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

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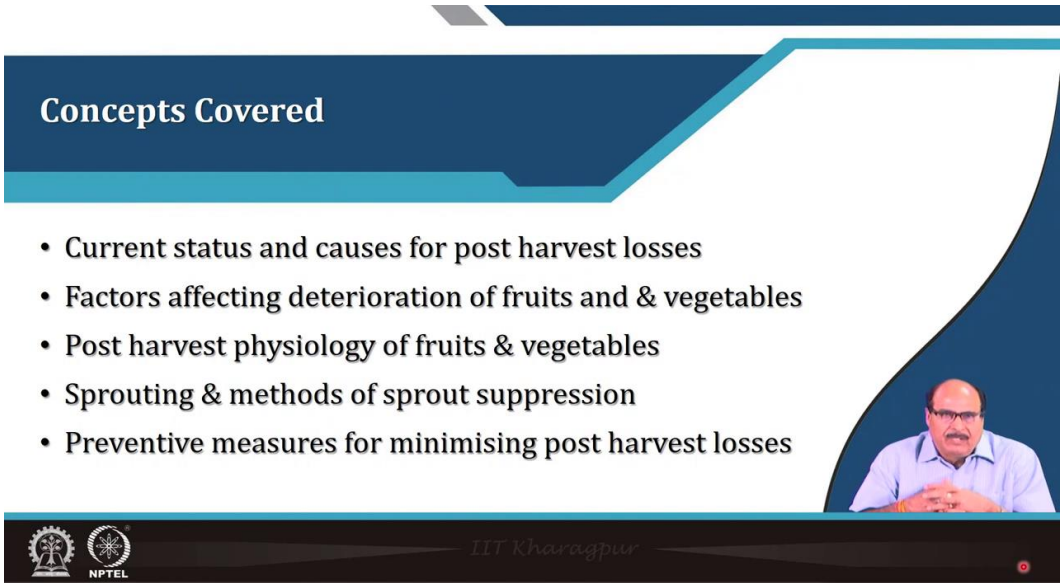
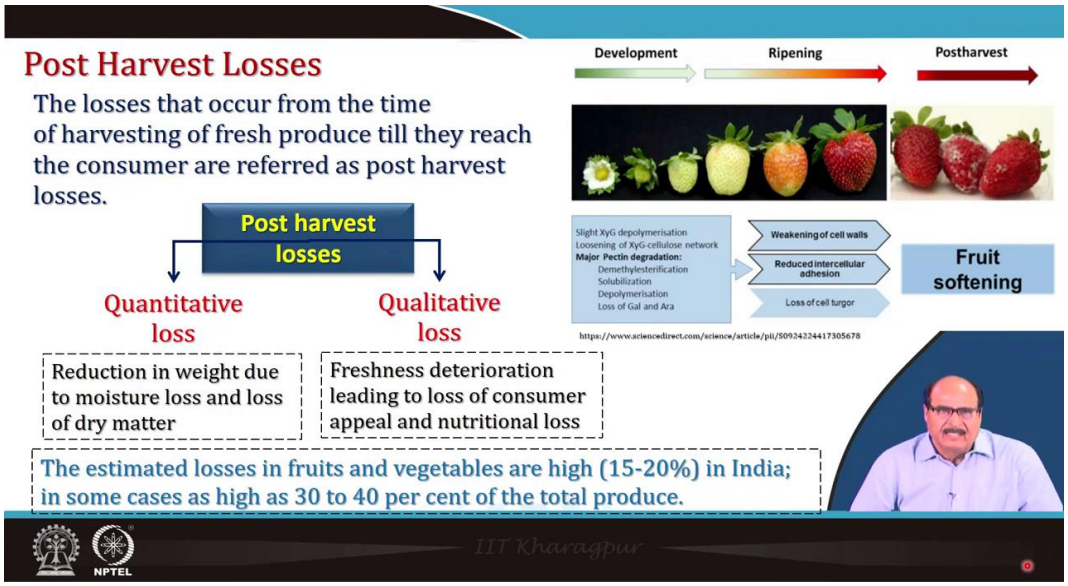
Lecture 06
Post-Harvest Losses, Causes and Preventive Measures

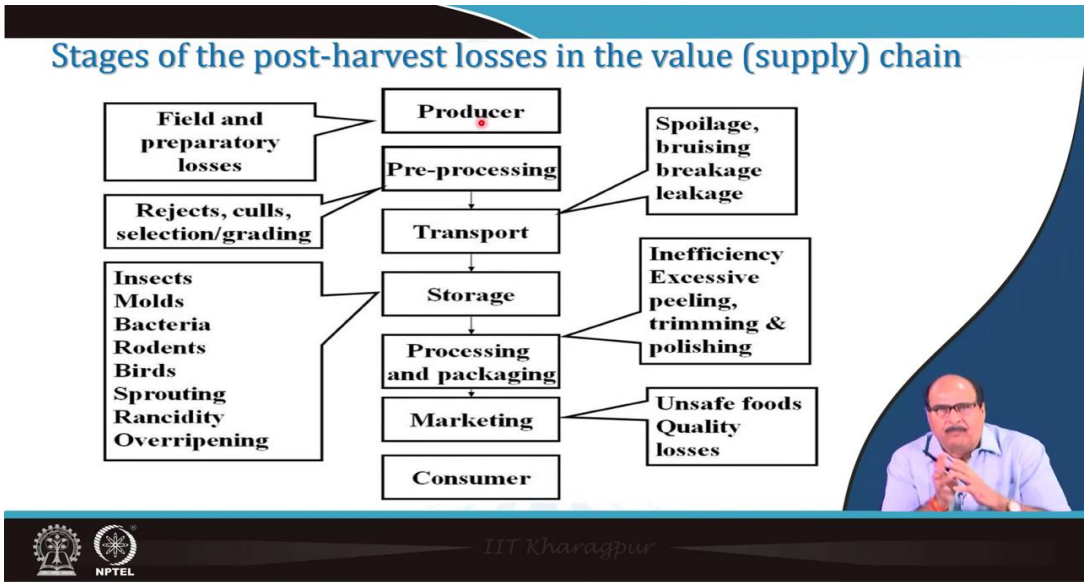
The concepts that has been covered in this lecture include current status and causes of post-harvest losses, factors affecting deterioration of fruits and vegetables, post-harvest physiology of fruits and vegetables, sprouting and methods of sprout suppression, and the preventive measures for minimizing the post-harvest losses.





