minimum amount of damage and losses.
3. At the rate required for optimum handling.
4. In a cost effective way.

Method of harvesting
Harvesting of crops can be done manually or mechanically.

Hand harvesting

Most of the fruit crops intended for the fresh consumption are picked by hand. Hand harvesting is selective and can be done several times. This method reduces mechanical damage of the commodity but it is slow and sometimes become expensive. Hand harvesting sometime requires use of different several tools such as pruning shears or secateurs, knives, clippers, and digging tools for root vegetables. Different fruits require different technique of harvesting.

Advantages
a. Human can accurately select the maturity of fruits
b. Human can handle fruit with minimum damage
c. Hand harvesting require minimum capital investment.

Disadvantages
1. Labor supply is problem for farmers who cannot offer a long employment season
2. Labor strikes during harvest period can be costly.

Mechanical harvesting

Fruit crops such as nuts are harvested mechanically. Crops harvested mechanically are commonly damaged and easily decayed than harvesting by hand. Mechanical harvesting is done once and thus harvested produce may not be uniform in ripeness, size, and color when harvested. Moreover, machines usually have high unit cost. In advanced countries, different machine are used for harvesting of different fruits.

Advantages
a. Potential for rapid harvest is available
b. Working conditions are improved
c. Problem associated with hiring and managing hand labor are reduced.

Disadvantages
a. Damage can occur to perennial crops
b. Processing and handling capacity may not be able to handle the high rate of harvest.

Harvesting technique for fruits

Fruits	Technique
Mango	Hand picking or mango harvester using a cutting tool attached to a long pole and picking with 8-10 mm stalk
Banana	Bunches are cut with stalk retaining 30 cm length
Citrus, guava, Grapes, litchi	Stalks clipped with the help of clipper
Papaya	Fruit is harvested by twisting the fruit till it snaps-off
Pineapple	Harvested by cutting the stalk with 2 cm
Sapota	Sapota harvester has been developed for harvesting
Aonla	Hand picking and with local harvester using long pole attached with netting bag
Ber	Hand picking of individual fruits
Date	Harvesting by cutting the whole cluster
Loquat	By clipping the cluster with stalk
Jack fruit	By cutting the stalk with 8-10 cm
Pomegranate	By clipping the stalk
Apple	Just lift the fruit from the bottom with the help of palm and press the stalk gently with the fore finger. The mature fruit will be separated from the mother tree without much force
Peach, pear, Apricot	Picked by hand with precaution as mentioned for apple
Dry fruits, Almond and walnut	By shaking the branches

Precooling of horticulture produce
Precooling 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. Precooling (prompt cooling after harvest) is important for most of the fruits because they may deteriorate as much in 1 h. At 32°C (90°F) as they do in 1 day at 10°C (50°F) or in 1 week at 0°C (32°F). In addition to the removal of field heat from commodities, precooling also reduce bruise damage from vibration during transit. Cooling requirement from a crop vary with the air temperature during harvesting, stage of maturity and nature of crops. Precooling produce reduces:
- Field heat
- Rate of respiration
- Rate of ripening
- Loss of moisture
- Production of ethylene
- Spread of decay.

There are many methods of precooling viz. cold air (room cooling, forced air cooling), cold water (hydro cooling), direct contact with ice (contact icing), evaporation of water from the produce (evaporative cooling, vacuum cooling), and combination of vacuum and hydro cooling (hydrovac cooling). Some chemicals (nutrients/growth/fungicides) can also be mixed with the water used in hydro cooling to prolong the shelf life by improving nutrient status of crops and preventing the spread of postharvest diseases.

Methods of precooling
Various methods of precooling used for different fruits are as follows:
1. Room cooling
2. Forced air cooling
3. Hydro-cooling
4. Vacuum cooling
5. Package icing.

Some commodities can be cooled by several methods, but most commodities respond best to one or two cooling methods [38].

