Post-Harvest Operations and Processing of Fruits, Vegetables, Spices and Plantation Crop Products

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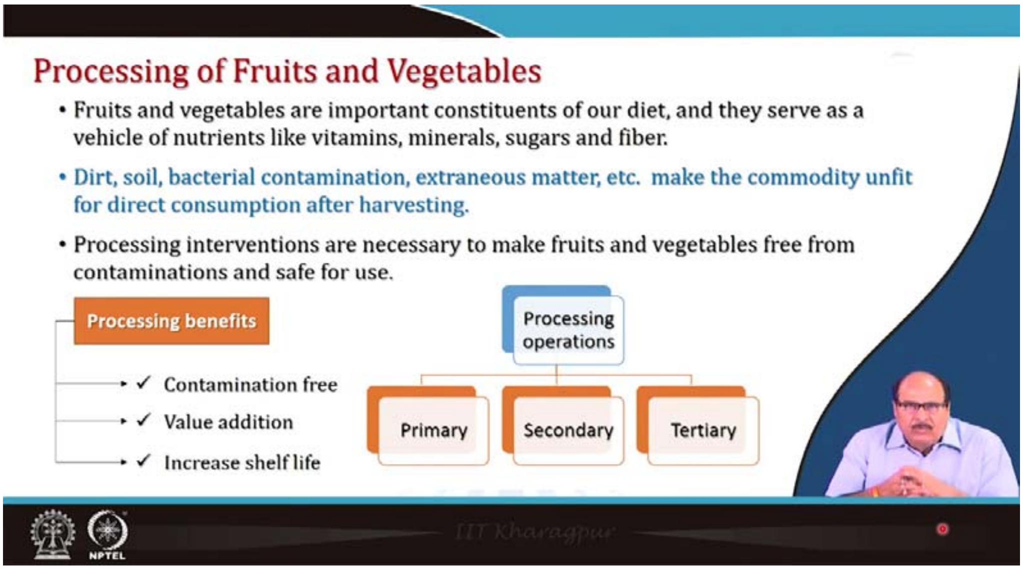
Lecture 07
Post-Harvest Operations

This lecture covers various aspects of post-harvest operations, such as primary, secondary and tertiary operations and pre-cooling technologies.

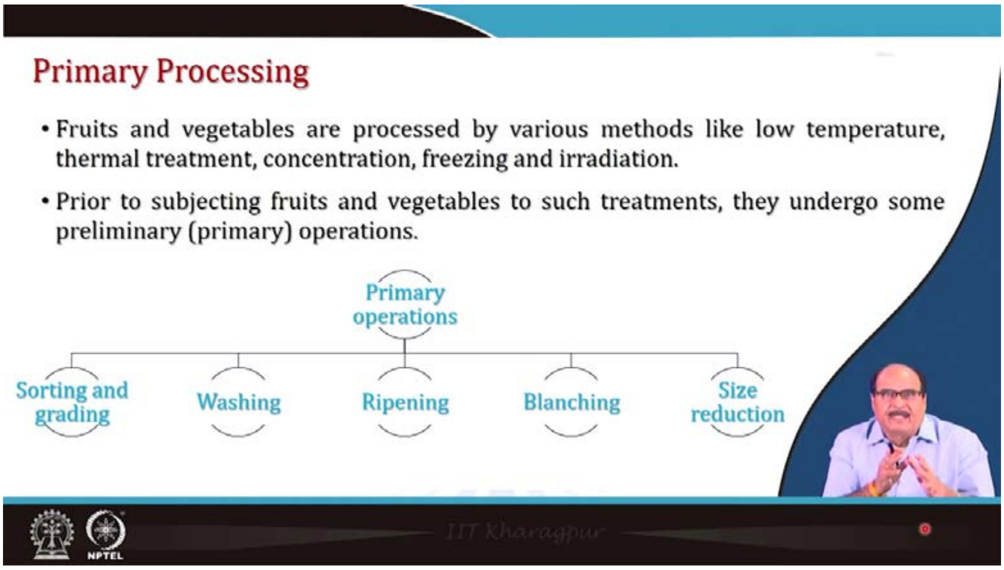


Processing of Fruits and Vegetables

Fruits and vegetables are important constituents of our diet and they serve as a vehicle for nutrients like vitamins, minerals, sugars and fibre. The presence of dirt, soil, bacterial contamination, extraneous matter, etc. make the commodity unfit for direct consumption after harvesting. To make the fruit or vegetable free from these contaminants and safe for consumption, various processing interventions necessary. The processing of commodities increases shelf-life, adds value into them, and keeps them contamination-free. The processing operations include primary, secondary, and tertiary operations.

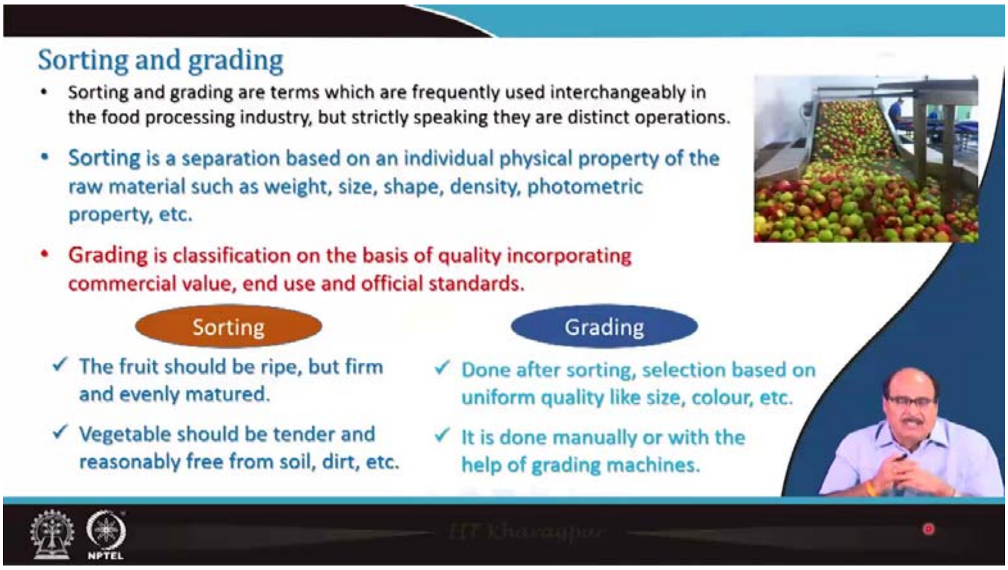
Primary Processing

Fruits and vegetables are processed by various methods like low temperature, thermal treatment, concentration, freezing and irradiation. But, prior to subjecting fruits and vegetables to such treatments, they undergo some preliminary (primary) operations. The major primary operations for fruits and vegetables are sorting and grading, washing, ripening, blanching and size reduction.



Sorting and grading

Sorting and grading are the terms which are frequently used interchangeably in the food processing industry. Sorting is a separation based on an individual physical property of the raw produce such as weight, size, shape, density, and photometric property. Grading is the classification on the basis of quality incorporating commercial value and use and official standards.



