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

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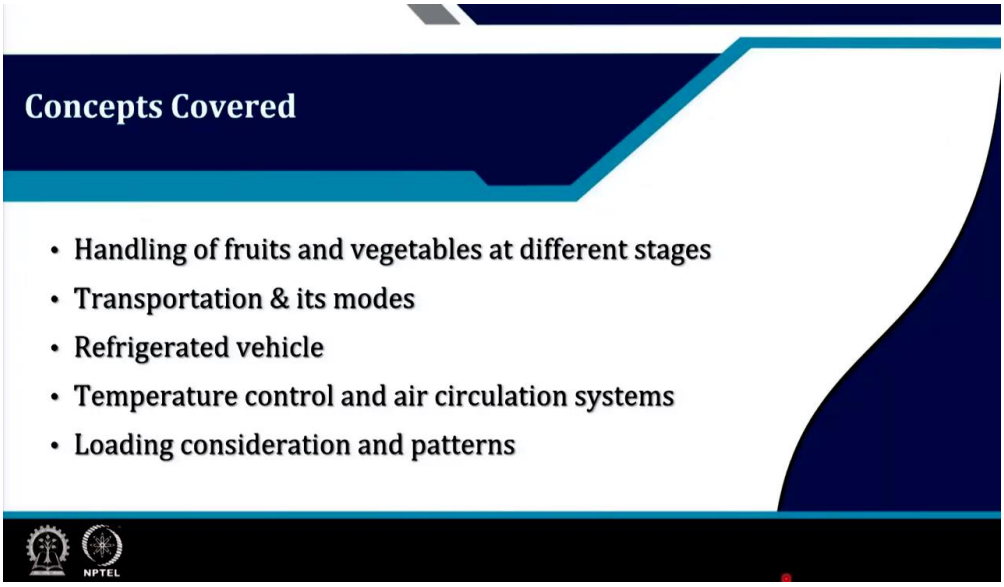
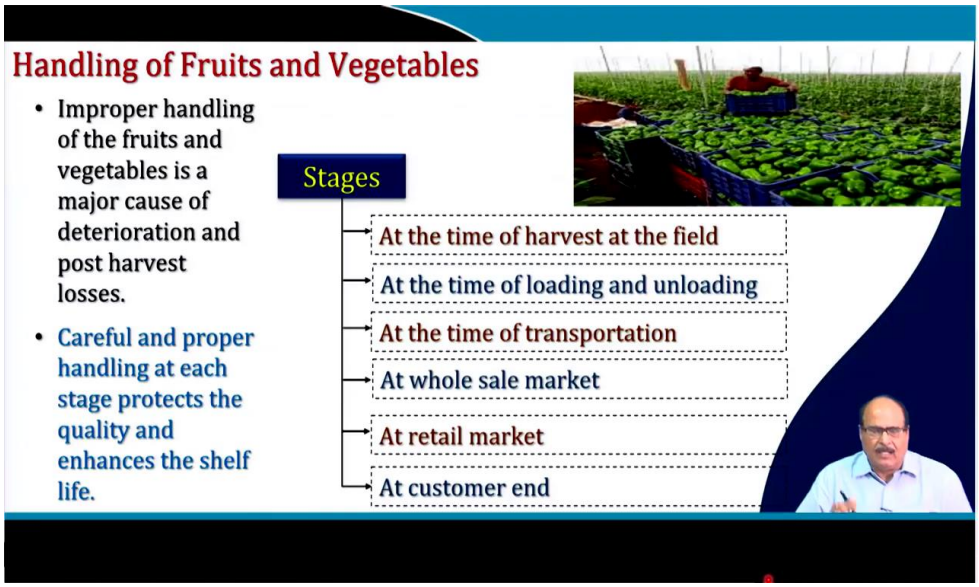
Lecture 08
Holding and Transportation