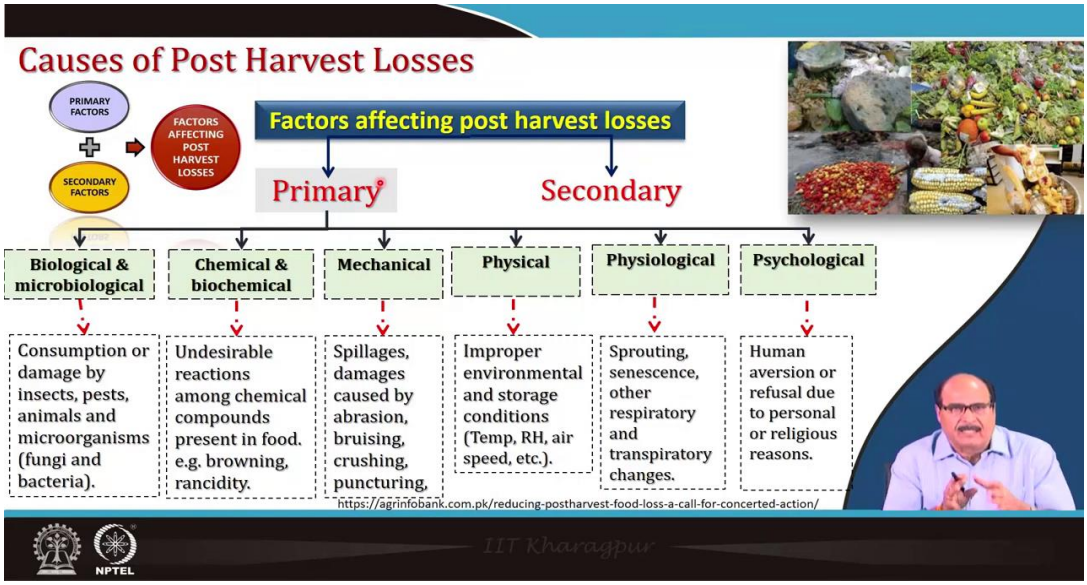
Post-harvest losses

The losses that occur from the time of harvesting of fresh produce till they reach the consumer are referred as post-harvest losses. Post-harvest losses may be quantitative loss like reduction in the weight due to moisture loss or loss of the dry matter in the value chain, or it may refer to the qualitative loss i.e. the freshness deterioration leading to loss of consumer appeal and the nutritional losses. The estimated losses in the fruits and vegetables are very high (15-20%) in India; in some cases as high as 30 to 40% of the total produce.



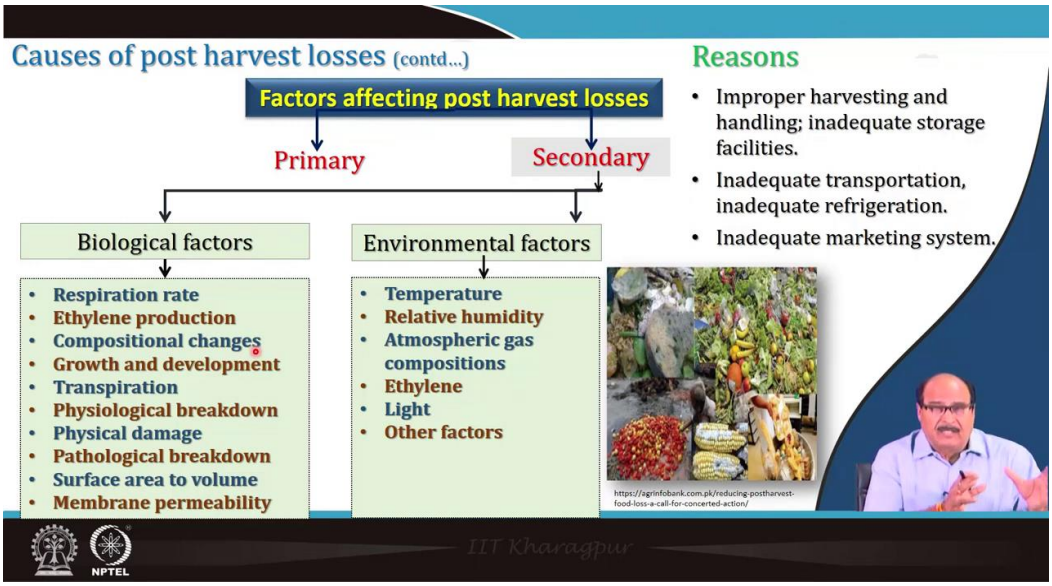
Stages of the post-harvest losses in the supply chain

It starts from the production point (various field and preparatory losses), then in the pre-processing stage, the rejects, culls, selection/grading causing losses. During transportation there may be spoilage, bruising, breakage, leakage that also result to significant amount of losses of the produce. Then during the storage, the loss may be due to various reasons like insect attack, molds, bacteria, rodents, birds or there may be sprouting of the material, rancidity, over ripening etc. All these factors may lead to the losses during the storage of the produce particularly if the storage conditions are not properly met. Then during processing and packaging, there may be inefficiency or excessive peeling, trimming, and polishing or other operations they also may result in the loss depending upon how the various operations are managed during processing and packaging. There is a significant amount of loss during marketing including unsafe foods, quality losses and some losses also occur at the consumer level.



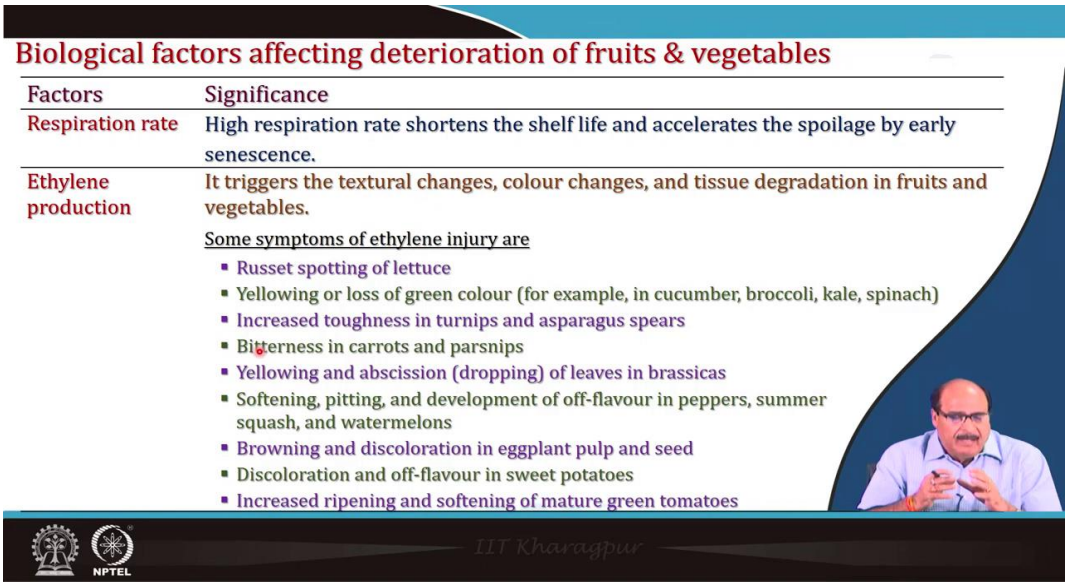
Causes of post-harvest losses

Causes of the post-harvest losses may be due to the primary and secondary factors. Primary factors include biological and microbiological factors (i.e. consumption of produce or damage of the produce by insects, pests, animals and microorganisms like fungi and bacteria), chemical and biochemical factors or undesirable chemical and biochemical reactions among chemical compounds present in food (e.g. browning, rancidity), mechanical factors (e.g. spillages, damages caused by abrasion and bruising, crushing, puncturing), physical factors (i.e. improper environmental and storage conditions like temperature, relative humidity, air speed), physiological factors (like sprouting, senescence or other respiratory and transpiratory changes), psychological factors (like human aversion or refusal due to personal or religious reasons).