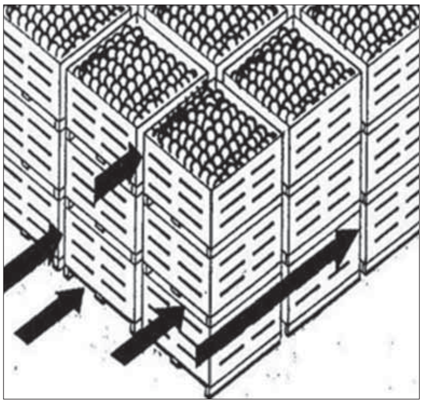
Room cooling

The produce to be cooled is brought from the field in large bins/crates and placed in cold room. This method is commonly used to produce having relatively longer shelf life, such as apples, citrus, potatoes, and pears. The produce is normally left for long-term storage in the same cold rooms.

Room cooling is a relatively low cost but very slow method of cooling when electricity for mechanical refrigeration is available. When using room cooling, produce is simply loaded into a cold room and cold air is allowed to circulate among the cartons, sacks, bins, or bulk load. Room cooling may be all you need if you handle sensitive crops that need to be cooled from early morning harvest temperatures to storage temperatures of 10-13°C (50-55°F). The design and operation of cold rooms are fairly simple and no special equipment is required.

It is important to leave adequate space between stacks of boxes inside the refrigerated room in order for produce to cool more quickly. About 1″ (2.5 cm) is sufficient to allow cold air to circulate around individual boxes. In many small-scale cold rooms, produce has been loaded into the room so tightly that cooling cannot take place at all and despite the high cost of running the refrigeration system, the produce temperature never decrease to recommended levels.

For best result, containers should be stacked so that the moving cold air can contact all container surfaces. Total fan airflow should be at least 0.3 m^3/minute per ton of product storage capacity (100 cfm/ton) for adequate heat removal. After cooling is complete, airflow can be reduced to 20-40 % of that needed for initial cooling.



Room cooling

Advantages

- Produce can be cooled and stored at the same room thus save on handling costs
- No extra cost for precooling equipment
- Suits produce, which is marketed soon after harvest
- Suits produce, which is stored unpacked
- Suits produce requiring mild cooling.

Disadvantages

- It is too slow for highly perishable products requiring fast cooling
- Space requirements for room cooling are more as compared to storage, thus loss of storage capacity
- Unsuitable for packed produce
- Excessive water is lost from the produce due to slow cooling.

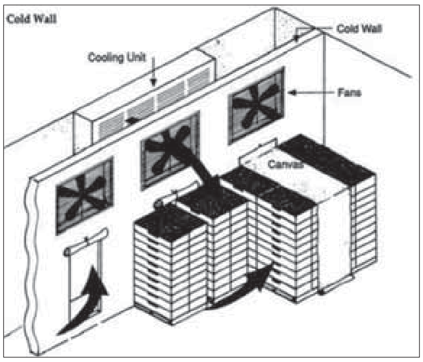
Forced-air cooling

Forced-air cooling is adaptable to a wider range of commodities than any other cooling method. It is much faster than room cooling because it causes cold air to move through rather than around [39]. This allows cold air to be in direct contact with warm product. With proper design, fast uniform cooling can be achieved through stacks of pallet bins or unitized pallet loads of container. Water loss varies with the moisture loss characteristics of individual products and can range from virtually none to 1-2% of initial weight. Forced-air is the most widely adaptable and fastest cooling method for small-scale operations.

The speed of forced-air cooling is controlled by the volume of cold air passing over the product. Maximum feasible cooling requires about 0.001-0.002 m^3/s/kg of product (1-2 cfm/lb). Rates greater than this only slightly reduce cooling time but as the air volume increases, the statics pressure required greatly increases, raising the energy consumption of the fan. Some products can withstand slower cooling and use air volume of 0.00025-0.0005 m^3/s/kg of product (0.25-0.5 cfm/lb). Static pressure needed to produce the airflow is very dependent on container vent design and the use of interior packaging materials [40].

Cooling time depend on: (i) the air flow, (ii) the temperature difference between the produce and the cold air, and (iii) produce diameter.

Horticultural produce suitable for forced air cooling: Grapes, berries, pears, peach, oranges, strawberries, and other tropical and subtropical fruits.