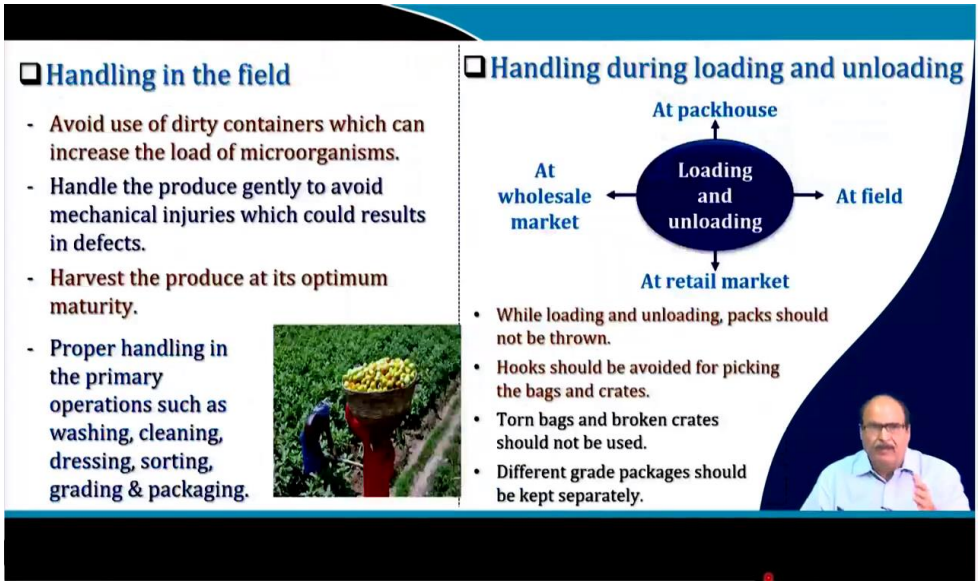


This lecture covers various issues related to handling and transportation of fruits and vegetables, handling of different fruits and vegetable at different stages, transportation and its various models, refrigerated vehicles, temperature control and air circulation systems in vehicle, and loading consideration and patterns with a view to prevent damage during the transportation and handling of the produce.



Handling of Fruits and Vegetables

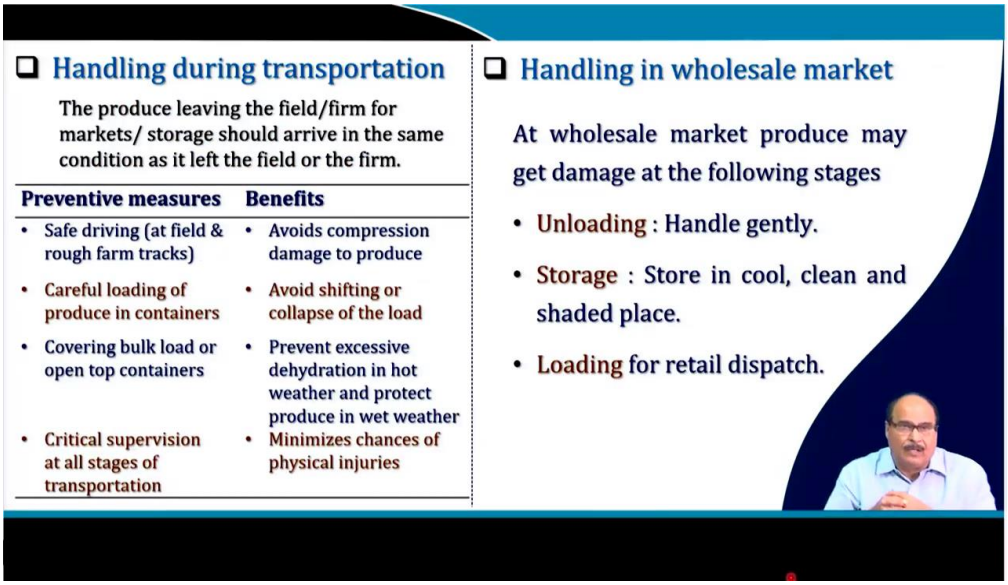
Improper handling of fruits and vegetables is the major cause of deterioration and post-harvest losses. So, careful and proper handling of the produce at each stage is necessary to protect its quality as well as enhance its shelf life. The different stages during the handling of the commodities are: (1) At the time of harvest at the field, (2) At the time of loading and unloading, (3) At the time of transportation, (4) At wholesale market, (5) At retail market, and (6) At the consumer end.



Handling in the field

The use of dirty containers which can increase the load of microorganisms should be avoided. The produce should be handled gently to avoid mechanical injuries which could results in defects. Harvesting of the produce should be done at its optimum maturity. Proper handling in the primary operations such as washing, cleaning, dressing, sorting, grading & packaging must be ensured. The handling during loading and unloading may be done at different places

like at the pack house, at the field, at the retail market or at the wholesale market. Some precautionary measures should be taken during loading and unloading such as the packs should not be thrown, the packets should be handled gently, hooks should be avoided for picking the bags and crates, torn bags and broken crates should not be used, and different grade packages should be kept separately.



Handling during the transportation

The produced leaving the field or firm for the market or storage should arrive in the same condition as it left the field or the firm.

Some preventive measures that should be taken during transportation are:

(1) Safe driving at the field as well as on rough farm tracks to avoid compression and damage to the produce thus it helps in maintaining the quality.

(2) Careful loading of the produce in the containers to avoid shifting or collapse of the load.

(3) The bulk load or open top containers should be covered to prevent excessive dehydration in hot weather and protect the produce in wet weather.

(4) Critical supervision at all stages of the transportation must be ensured to minimize the chances of physical injury to the produce.