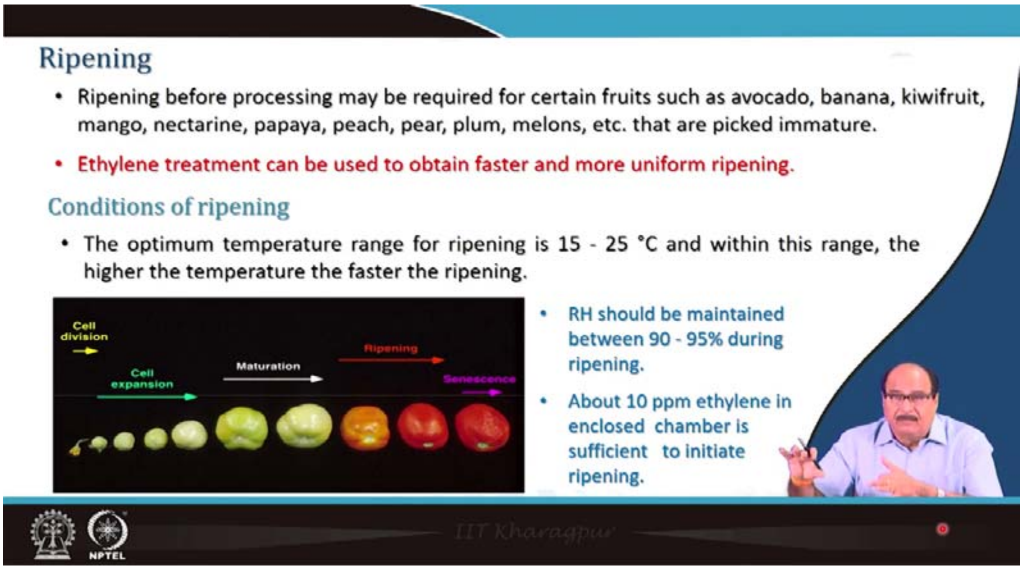
In sorting, the fruits should be ripe but firm and evenly matured. Vegetables should be tender and reasonably free from soil and dirt. But grading is generally done after sorting, the selection is based on the market appeal like uniform quality, size and colour. So, it is done manually or with the help of grading machines.

Washing

The graded fruits and vegetables are washed with water in different ways like soaking and subsequent washing, in running water or spraying with water or dry air to remove surface adhering material. A thorough wash is very essential for improving microbiological quality of the product (e.g. the roots, tubers or bulbs which are grown inside the soil).

Method of washing

Vegetables are soaked in a dilute solution (0.1%) of potassium permanganate or sodium hypochlorite solution to disinfect them. Agitation of the washing water is affected by means of compressed air or a force pump or propeller-type equipment. Amongst all, spray washing is the most efficient method for washing fruits and vegetables.

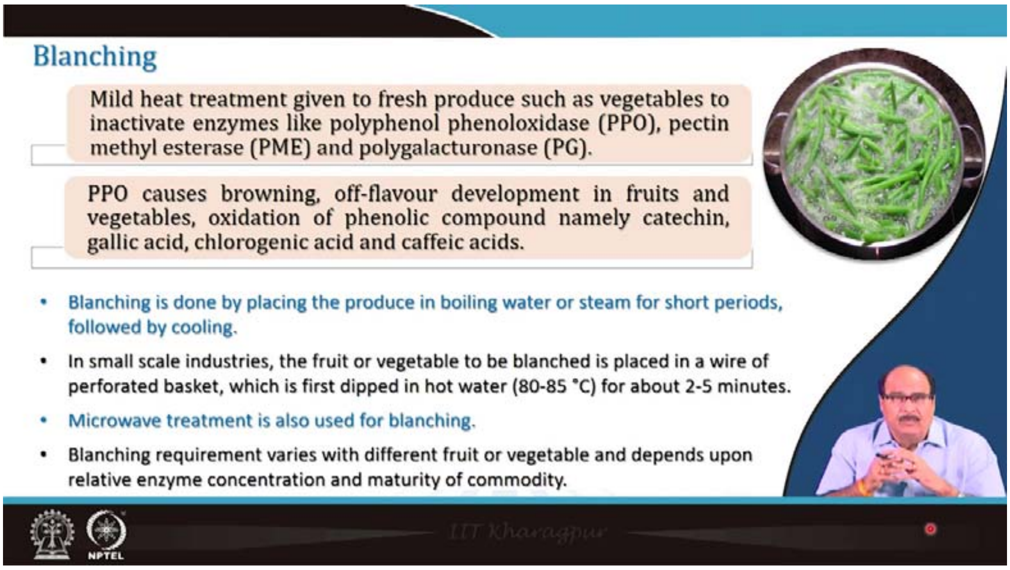


Ripening

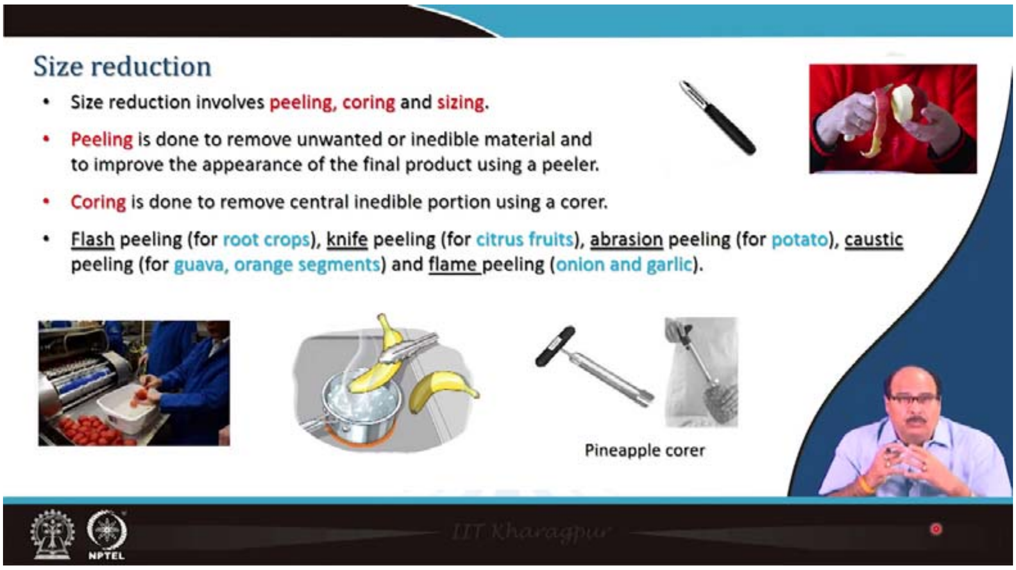
Ripening before processing may be required for certain fruits such as avocado, banana, kiwifruit, mango, nectarine, papaya, peach, pear, plum, melons, etc. that are picked immature. For preparation of intermediate moisture food, they need to be properly ripening. So, often they are artificial ripened under control environment. Ethylene treatment can be used to obtain faster and more uniform ripening. About 10 ppm ethylene in enclosed chamber is sufficient to initiate ripening. The optimum temperature range for ripening is majority 15 to 25 □ and within this range, the higher the temperature faster will be ripening. RH should be maintained between 90 - 95% during ripening.

Blanching

Mild heat treatment is given to fresh produce such as vegetables to inactivate enzymes like polyphenol phenoloxidase (PPO), pectin methyl esterase (PME) and polygalacturonase (PG). These enzymes if they are not controlled, they may bring about certain changes in the produce during their subsequent operations like drying, canning, and freezing. For instance, after peel the surface of potato, PPO enzyme act on the substrate leading to a series of reactions which produces a dark brown colour compound.