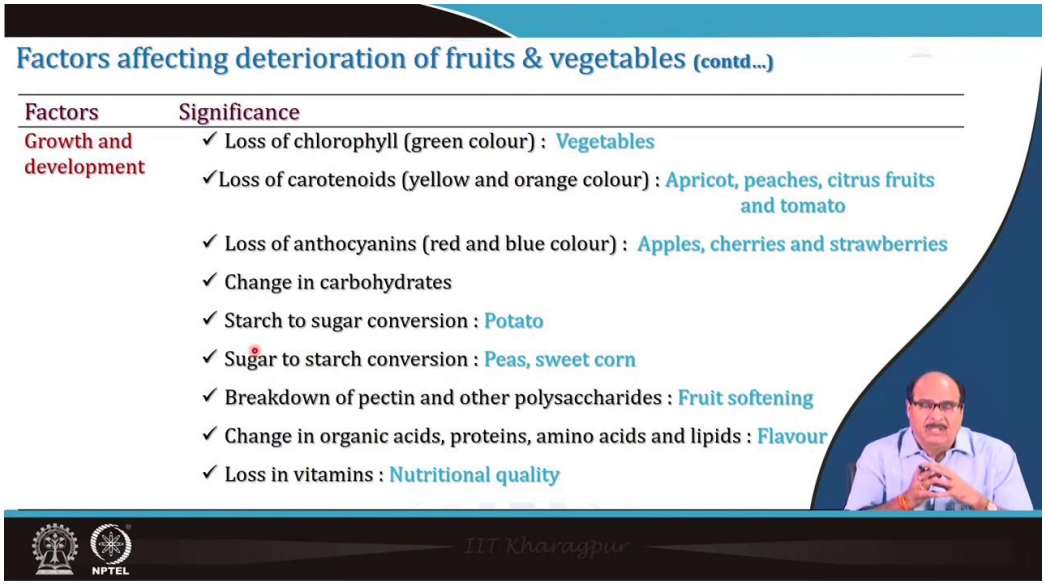
The secondary factors affecting the post-harvest losses include biological factors (like respiration rate, ethylene production, compositional changes, changes during growth and development, transpiration, physiological breakdown, physical damage, pathological break

down, surface area to volume, membrane permeability of the material), and environmental factors (like temperature, relative humidity, composition of the atmospheric gases, ethylene, light and other factors). The primary reasons behind the losses are improper harvesting and handling, inadequate storage facilities, inadequate transportation, inadequate refrigeration and inadequate supply chain and marketing system. These are the major causes of the post-harvest losses.



Biological factors affecting deterioration of fruits & vegetables

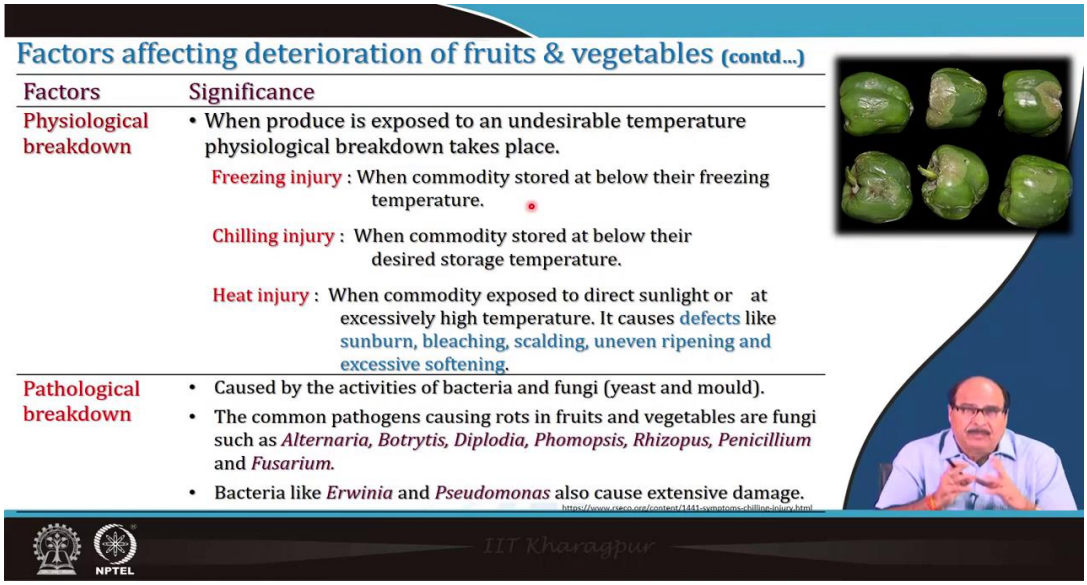
Respiration rate is an important biological factor. High respiration rate shortens the shelf life and accelerates the spoilage by early senescence. The production of ethylene triggers the textural changes, colour changes, and tissue degradation in fruits and vegetables. Some symptoms of ethylene injury are russet spotting of lettuce, yellowing or loss of green colour (for example, in cucumber, broccoli, kale, spinach), increased toughness in turnips and asparagus spears, bitterness in carrots and parsnips, yellowing and abscission (dropping) of leaves in brassicas, softening, pitting, and development of off-flavour in peppers, summer squash, and watermelons, browning and discoloration in eggplant pulp and seed, discoloration and off-flavour in sweet potatoes, and increased ripening and softening of mature green tomatoes etc.



Similarly, during growth and the development of the produce, there may be some changes, which may lead to the some quality or quantity loss like there may be loss of green colour or loss of chlorophyll in the vegetables; loss of carotenoids like yellow and orange colour in the case of apricot, peaches, citrus fruit and tomato; loss of anthocyanins (red and blue colour) in case of apple, cherries and strawberries; changes in the carbohydrate may takes place during growth and development stage like starch is converted into sugar (potato); sugar to starch conversion (peas, sweet corn); breakdown of pectin and other polysaccharides in fruit softening; change in organic acids, proteins, amino acids and lipids may lead to the undesirable changes in the flavour of the commodity; loss of vitamin, which will degrade the nutritional quality of the food.

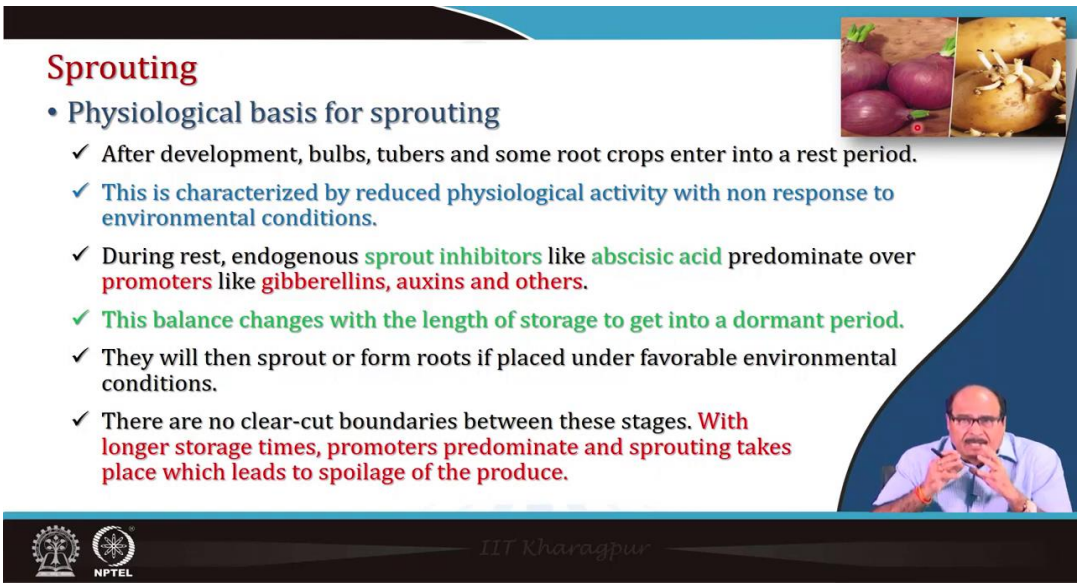
Compositional changes in some commodities during the growth and development continues even after harvest and which accelerate deterioration. For example, sprouting of potato, onion and garlic during storage, fresh routing of onions or harvested crop continues to grow even after harvest, which is very much evident in asparagus, there is increase in the volume in lettuce. So, these changes result into the significant qualities and other changes of the produce. Heavy transpiration causes loss in weight, loss in appearance like wilting, shrivelling of the produce. There may be loss in the textural quality there may be softening or loss of crispiness and juiciness of the product.