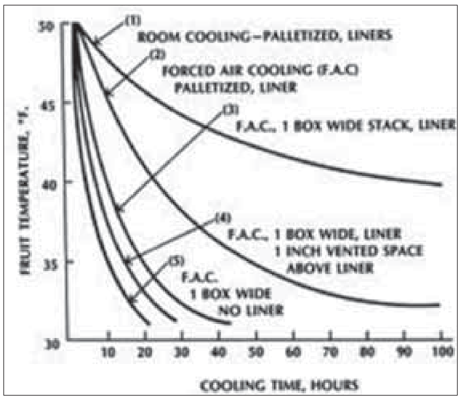


Source: Gast KLB and Flores R 1991. Precooling Produce. Kansas State University Cooperative Extension, Manhattan, Kansas

Forced-air cooling is one of the most efficient precooling methods [41]. Forced-air cooling has also been used in strawberry and was demonstrated to be a very important treatment prior to cold storage for the maintenance of acceptable appearance, texture, and nutritive value of the fruits [42,43].

Advantages

- It is fast cooling method and is suitable for a range of highly perishable commodities
- Cooling times can be controlled for different type of produce by controlling the air flow rates
- Most suitable for small scale operation
- It is energy efficient.



Hydro-cooling

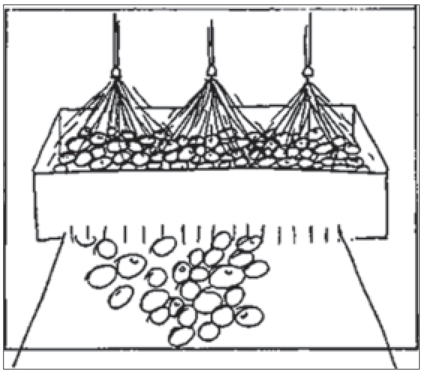
The use of cold water is an old and effective cooling method used for quickly cooling a wide range of fruits before packaging. For the packed commodities, it is less used because of difficulty in the movement of water through the containers and because of high cost involved in water tolerant containers. This method of cooling not only avoids water loss but may even add water to the commodities.

The hydro-cooler normally used are of two types:

a. Shower type: In this type of hydro-cooler, cold water is pumped to an overhead perforated pan which produces a shower over the produce which may be in bins or boxes or loose on a conveyer belt passing beneath. The water leaving the produce may be filtered to remove debris, then passed over refrigeration coil where it is re-cooled.
b. Immersion type: In this type of hydro-cooler, the produce is brought in contact with cold water by using a conveyor (flume type) or by lowering bins/boxes in tank of water which is continuously cooled by mechanical refrigeration system. Poor cooling would result if the product simple moved with the water. Flume hydro-coolers convey the product either against (counter flow) or across (cross flow) the flow.

Both the above types of hydro-coolers can be batch type or continuous type (for large capacities) and can be made portable type to be used in different locations for small scale operations.

Efficient cooling depends upon adequate water flow over the product surface. For product in bins or boxes, water flows of 13.6-17.0 L/s/m (20-25 gal/minute/ft2) of surface area are generally used. Immersion type hydro-coolers usually take longer time to cool produce than shower type cooler. Generally, the small quantity chlorine or other chemicals are added in the water to sanitize it.



Batch-type hydro-cooler

Hydro-cooling is a procedure in which, fruit are either sprayed with or immersed in cold water to reduce their temperature. Likewise, many other perishable fruits, pears, and peaches needed to be precooled immediately after harvest and efficient hydro-cooling with accurate cooling time is strongly recommended [44]. Additional useful effects of the hydro-cooling process include cleaning products (by removing chemical residues and debris), delaying fruit decay and reducing surface scald, bronzing, and pitting [45]. Hydro-cooling is a less expensive cooling method than the forced-air cooling method because water is more efficient than air in transferring the heat. This process remove field heat from produce up to 15 times more rapidly than the forced-air cooling method [46]. Crisosto [47] reported that exposing fruit to clean water with high pH during hydro-cooling does not induce inking and discoloration.

Advantages

- Less energy is used as compared to forced air cooling
- Moisture loss does not take place
- Fast online cooling is possible
- Cooling times are shorter as compared to room cooling and forced-air cooling and so can be used for cooling bulk bins and large size produce
- Hydro-cooler can be easily integrated into an packing operations and become a step within a simple packing line.

Disadvantages

- Most of the packages do not tolerate wetting.
- Wax layer of some fruits such as pear, plum, and apple are removed by using spray type of hydro-cooler.