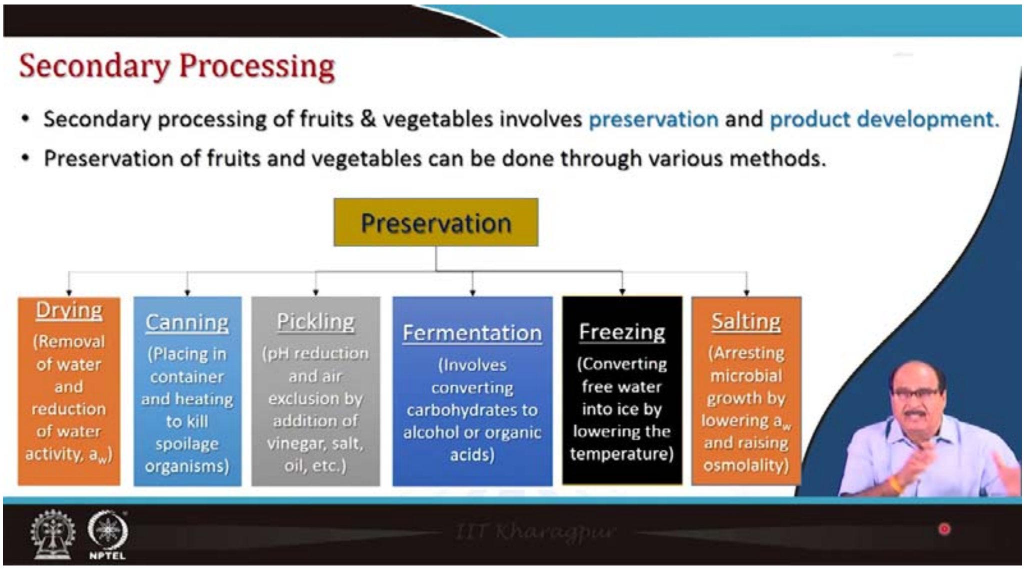
PPO causes browning, off-flavour development in fruits and vegetables, oxidation of phenolic compound namely catechin, gallic acid, chlorogenic acid and caffeic acids. Blanching is done by placing the produce in boiling water or steam for short periods, followed by cooling. In small scale industries, the fruit or vegetable to be blanched is placed in a wire of perforated basket, which is first dipped in hot water (80-85 °C) for about 2-5 mins. Microwave treatment is also used for blanching. Blanching requirement varies with different fruit or vegetable and depends upon relative enzyme concentration and maturity of commodity.



Size reduction

Size reduction involves peeling, coring and sizing. Peeling is done to remove unwanted or inedible material to improve the appearance of the final product using a peeler. Coring is done to remove central inedible portion using a corer (eg. Pineapple).

The peeling methods include flash peeling for root crops, knife peeling for citrus fruits, abrasion peeling for potatoes, caustic peeling for guava and orange segments, and flame peeling for onion and garlic.



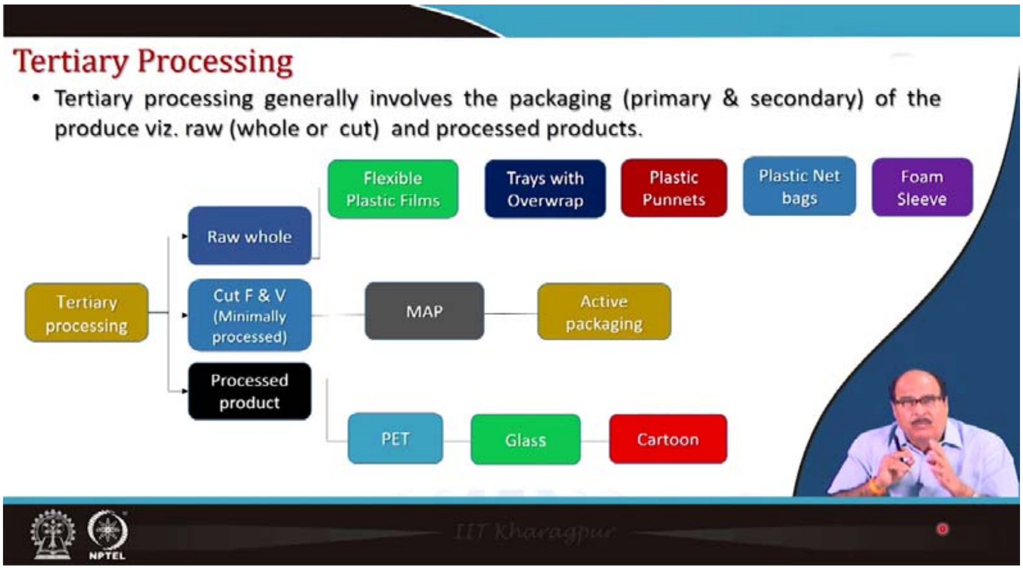
Secondary Processing

Secondary processing of fruits and vegetables involves preservation and product development. Preservation of fruits and vegetable can be done by various methods like:

1. **Drying**: The main principle is removal of water and reduction of water activity.
2. **Canning**: It is done by placing the commodity in a container packing the commodity in a container and heating to kill the spoilage microorganisms.
3. **Pickling**: It is done by reducing the pH and air exclusion by addition of vinegar, salt, or oil. It improves the taste as well as increases the self-life.
4. **Fermentation:** It involves converting the carbohydrates into alcohol or organic acid.
5. **Freezing:** The free water present in the commodity is converted into ice by lowering the temperature below its freezing point.
6. **Salting:** It arrests microbial growth by lowering the water activity or raising the osmolality of the produce.

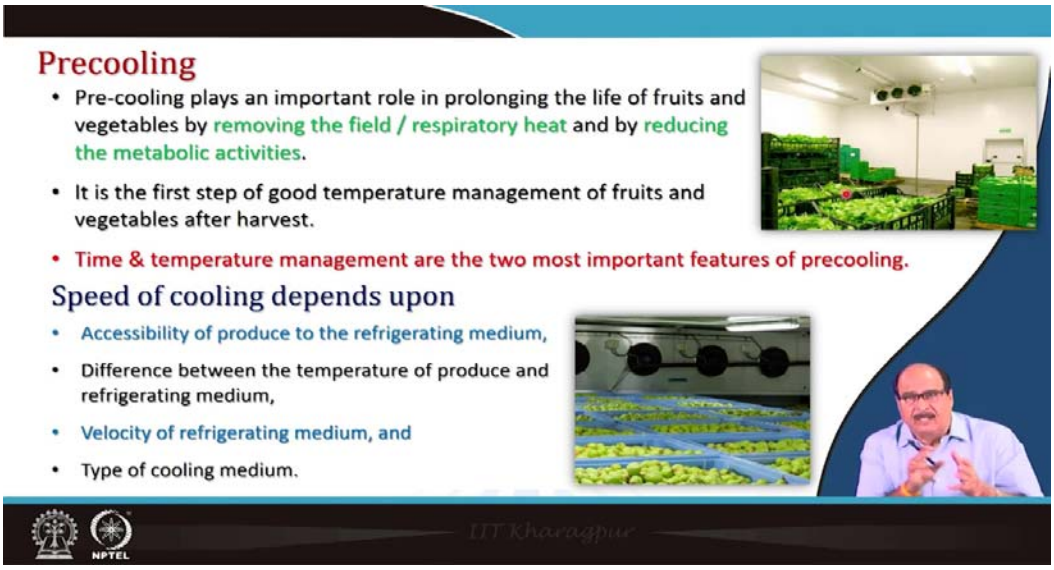
Product development

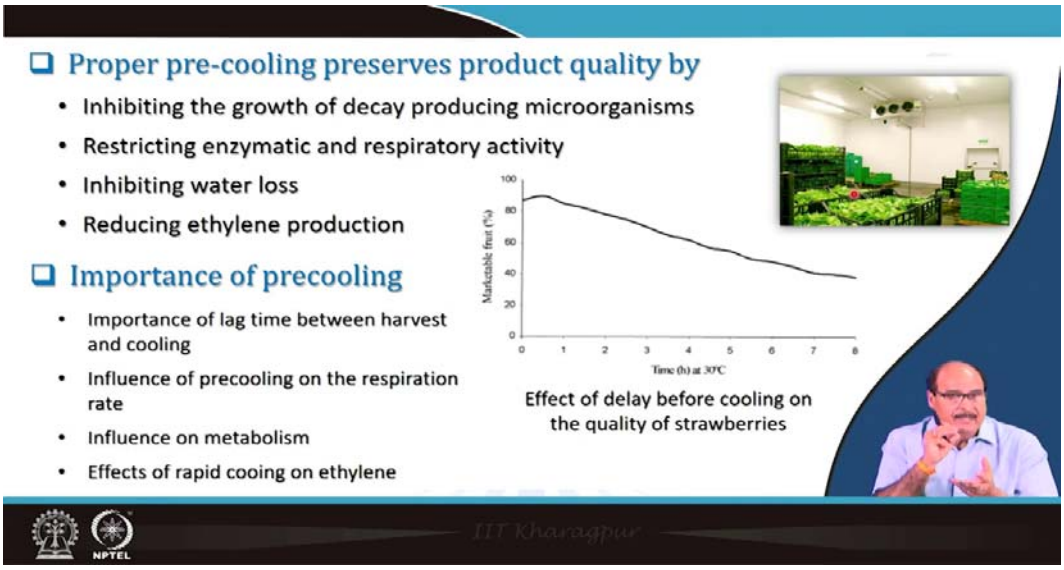
The fruits and vegetables can be converted into various value added product through various methods. The products can range from self-stable products like chips, juices, concentrates to intermediate moisture foods products (e.g. jam, jelly) or high moisture fruit products. Fruits or vegetables also can be converted into powders, concentrates, juices, jams, or beverages.