Physical damage like mechanical injury or cut during harvesting, handling, storage transportation etc. may result into the loss of the produce. Bruising due to vibration (during transportation), impact if the uncontrolled or improper dropping or there maybe compression if there is overfilling of the material. So, all these factors may result in the damage of the produce.



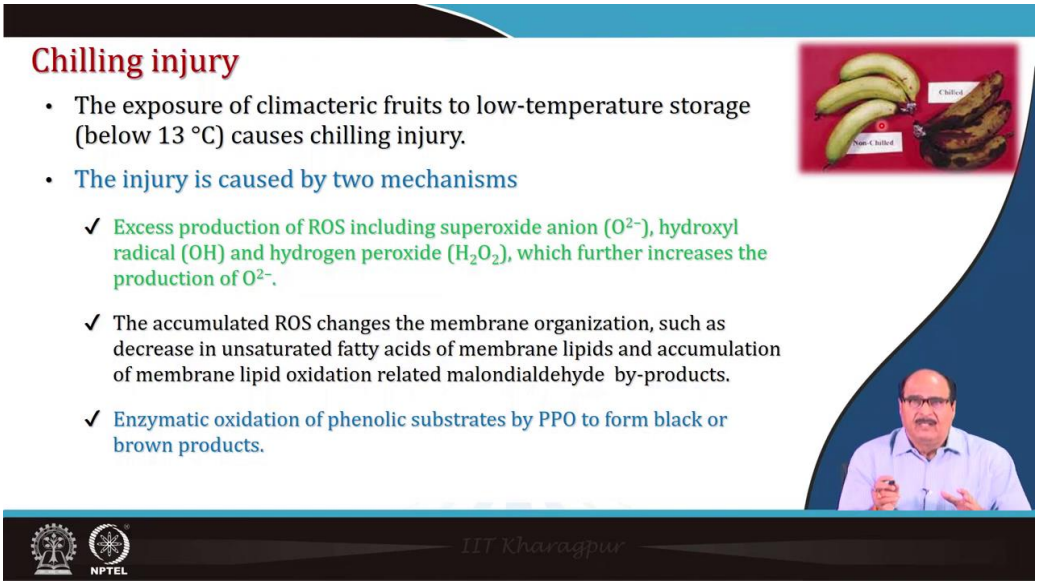
Physiological breakdown particularly when the produce is exposed to an undesirable temperature. For example, freezing injury occurs when the commodity is stored at below its freezing point temperature. Chilling injury is due to when the commodity is stored at below their desired storage cool storage temperature then it may result in the different spot which is a common problem in the community like banana. The heat injuries occurs when commodity is exposed to direct sunlight or at excessively high temperature, it causes defects like sunburn, bleaching, scalding, uneven ripening, excessive softening.

Pathological breakdown may be caused by the activities of bacteria and fungi (yeast and mould), particularly the fruits and vegetables because of their nature, they are more prone to attack by bacteria due to the high sugar content.The common pathogens causing rots in fruits and vegetables are fungi such as *Alternaria*, *Botrytis*, *Diplodia*, *Phomopsis*, *Rhizopus*, *Penicillium* and *Fusarium*. Bacteria like *Erwinia* and *Pseudomonas* also cause extensive damage.



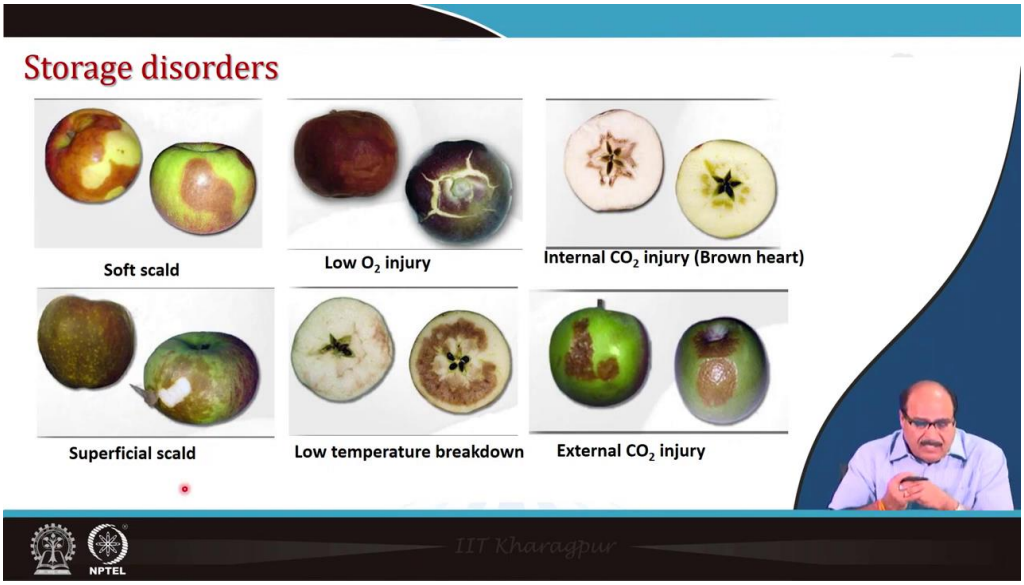
Sprouting

Physiological basis for sprouting i.e. after development, bulbs, tubers and some root crops enter into a rest period. This is characterized by reduced physiological activity with non-response to environmental conditions. During rest, endogenous sprout inhibitors like abscisic acid predominate over promoters like gibberellins, auxins and others. This balance changes with the length of storage to get into a dormant period. They will then sprout or form roots if placed under favorable environmental conditions. There are no clear-cut boundaries between these stages. With longer storage times, promoters predominate and sprouting takes place which leads to spoilage of the produce.