Vacuum cooling

Vacuum cooling takes place by evaporating water from the product at very low atmospheric pressure. Products that easily release water may cool in 20-30 minutes. In this method, air is pumped out from a larger steel chamber in which the produce is loaded for precooling. 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 6°C of cooling. Like hydro-cooling water, this water must be disinfected if it is re-circulated. Water can also sprayed on the product before it enters the cooler. The rapid release of the vacuum at the end of the process can force surface water into some vegetables, giving them a water soaked appearance.

Advantages

- Packed produce can be cooled if the pack allows moisture transfer
- Fast and uniform cooling take place
- Suitable for leafy vegetables.

Disadvantages

- High capital cost
- Produce losses more moisture
- High energy use.

Package-icing

Some commodities are cooled by filling packed containers with crushed or naked ice. Initially, the direct contact between product and ice causes fast cooling. However, as the ice in contact with the product melts, the cooling rate slows considerably. The constant supply of melt water keeps a high RH around the product. Liquid ice, a slurry of ice and water, distributes ice throughout the box, achieving better contact with the product. Ice can be produced during off-peak hours when electricity is cheap and stored for daytime use. Package ice can be used only with water tolerant, non-chilling sensitive products, and with water tolerant packages (waxed fiber board, plastic, or wood).

Package-icing requires expensive, water tolerant packages. The packages should be fairly tight but should have enough holes to drain melt water. In small operations the ice is hand-raked or shoveled into containers. Large operations use liquid-ice machines to automatically ice pallet load of packed cartons.

The product must be tolerant of prolonged exposure to wet conditions at 0°C (32°F). Some low density products have excess space in which to load ice within the package and ice not melted during cooling can remain in package even after transport. This excess ice can keep the product cold if the cold chain is broken. An ice weight equal to 20-30% of the product weight is needed for initial cooling, but liquid icing often adds an ice weight equal to the product weight.

Should be top-iced	Can be top-iced
Beets with tops	Artichokes, globe
Broccoli	Beet greens
Carrots with tops	Beets topped
Parsley	Celeriac
Radishes with tops	Chard
Radish greens	Kohlrabi
Spinach	Leeks
Turnips	Mustard greens

Sources: McGregor, 1989 [48]; Thompson, 2002 [49]

Maintaining the cold chain for perishables

Harvest	Protect the product from the sun Transport quickly to the packing house
Cooling	Minimize delays before cooling Cool the product thoroughly as soon as possible
Temporary storage	Store the product at optimum temperature Practice first in first out rotation Ship to market as soon as possible
Transport to market	Use refrigerated loading area Cool truck before loading Load pallets toward the center of the truck Avoid delays during transport Monitor product temperature during transport
Handling at destination	Use a refrigerated unloading area Measure product temperature Move product quickly to the proper storage area Transport to retail market in refrigerated trucks Display at proper temperature range
Handling at home	Store product at proper temperature Use the product as soon as possible

Grading
Grading is a unit operation in packing house. This is done by machine or manual inspection. Manual grading is necessary to remove all blemished items of crops which would not normally be recognized by machine grading system. Conformity of size is particularly desirable for packaging and display purpose. Some fruits cultivars have a consistent shape, so that they can be conveniently weighed and sorted. The result is a produce that is consistent in volume and shape and packs easily.

Mechanical graders
Grading machines fit into four main categories depending on quality to be graded, namely, size, mass, color, and profile. Various graders working under above principles are screen grader, diverging belt grader, rotary cylinder grader, roller grader, link grader, iris grader, mass grader, and color sorter.

Graders are available in several different forms, which have different numbers of contact points and different shaped apertures. The major limitation is that most machines are two-dimensional and items may be upended to pass through. Other important aspects are gentleness to the crop, throughout, capital cost of machine, and flexibility to handle a range of crops.

Screen grader
A super imposed vibration on belt ensures that any item smaller than the hole size of belt will drop through on to a chute or crosswise conveyor. The machine would typically have two or three belt, with smaller one coming first to allow smaller size to be removed first. Size of mesh increase for successive belts and the largest fraction would be the carry-over crop from the larger mesh belt. Shape of hole in the belt is usually square but hexagonal is also available.