Tertiary processing

Tertiary processing generally involves the packaging (primary & secondary) of the produce viz. raw (whole or cut) and processed products. It includes that the packaging of both primary and secondary packaging of the raw whole produce, or cut fruits and vegetables or the processed products. The packaging of raw produces may be done by flexible plastic films, trays with over wrap, plastic punnets, plastic net bags or foam sleeves. Cut fruits and vegetables that are minimally processed can be packed in a modified atmosphere packaging or active packaging. Similarly, the processed products can be stored in PET, glass, or cartoons.





Precooling

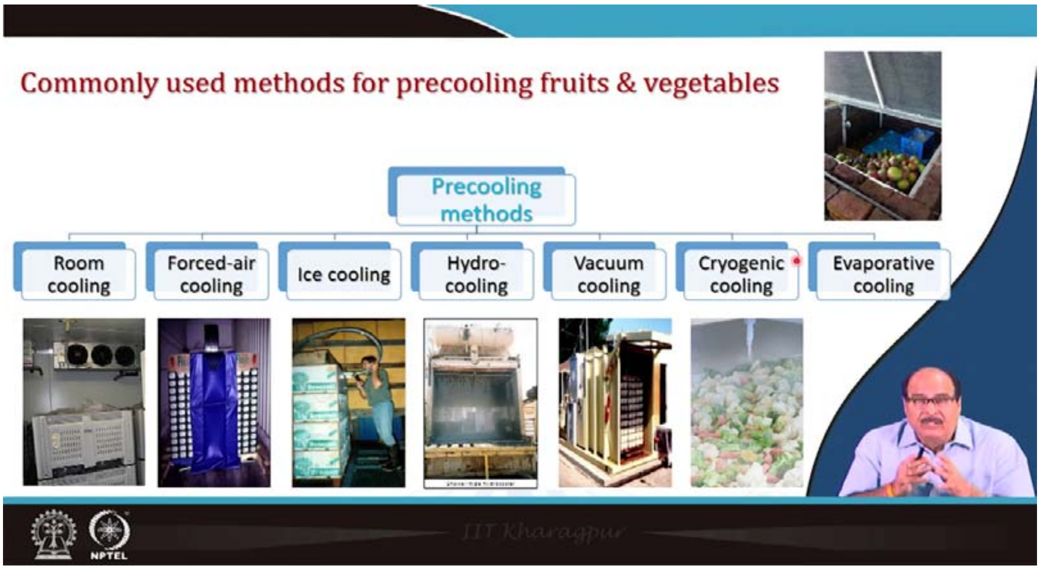
Pre-cooling plays an important role in prolonging the life of fruits and vegetables by removing the field / respiratory heat and by reducing the metabolic activities. It is the first step of good temperature management of fruits and vegetables after harvest. Subsequently, time and temperature management are the two most important features of pre cooling.

The speed of cooling depends on four factors, (1) Accessibility of produce to the refrigerating medium, (2) Difference between the temperature of the produce and the refrigerating medium, (3) Velocity of the refrigerating medium, and (4) Type of the cooling medium.

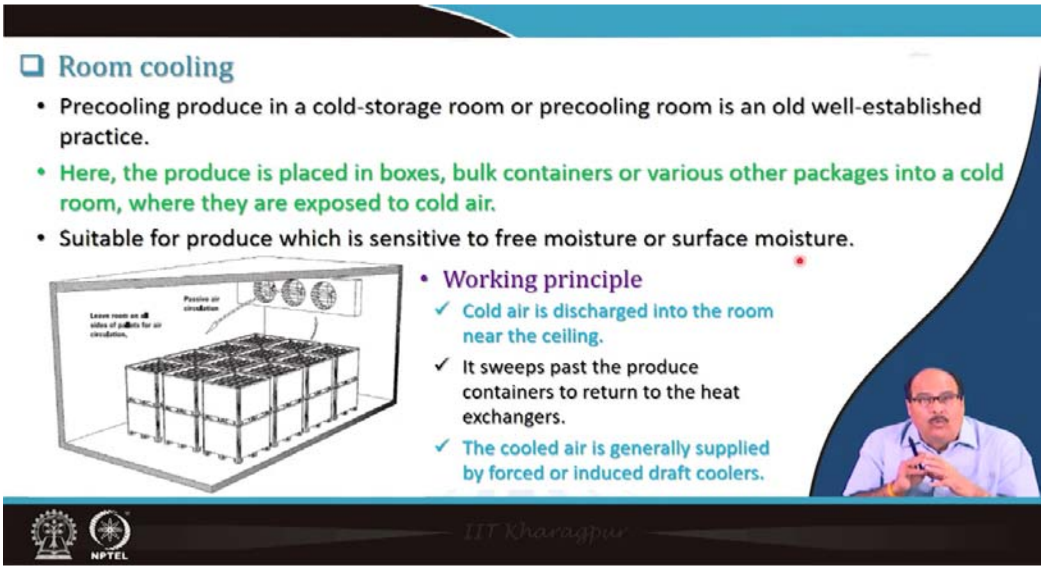
Proper precooling preserves the product quality by inhibiting the growth of decay producing microorganisms, restricting enzymatic and respiratory activity, inhibiting water loss and reducing ethylene production. There should be a minimum lag time between harvest and the cooling. The precooling influences the respiration rate, metabolism, and ethylene production of fruits and vegetables. On this context, the effect of delay before cooling on the market quality of strawberries has been shown. It is evident that on delaying the storage of the fruit by 8 hours at 30 □, marketability was reduced by half.

Precooling temperature

Generally, horticulture produces are cooled to their recommended storage temperatures. For example, recommended storage temperature for grape is 1 to 4 □, potatoes are normally precooled to 5 to 9 □, banana, mango, and tomato are cooled to > 10 degrees □. All fruits and vegetables are mostly cooled by room cooling or mechanical refrigeration. According to the Indian Board of Horticulture, fruits and vegetable such as oranges, grapes, tomatoes, beans, brinjal, okra, spinach etc. should be rapidly precooled.



The commonly used methods for precooling of fruits and vegetables include room cooling, forced-air cooling, ice cooling, hydro cooling, vacuum cooling, cryogenic cooling, and evaporative cooling.