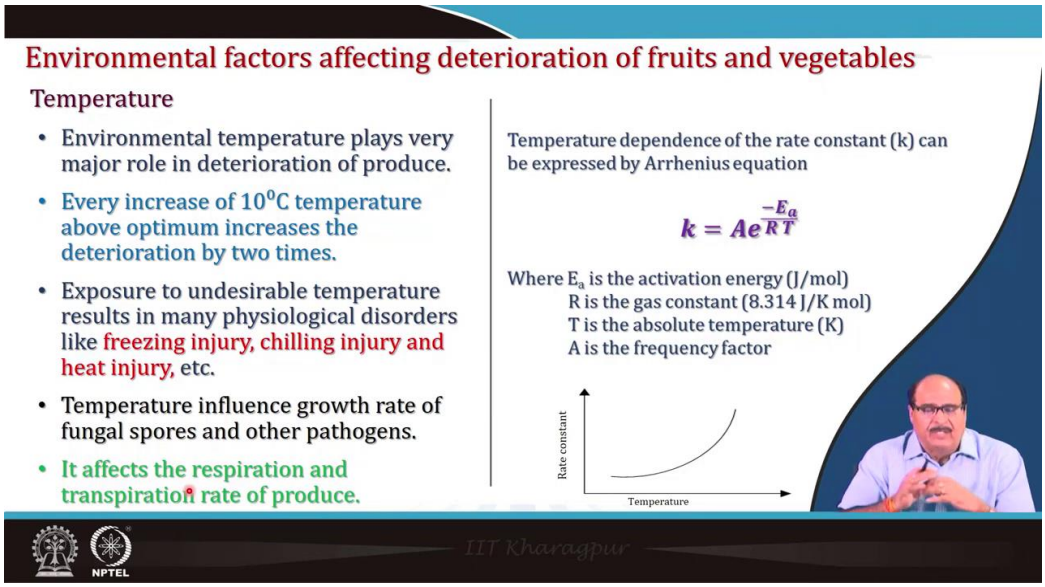


Chilling injury

The exposure of climacteric fruits to low-temperature storage (below 13 °C) causes chilling injury. The injury is caused by two mechanisms. These include excess production of ROS including superoxide anion ($O2^{-}$), hydroxyl radical (OH) and hydrogen peroxide (H_2O_2), which further increases the production of $O2^{-}$. The accumulated ROS changes the membrane organization, such as decrease in unsaturated fatty acids of membrane lipids and accumulation of membrane lipid oxidation related malondialdehyde by-products. Enzymatic oxidation of phenolic substrates by polyphenol oxidases (PPO) enzyme to form black or brown products.



The slide shows various major storage disorders in fruits and vegetables, which include soft scald, low O_2 injury, internal CO_2 injury, superficial scald, low temperature breakdown, and external CO_2 injury.



Environmental factors affecting deterioration of fruits and vegetables

Temperature

Environmental temperature plays very major role in deterioration of produce. Every increase of 10 ^{0}C temperature above optimum increases the deterioration by two times. Exposure to undesirable temperature results in many physiological disorders like freezing injury, chilling injury and heat injury, etc. Temperature influence growth rate of fungal spores and other pathogens. It affects the respiration and transpiration rate of produce.

Temperature dependence of the rate constant (k) can be expressed by the Arrhenius equation:

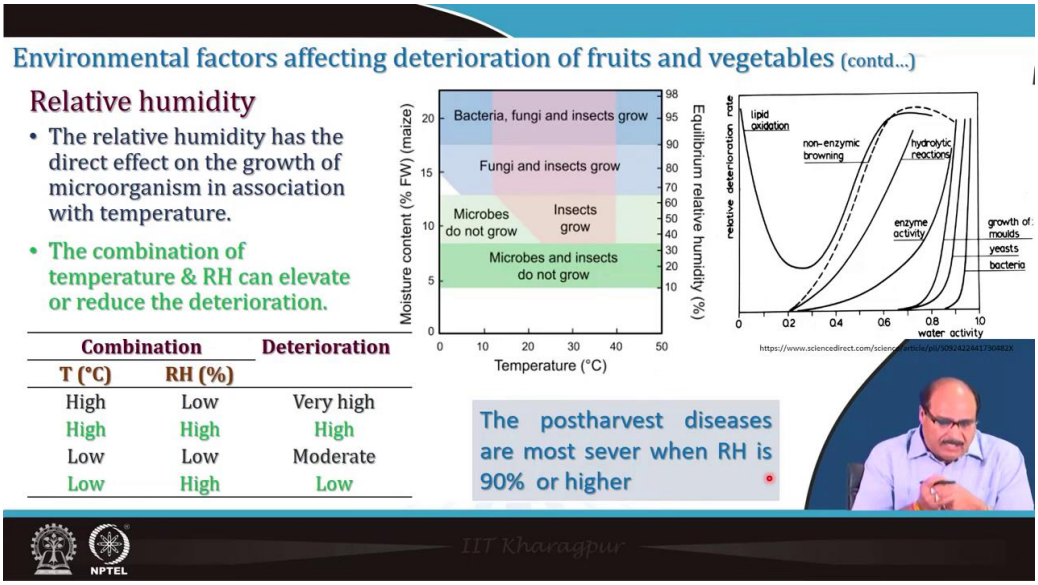
$$k = Ae^{-E_a/RT}$$

Where, E_a is the activity activation energy (J/mol)

R is the gas constant (8.314 J/K mol)

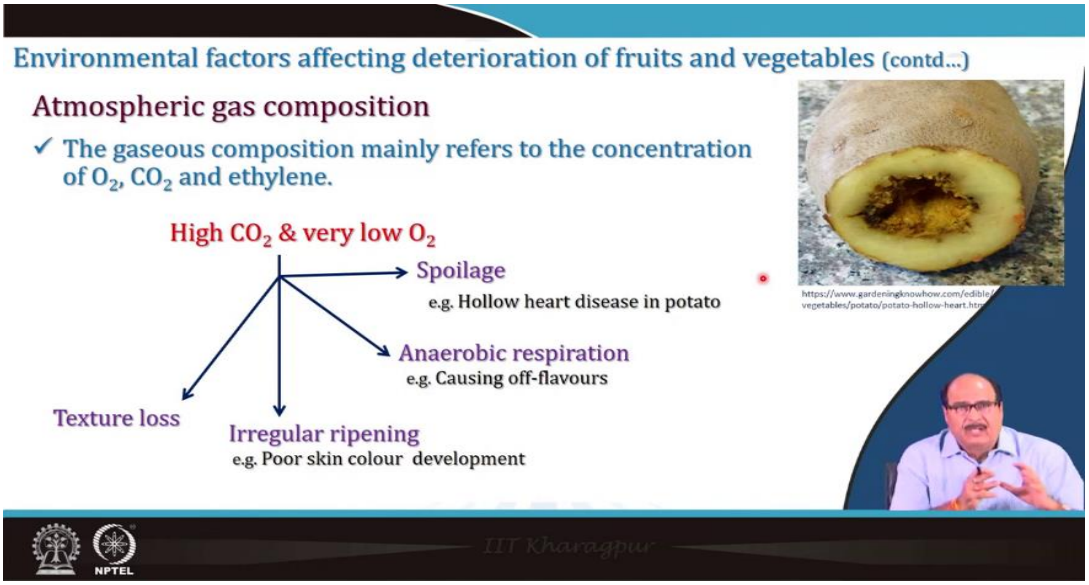
T is the absolute temperature (K)