Diverging belt grader
There is a wide range of equipment, which employs same principle of diverging elements. Crop is conveyed along a narrow channel which increases in width as it travels along until it is so wide that fruit drops through by gravity on to a belt or chute below. Channel can be formed from a pair of belts, which themselves are round-sectioned and endless in polyethylene or other flexible plastic. Belt should be capable of adjustment, resist wear, be flexible, wipe clean, and not be too temperature sensitive. Belts have to be adjustable in width to suit any fruit size, which is round in shape. Shape such as citrus and tomatoes are ideal although it is not possible to use diverging principle to grade even long thin crops such as leeks or spring onions.

Rotary cylinder grader
Rotary cylinder grader is composed of five hollow cylinder which rotate in a counter clockwise when driven by an electric motors. Each cylinder is perforated with holes large enough to let fruits drop through. The first cylinder has the smallest diameter holes and the fifth has the largest holes. When fruits fall through, they are caught on a slanted tray (the chute) and roll into the containers. Care should be taken that the distance of the drop is as short as possible to prevent bruising. Oversized fruits are accumulated at the end of the line. This equipment works the best with round commodities.

Mass grader
If fruits are to be sorted according to weight, singulator separates fruit into pockets or cups, so that each fruit can be weighed independently. Fruit can then be separated into appropriate sizes by sorting according to weight recorded for the cups. Various devices including transfer wheels and expanding belts can be used for singulation.

Image processing
Image processing is used to sort fruits on basis of length, diameter, number of surface defects, and orientation of fruit on a conveyor as well as color. The fruit passes beneath three video cameras, placed 120^0 apart above a conveyor belt. Image of surface of fruit are recorded and stored in memory of a microprocessor. The information is then analyzed and compared with preprogrammed specifications for product and fruit is either rejected or moved into a group with similar characteristics.

In another system, a video camera views fruits and an operator compares the shapes with an electronic template overlaid on a monitor screen. The template reduces operator fatigue and allows greater concentration on selection process.

Color sorting
Fruits can be automatically sorted at very high rates using microprocessor controlled color sorting equipment. Fruits are fed into chute one at a time. The angle, shape, and lining material of the chute are altered to control velocity of fruits as they pass a photo detector. Color of background and type and intensity of light used for illuminating fruit are closely controlled for each product. Photo detectors measure reflected color of each piece and compare it with preset standards. Reflected light is measured by a microprocessor, which operates an automatic reject system. Defective fruits are separated by a short blast of compressed air.

The grades of different fruits suggested by directorate of marketing and inspection (DMI) are as follows:

1. *Kinnow*

Size code	Fruit size (diameter) mm	Number of fruits in 10 kg pack
A	60-64	84
B	65-69	72
C	70-72	60
D	72-74	54
E	75-79	51
F	80-85	45

2. *Mangoes*

Grade	Fruit weight (g)	Maximum permissible difference between fruit within packages (g)
A	100-200	50
B	201-350	75
C	351-550	100
D	551-800	125

3. Grapes

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

4. Guava

Size code	Weight (g)	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

5. Litchi

Grade	Fruit diameter (mm)
Extra class	33
Class I	28
Class II	23

6. Pomegranate

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

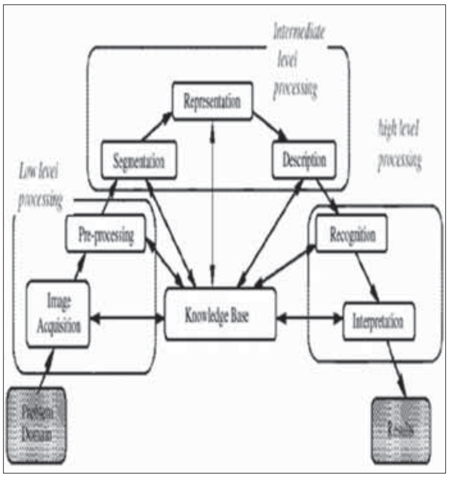
Grading systems give us many kinds of information such as size, color, shape, defect, and internal quality. Among these color and size are the most important features for accurate classification and/or sorting of citrus such as oranges, lemons, and tangerines. Basically, two inspection stages of the system can be identified: External fruit inspection and internal fruit inspection. The former task is accomplished through processing of color images, whereas internal inspection requires special sensors for moisture, sugar, and acid contents.