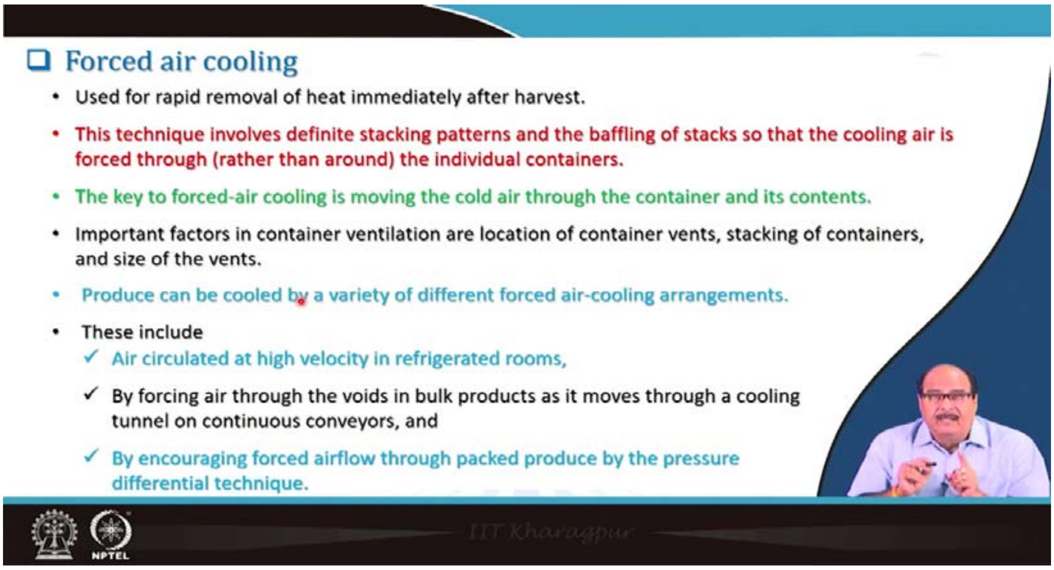


Room cooling

Precooling produce in a cold-storage room or precooling room is an age old or well established practice. The produce is placed in boxes, bulk containers or various other packages into a cold room, where they are exposed to cold air.

Working principle

Firstly, the cold air is discharged into the room near the ceiling. It then sweeps past the produce containers to return to the heat exchangers. The cooled air is general supplied by forced or induced draft coolers.



Forced air cooling

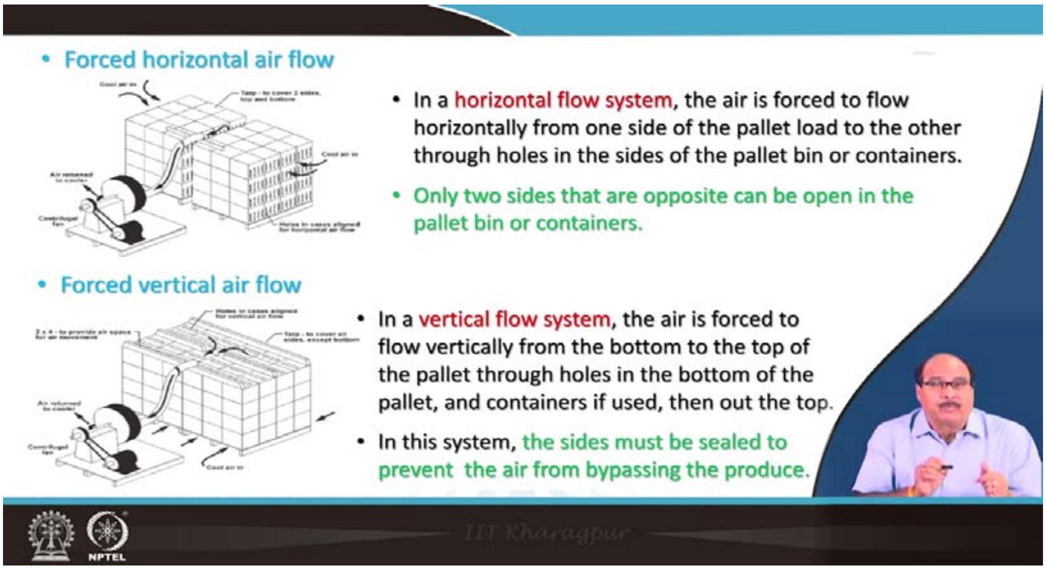
It is used for rapid removal of heat immediately after harvest. This technique involves definite staking pattern and the baffling of stacks so that the cooling air is forced through the individual containers. The key to the forced air cooling is moving the cold air through the container and its contents. The important factors in container ventilation are location of the container vents, stacking of containers, and size of the vents. Produce can be cooled by a variety of different forced air-cooling arrangements. These include, (1) Air circulated at high velocity in refrigerated rooms, (2) By forcing air through the voids in bulk products as it moves through a cooling tunnel on continuous conveyors, and (3) By encouraging forced airflow through packed produce by the pressure differential technique.

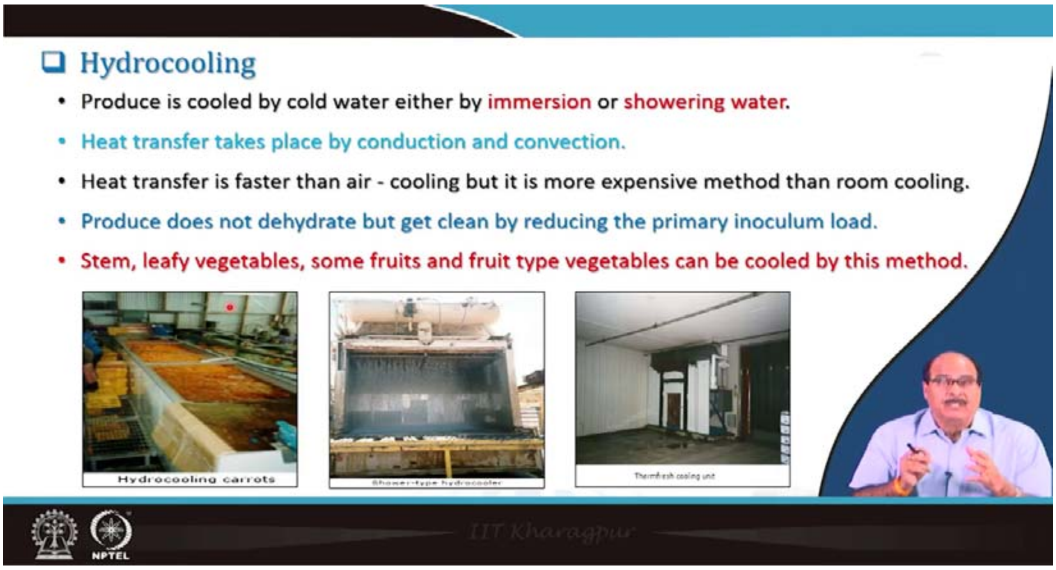
Forced horizontal air flow

In a horizontal flow system, the air is forced to flow horizontally from one side of the pallet load to the other through holes in the sides of the pallet bin or containers. Only two sides that are opposite can be open in the pallet bin or containers.