A is the frequency factor

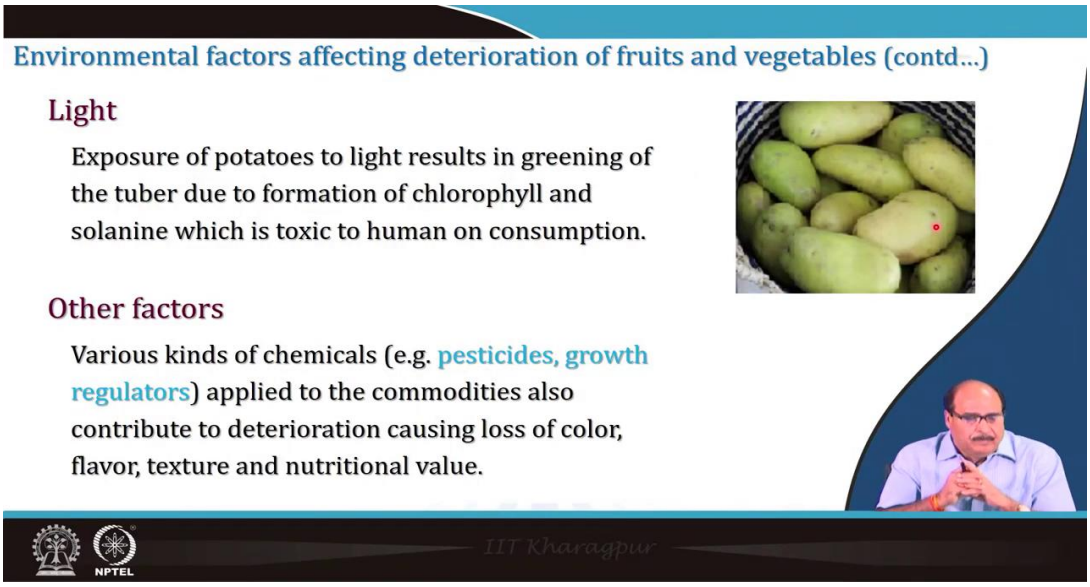


Relative humidity has the direct effect on the growth of the microorganism in association with the temperature. So, the combination of the relative humidity and temperature can elevate or reduce the deterioration. If the temperature is maintained at a higher level and relative humidity is low then deterioration will be very high. If the temperature and relative humidity both are high then the deterioration or spoilage will be high. If the temperature and relative humidity in the storage environment, there will be very less or moderate deterioration and spoilage. If the temperature is low, but relative humidity is high then this results into a less deterioration.

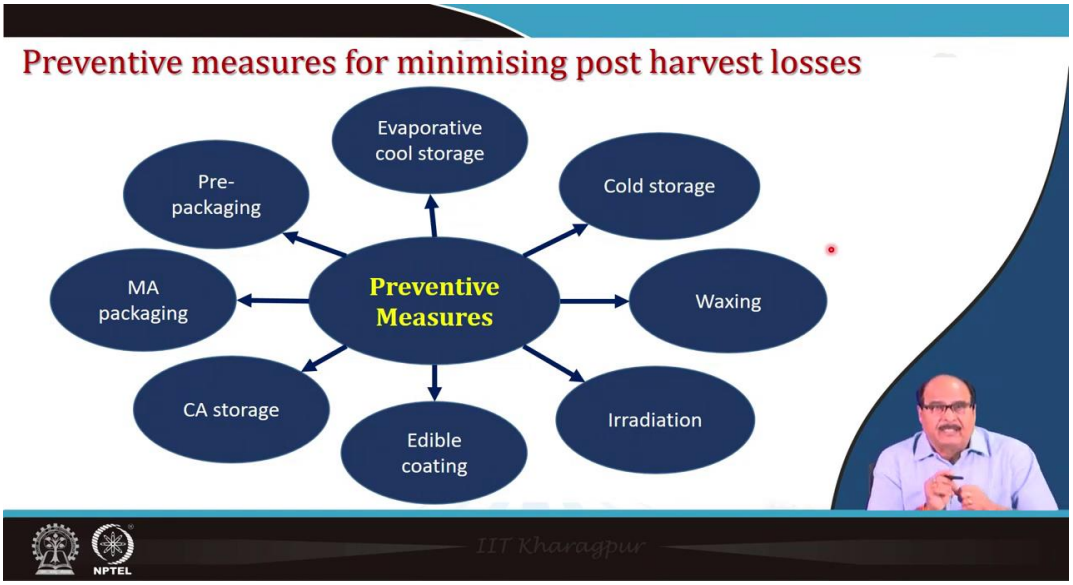
The figure shows the effect of moisture content, temperature, and relative humidity on the growth of bacteria, fungi, and insects as well as on the occurrence of biochemical reactions such as non-enzymatic browning, lipid oxidation, and hydrolytic reactions etc. It has been observed that the postharvest diseases are most severe when RH is 90% or higher.



The gaseous composition mainly refers to the concentration of O_2, CO_2, and ethylene. In CA/MA storage, modified atmosphere packaging, the concentration of CO_2 is kept high and concentration of O_2 is kept low. But mind it, it has to be optimum depending upon the respiratory behaviour of produce. So, there should be proper balance between O_2 and CO_2 concentrations. If there is a very high CO_2 or very low O_2, then there will be texture loss, irregular ripening like poor skin colour development, anaerobic respiration which may cause off flavour development, and spoilage like hollow heart disease in potato.

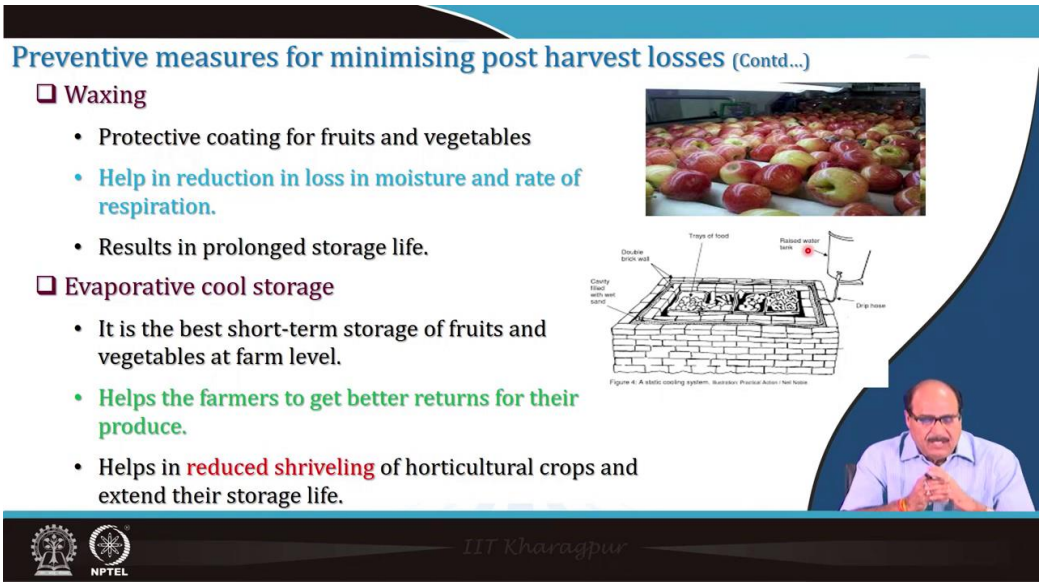


The exposure of potato to light results in greening of the tuber due to the formation of chlorophyll and solanine, which is the toxic to human on consumption. Other factors like various chemicals (pesticide, growth regulators) are applied to the commodities also contribute to deterioration causing loss of color, flavor, texture and nutritional value.