Fruit size estimation is also helpful in planning packaging, transportation, and marketing operations. Among the physical attributes of agricultural materials, volume, mass, and projected areas are the most important ones in sizing systems [50,51]. Computer vision has been used for quality inspection of fruits. Quality inspections of fruits have two different objectives: Quality evaluation and defect finding. In recent years, computer machine vision and image processing techniques have been found increasingly useful in the fruit industry, especially for applications in quality inspection and shape sorting. Researches in this area indicate the feasibility of using machine vision systems to improve product quality while freeing people from the traditional hand sorting of agricultural materials. Raji and Alamutu [52] reviewed the recent development and application of image analysis and computer machine vision in sorting of agricultural materials and products in the food industries.

Generally, quality grading includes outer parameters (size, color intensity, color homogeneity, bruises, shape, stem identification surface texture, and mass), inner parameters (sweetness, acidity, or inner diseases), and freshness. Although both outer and inner quality information can be collected by an automatic grading system in a factory, but machine vision is more effective for measuring outer parameters [53-60]. The algorithm can successfully estimate size, sort color, classify shape, detect bruises or scar tissue and predict the mass of the pepper fruits. Njoroge *et al.* [61] described the operations and performance of an automated quality verification system for agricultural products. Kondo *et al.* [62] proposed a multi-product grading system for agricultural products.

Khojastehnazhand *et al.* [63] reported that recently they developed an image processing technique for estimating citrus fruits physical attributes including diameters, volume, mass, and surface area using image processing technique. There we developed a machine vision system to automatically determine the diameter, volume, and surface area of tangerine. This image processing procedure can be readily applied to other axisymmetric agricultural products such as eggs, pearl, pepper, carrot, limes, and onions. The objective of this work is to extend the scope of the algorithm for a sorting system, designed specifically for citrus fruits such as lemon.

The design requirements for building a computer mediated fruit sorting system vary from fruit to fruit (product to product as well) for which it is designed to process. Therefore, most of the research works are focused on building dedicated systems that can sort a particular fruit or product type. Although, there are efforts to build general fruit sorting and classification systems but most of the systems are dedicated systems like the system that can sort apples [64], citrus fruit [65,66]. Dedicated quality control vision based systems are also being built for other agricultural products such as cereal grain [67], lentils [55]. Antonio *et al.* [68] research is to evaluate a new open software that enables the classification system by recognizing fruit shape, volume, color and possibly bruises at a unique glance. The software named ImageJ, compatible with Windows, Linux, and MAC/OS, is quite popular in medical research and practices, and offers algorithms to obtain the abovementioned parameters. The software allows the calculation of volume, area, averages, border detection, image improvement, and morphological operations in a variety of image archive formats.



Different levels in the image processing [69]

Computer-mediated approaches to assess the fruit quality differ from one another on the basis of the quality factors and the classification methods that are used in their design. If they use internal quality factors and do not destroy the fruit while measuring them, such approaches are referred to as nondestructive approaches [70-73]. These techniques generally utilize spectroscopic and hyperspectral imaging. Computer-mediated technique has many advantages as compared to the classical methods. It is proving beneficial in determining the fruit defects [64], discovering fruit quality attributes [74], and fruit quality evaluation [75] in general.

CONCLUSION

Maturity of fruits has prime importance in maintaining after harvest traits, viz. appearance, flavor, nutritional value, taste, and shelf life. Most of the fruits are harvested at physical maturity (after cessation of cell growth) and ripening (development of color, flavor, and taste) is allowed off the tree. Market forces and consumer preference have least effect on harvest maturity decision of fruit crops. Fruits such as sapota, kiwi, pineapple, Japanese persimmon, pomegranate, and kinnow give pseudo appearance of maturity and growers, traders and consumers suffer a lot in post-harvest monetarly and quality losses. There are several preharvest factors which affect the maturity of fruits as a single factor or in combinations. Factors such as soil, altitude, temperature, humidity, fruiting position, nutrition, and water supply exert passive impact on crop maturity. Variety, rootstock, interstock (interstem), training, pruning, sapling age, crop load, and use of plant growth regulators exert active role in setting the maturity of fruits. With the advent of new maturity determination methods, it is imperative to develop simple, low cost, manually/solar operated handy tools for unskilled and skilled growers.

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