Forced vertical air flow

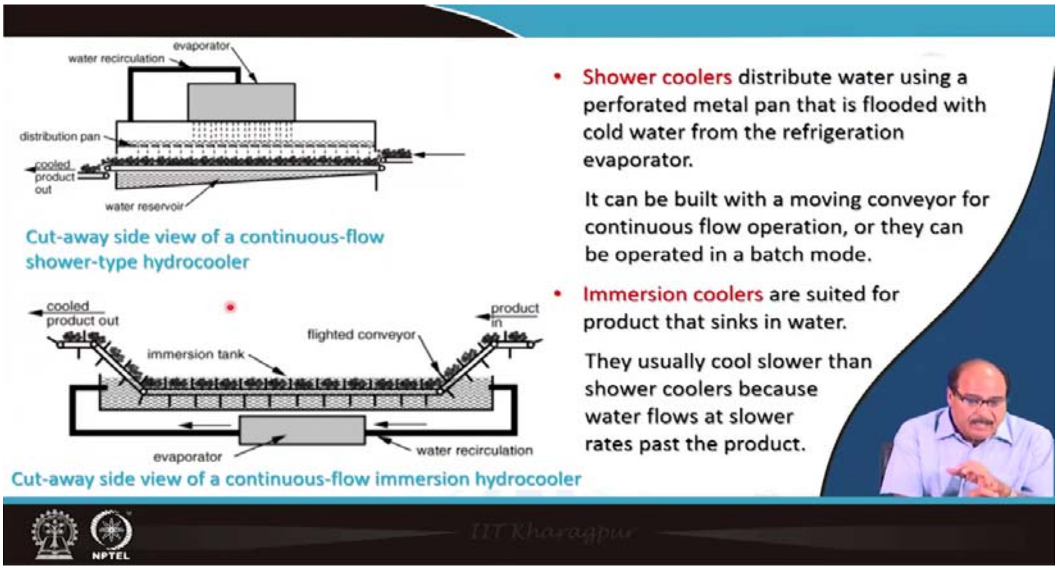
In a vertical flow system, the air is forced to flow vertically from the bottom to the top of the pallet through holes in the bottom of the pallet, and containers if used, then out the top. In this system, the sides must be sealed to prevent the air from bypassing the produce.





Hydro cooling

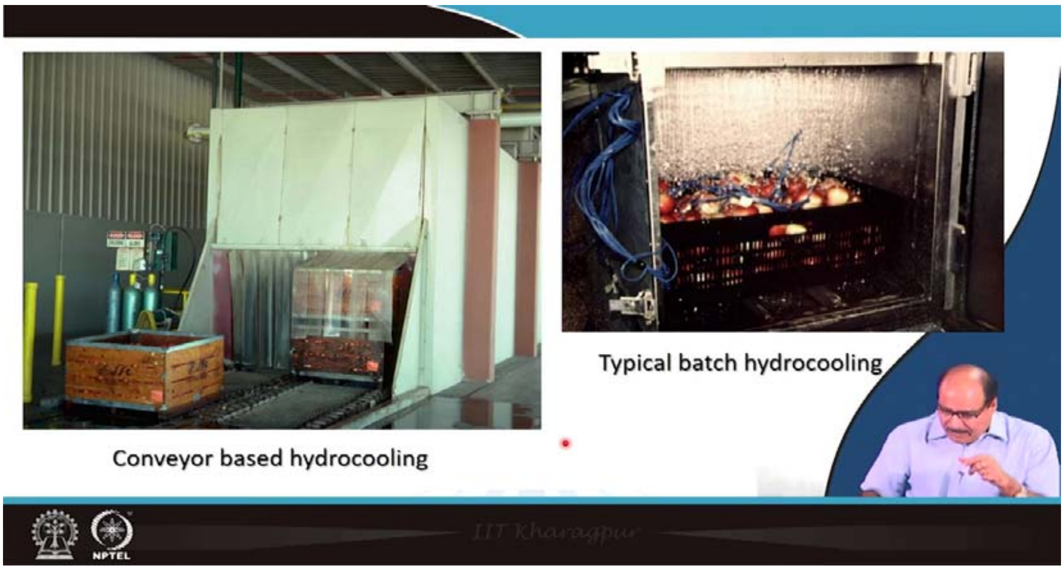
The produce is cooled by cold water either by immersion or showering water. The heat transfer takes place by conduction and convection. In this method, heat transfer is faster than air cooling but it is more expensive method than the room cooling. Produce does not dehydrate but get clean by reducing the primary inoculum load. Stem, leafy vegetables some fruits and fruit type vegetables can be cooled by this method.



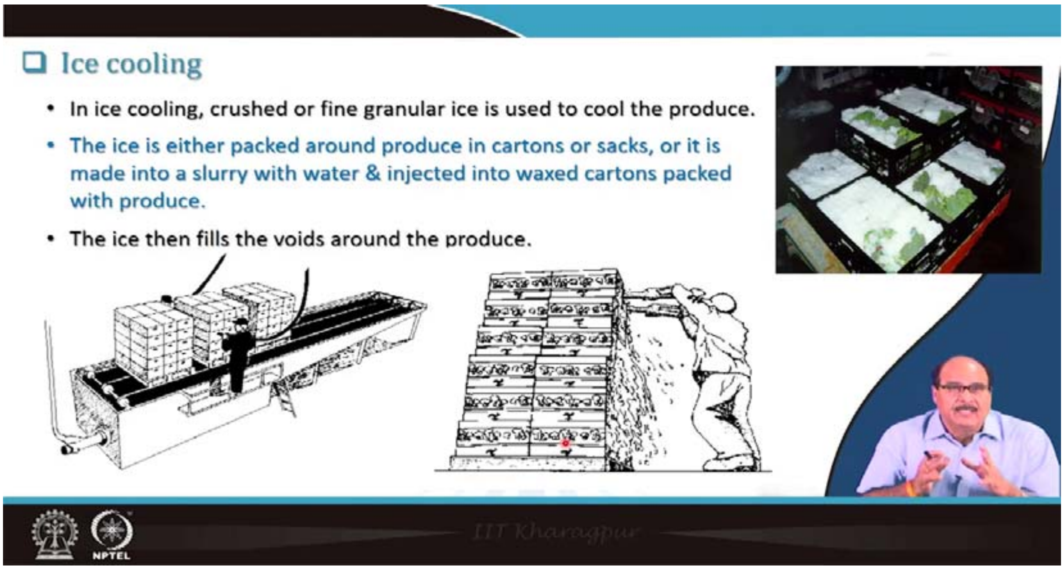
Continuous flow immersion hydro cooler

Shower coolers distribute water using a perforated metal pan that is flooded with cold water from the refrigeration evaporator. It can be built with a moving conveyor for continuous flow operation, or they can be operated in a batch mode.

Immersion coolers are suited for product that sinks in water. They usually cool slower than shower coolers because water flows at slower rates past the product.

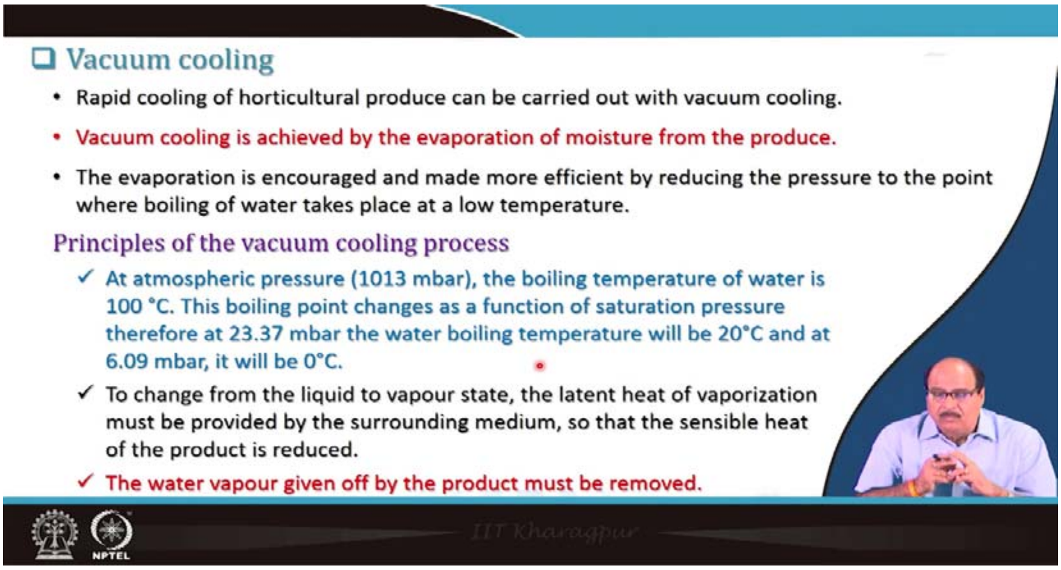


These are some of the photographs of conveyor based hydro cooling or typical batch hydro cooling.