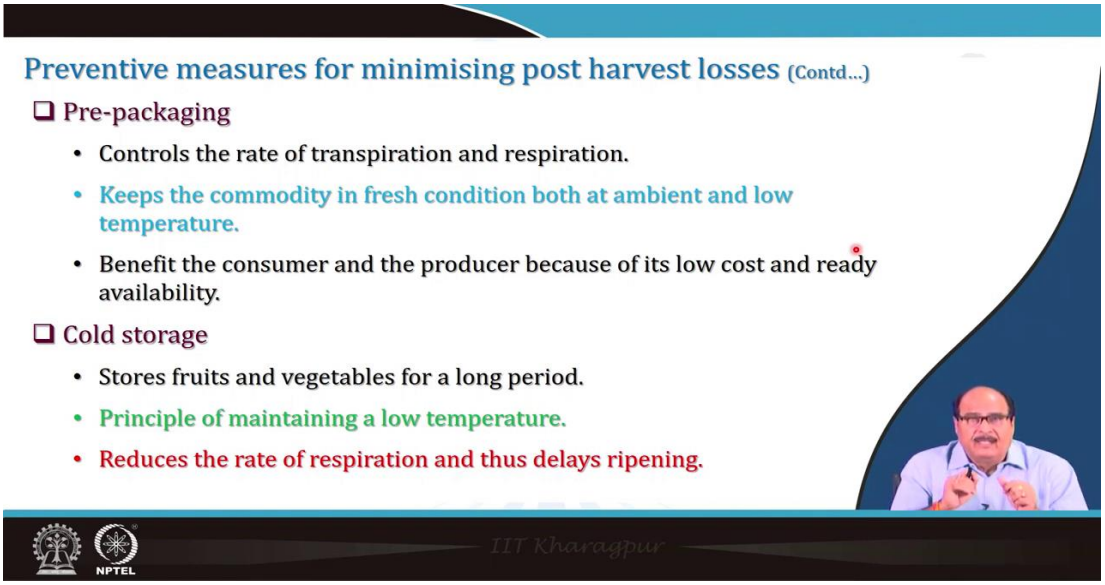
Preventive measures for minimising post-harvest losses

These involve: evaporative cool storage, waxing, irradiation, edible coating, control atmospheric storage, modified atmosphere packaging, pre-packing etc.



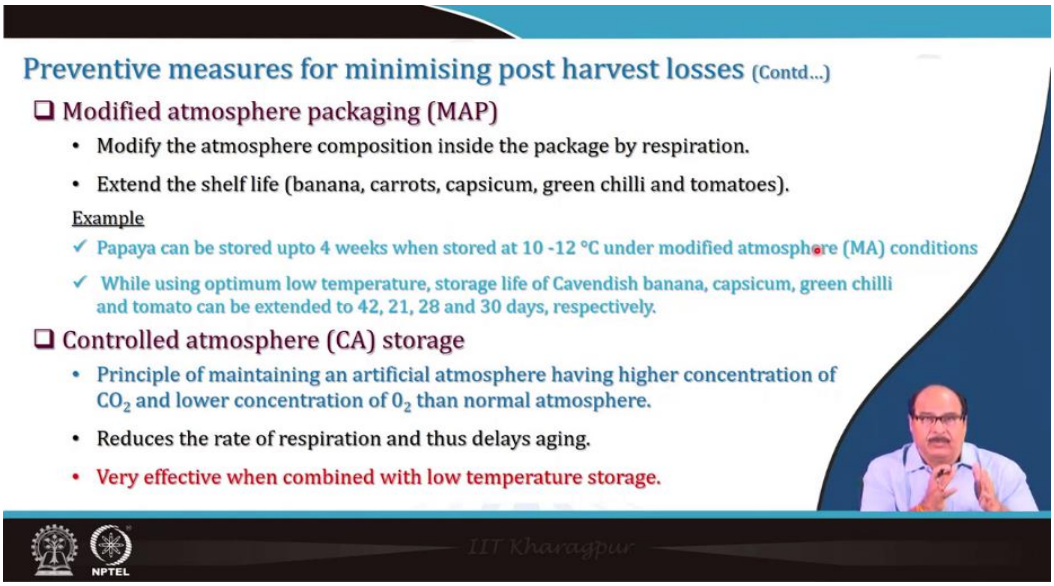
1. ***Waxing*:** protective coating for many of the fruits and vegetables and it helps in the reduction in loss of moisture and also reduces the rate of respiration. So, it results in prolonged storage life.

2. *Evaporative cool storage*: It is the best short-term storage of fruits and vegetables at farm level and helps the farmers to get better returns for their produce. It also helps in reduced shriveling of horticultural crops and extend their storage life.



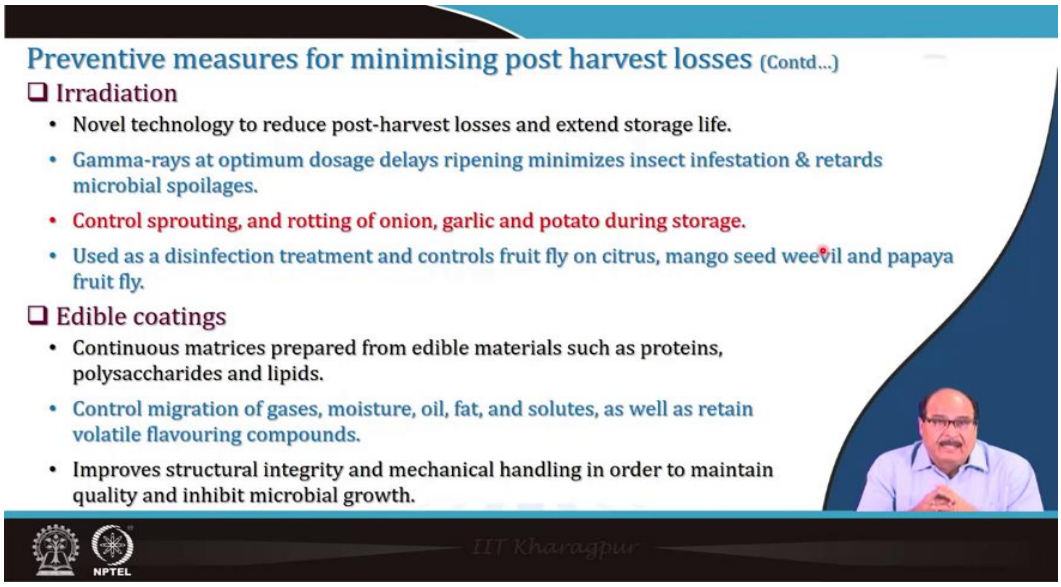
3. *Pre-packaging*: is another method that is which controls the rate of respiration and rate of transpiration and extends the self-life, it keeps the commodity in fresh condition both at ambient as well as at the low temperature. The pre-packaging benefits the consumer and the producer because of its low cost and ready availability.

4. *Cold storage*: it is a traditionally used practice for the prevention of post-harvest losses by storing the fruits and vegetable at low temperature because it lowers down the rate of respiration and transpiration. The principle of maintaining the cold storages principle of maintaining the lower temperature in the storage environment. It reduces the rate of respiration and delays the ripening.