Ice cooling

In ice cooling the crust or fine granular ice is used to cool the produce. The ice is either packed around the produce in cartoons or sacks or it is made into a slurry with water and injected into waxed cartoons packed with the produce. The ice then fills the voids around the produce and the heat transfer takes place to cool the material.

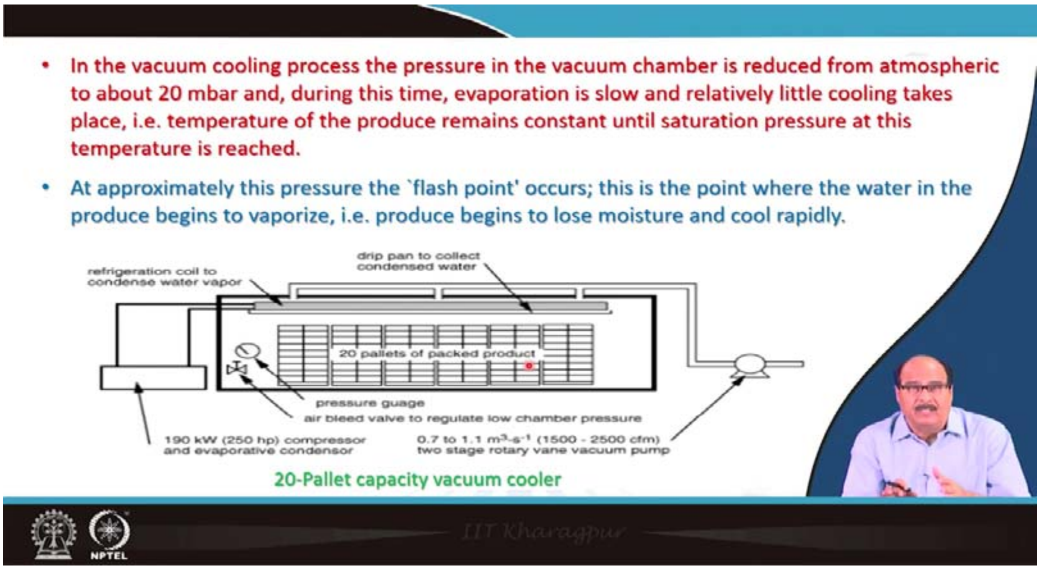


Vacuum cooling

Rapid cooling of horticultural produce can be carried out with the vacuum cooling. Vacuum cooling is achieved by the evaporation of moisture from the produce. The evaporation is encouraged and made more efficient by reducing the pressure to the point where boiling of water takes place at low temperature.

Principle of vacuum cooling

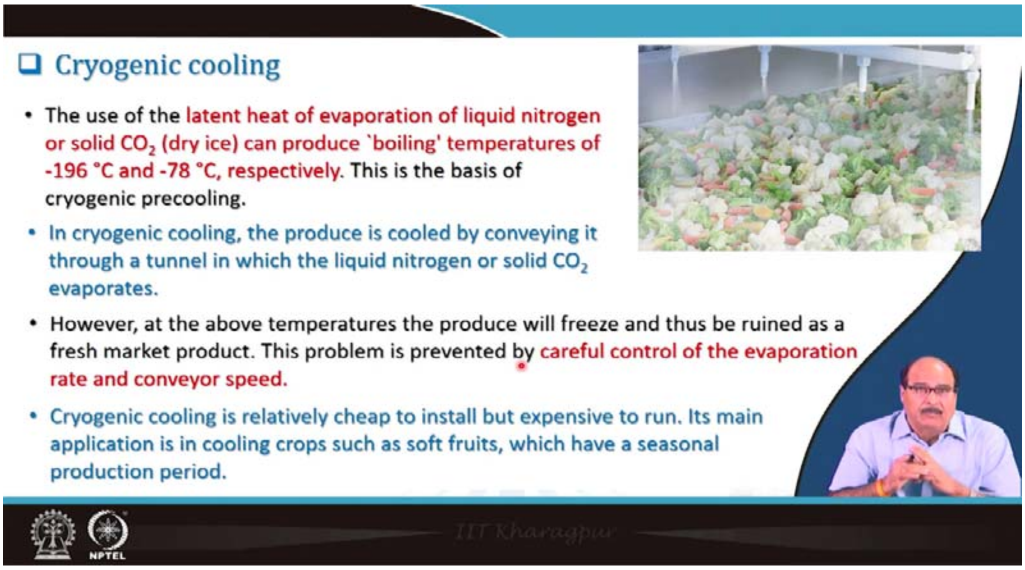
At atmospheric pressure (1013 mbar), the boiling temperature of water is 100 °C. This boiling point changes as a function of saturation pressure therefore at 23.37 mbar the water boiling temperature will be 20 °C and at 6.09 mbar, it will be 0 °C. To change from the liquid to vapour state, the latent heat of vaporization must be provided by the surrounding medium, so that the sensible heat of the product is reduced. The water vapour given off by the product must be removed for efficient cooling.

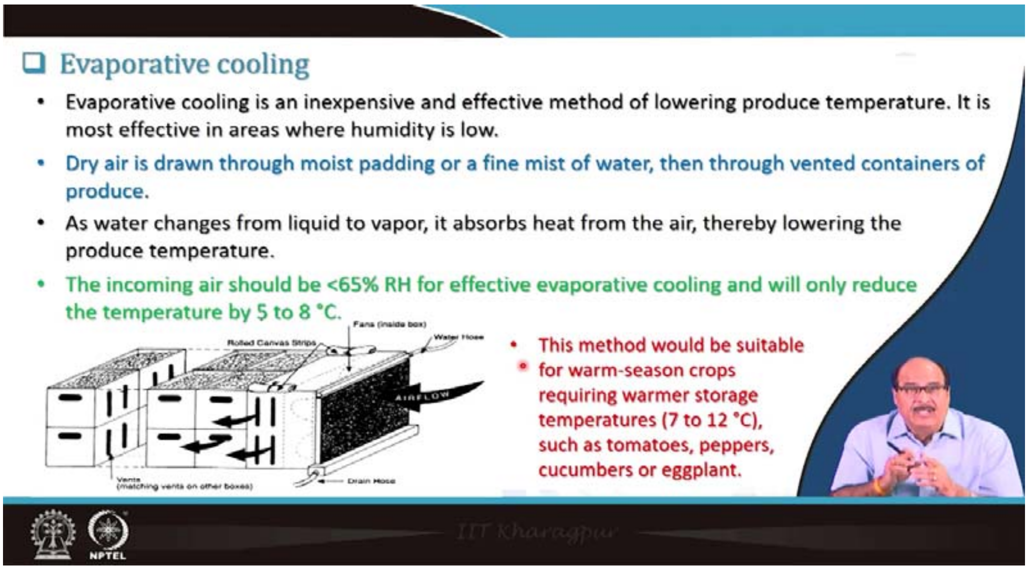


In the vacuum cooling process, the pressure in the vacuum chamber is reduced from atmospheric to about 20 mbar and during this time, the evaporation is slow and relatively little cooling takes place, i.e. temperature of the produce that remains constant until saturation pressure at this temperature is reached. At approximately this pressure the 'flash point' occurs, this is the point where the water in the produce begins to vaporize where the produce begins to lose moisture and cooled rapidly.