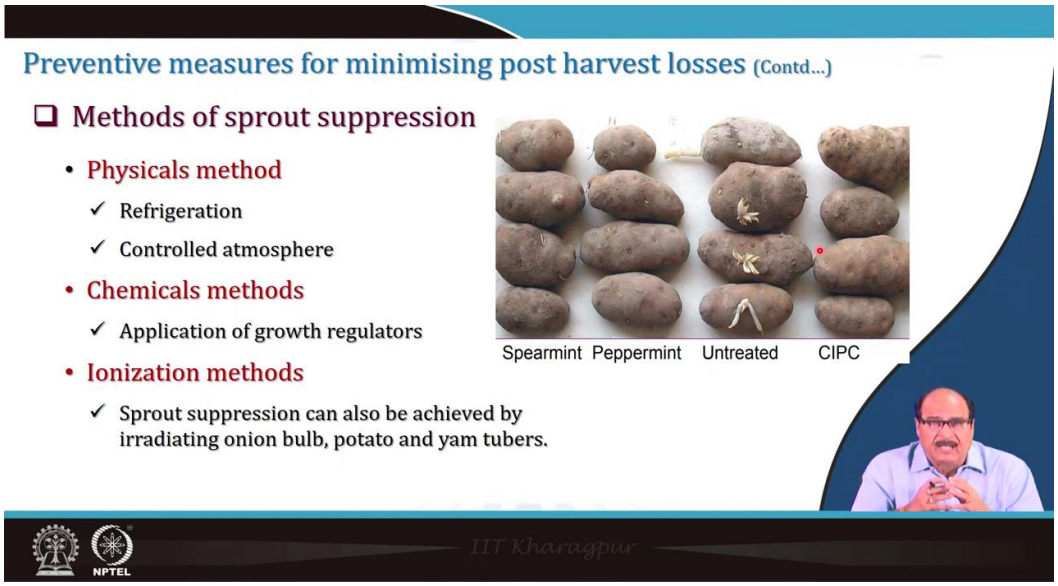
5. *Modified atmosphere packaging (MAP)*: modify the atmosphere composition inside the package by respiration. For example, Papaya can be stored up to 4 weeks when stored at 10 - 12 °C under modified atmosphere (MA) conditions. While using optimum low temperature, storage life of Cavendish banana, capsicum, green chilli and tomato can be extended to 42, 21, 28 and 30 days, respectively.

6. *Controlled atmosphere (CA) storage*: principle of maintaining an artificial atmosphere having higher concentration of CO_2 and lower concentration of O_2 than normal atmosphere, reduces the rate of respiration and thus delays aging. It is very effective when combined with low temperature storage.



7. *Irradiation*: It is a novel technology to reduce post-harvest losses and extend storage life. Gamma-rays at optimum dosage delays ripening, minimizes insect infestation and retards microbial spoilages, control sprouting, and rotting of onion, garlic and potato during storage. This process is used as a disinfection treatment and controls fruit fly on citrus, mango seed weevil and papaya fruit fly.

8. *Edible coating*: It involves continuous matrices prepared from edible materials such as proteins, polysaccharides and lipids. It is also effective for controlling the migration of gases, moisture, oil, fat, and solutes, as well as retaining volatile flavouring compounds. It improves structural integrity and mechanical handling in order to maintain quality and inhibit microbial growth.

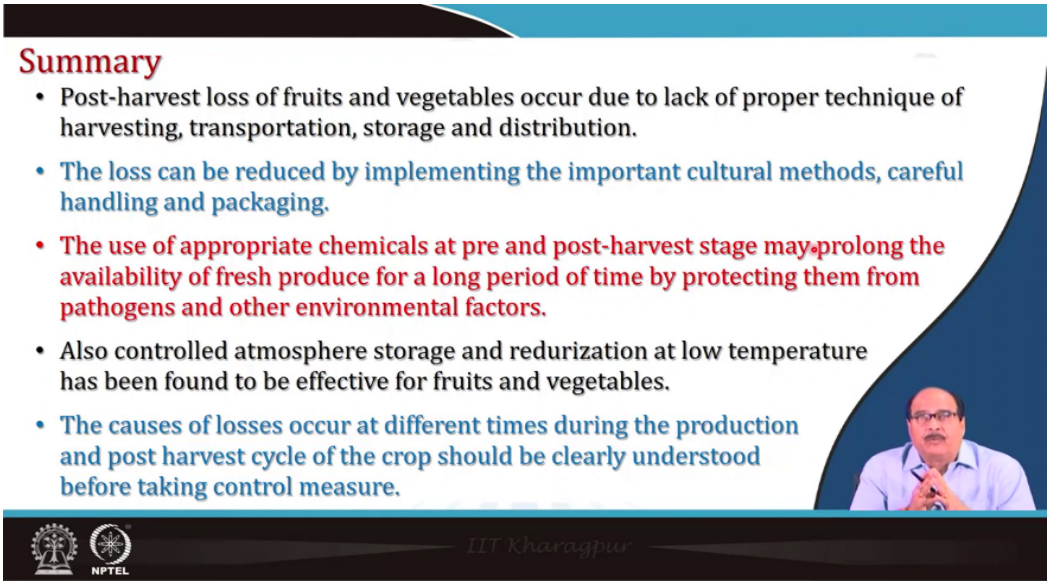


Methods for sprout inhibition

The methods for sprout inhibition are classified as physical (refrigeration, controlled atmosphere), chemical (application of growth regulators), and ionization (sprout suppression can also be achieved by irradiating onion bulb, potato and yam tubers) methods.

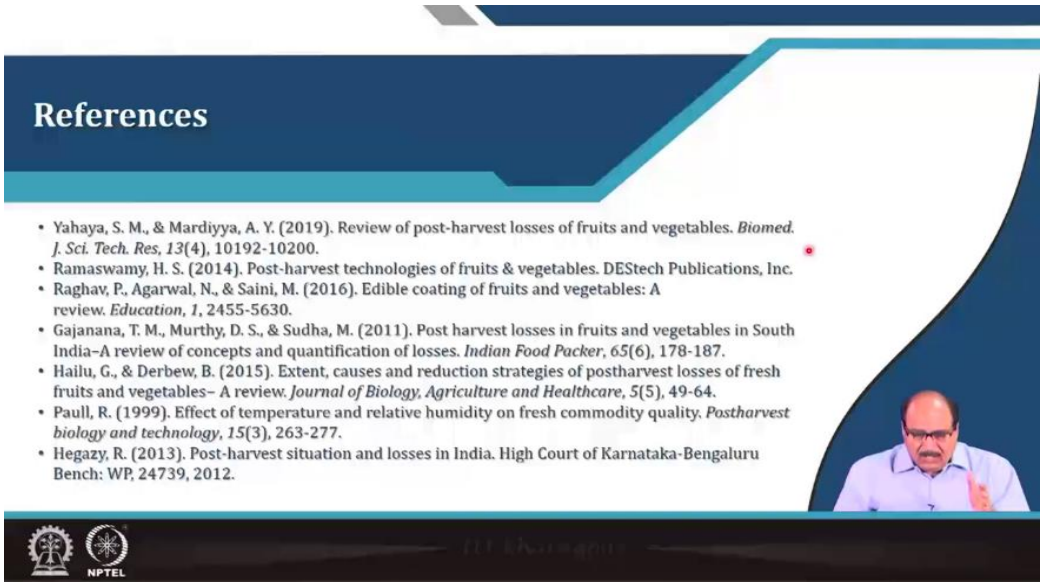
This slide emphasizes on the chemicals which are used to control spoilage and improve quality in fruits and vegetables such as sodium phenyl phenate for apple, hot water for mango and papaya, hypo chlorite for potato etc.

There are the chemicals which are used to extend the self-life and quality of the produce like in the case of mango, calcium nitrate (1%) and calcium (1-4%) for apples etc.



Summary

Post-harvest loss of fruits and vegetables occur due to lack of proper technique of harvesting, transportation, storage and distribution. The loss can be reduced by implementing the important cultural methods, careful handling and packaging. The use of appropriate chemicals at pre and post-harvest stage may prolong the availability of fresh produce for a long period of time by protecting them from pathogens and other environmental factors. Also controlled atmosphere storage and redurization at low temperature has been found to be effective for fruits and vegetables. The causes of losses occur at different times during the production and post-harvest cycle of the crop should be clearly understood before taking control measure.



These are the references for further study. Thank you.