Cryogenic cooling

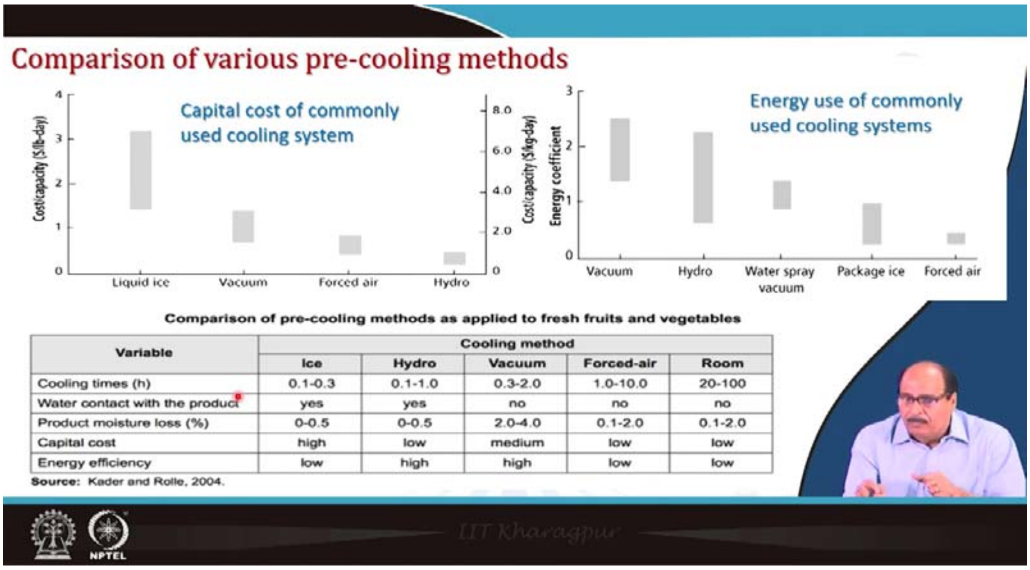
The use of the latent heat of evaporation of liquid nitrogen or solid CO_2 (dry ice) can produce `boiling' temperatures of -196 °C and -78 °C, respectively. This is the basis of cryogenic precooling. In cryogenic cooling, the produce is cooled by conveying it through a tunnel in which the liquid nitrogen or solid CO_2 evaporates. However, at the above temperatures the produce will freeze and thus be ruined as a fresh market product. This problem is prevented by careful control of the evaporation rate and conveyor speed. Cryogenic cooling is relatively cheap to install but expensive to run. Its main application is in cooling crops such as soft fruits, which have a seasonal production period.





Evaporative cooling

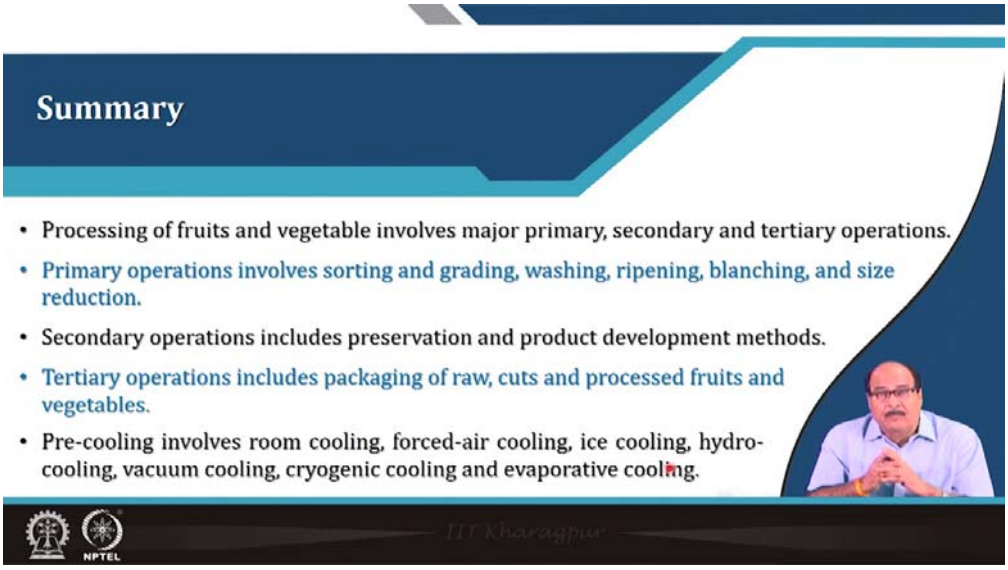
It is an inexpensive and effective method of lowering produce temperature. It is most effective in the areas where humidity is low. Dry air is drawn through moist padding or a fine mist of water then through the vented containers of the produce. As water changes from liquid to vapour, it absorbs heat from the air and thereby lowers the produce temperature. The incoming air should be < 65% relative humidity (RH) for effective evaporative cooling. This method will only reduce the temperature by 5 to 8 ℃. Therefore, this method would be suitable for the warm season crops which require warmer storage temperatures (7 to 12 ℃), such as tomatoes, peppers, cucumbers, or eggplant.



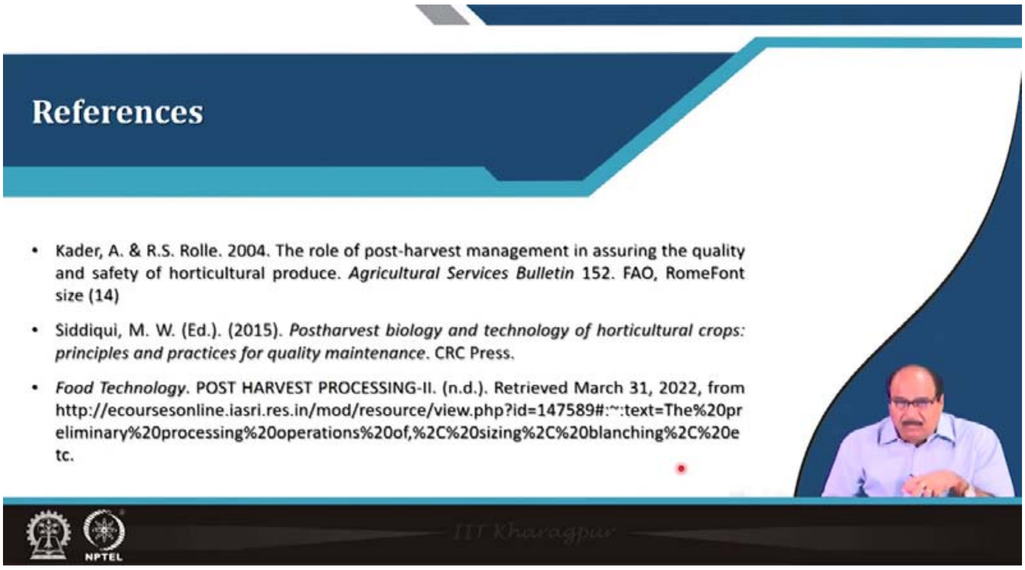
Comparison of various pre cooling methods

In view of the capital cost of commonly used cooling system, liquid ice cooling has the highest cost, followed by vacuum cooling, forced air cooling and hydro cooling.

From the energy-use point of view, vacuum cooling uses maximum energy followed by hydro cooling, water spray vacuum, then packaging ice and forced air. Depending on the load of the material, hydro cooling takes 0.1 to 1 h, ice cooling takes 0.1 to 0.3 h, vacuum cooling takes 0.3 to 2.0, forced-air cooling takes 1 to 10 h and cooling at room temperature takes 20 to 100 h. Amongst all methods, hydro cooling and vacuum cooling has the highest energy efficiency.



In summary, the processing of fruits and vegetables involves major primary, secondary and tertiary operations. Primary operations involve sorting, grading, washing, ripening, blanching and size reduction. Secondary operations include preservation and product development methods. Tertiary operations include packaging of raw, cut and processed fruits and vegetables. Pre-cooling involves the cooling room cooling, forced-air cooling, ice cooling, hydro cooling, vacuum cooling, cryogenic cooling, and evaporative cooling. It is an important operation to reduce the heat to lower down the metabolic activity so that the material is delivered to the processing plant or to the market in the desired state of quality and value.



These are the references for further study lecture. Thank you.