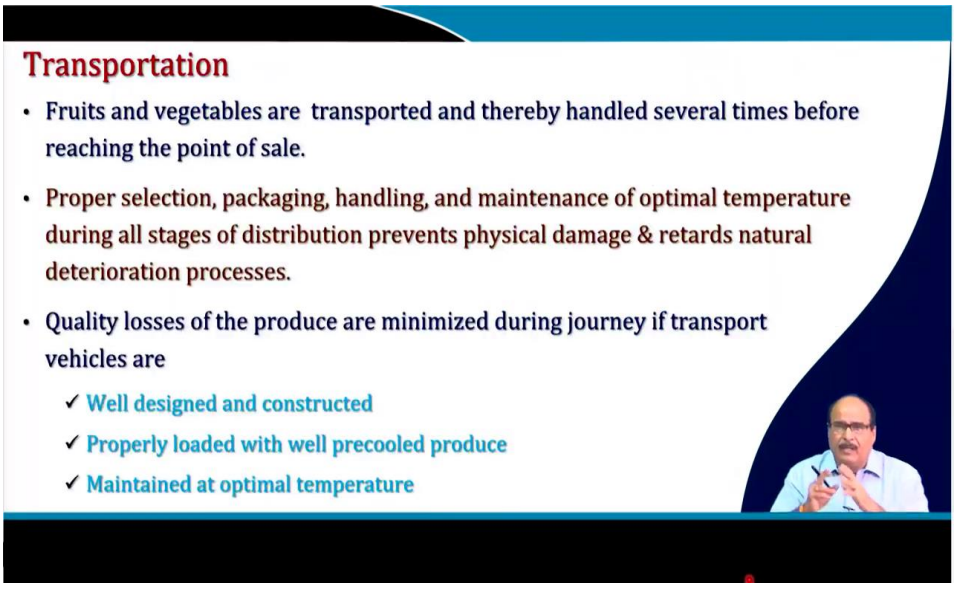
While handling in the wholesale market, the produce may get damaged during unloading, hence it must be handled gently. During storage it may get damaged, thus, the store should be cool, clean and in shade. To avoid damage of the produce during loading for the retail dispatch, they must be handled properly.

Handling at retail market

At the retail market to avoid mishandling of the produce, only required quantity should be kept at display and other remaining materials should be kept in proper place. Periodic spraying of water on leafy vegetables to maintain its quality for longer period. This process helps in keeping the commodity fresh. Also, the produce which is not kept in display should be stored in controlled environment.

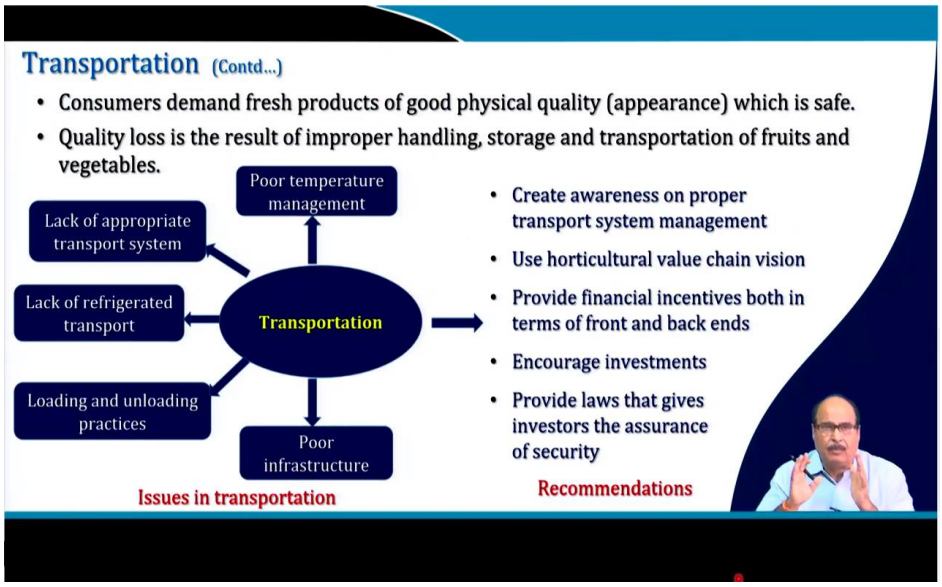
Handling at consumer end

The produce can be kept fresh for a longer period at low temperature by wrapping green leafy vegetable in wet cloth, by keeping beans, brinjals, cauliflowers, cabbage, radish, carrot, chilli, capsicum and rooty vegetables in polythene bags and before keeping in the bag extra moisture should be removed. Commodities like apple, guava, onion, and garlic should not be kept together with the other vegetables due to their typical flavor and aroma to prevent the transfer of flavor from one vegetable to the other.



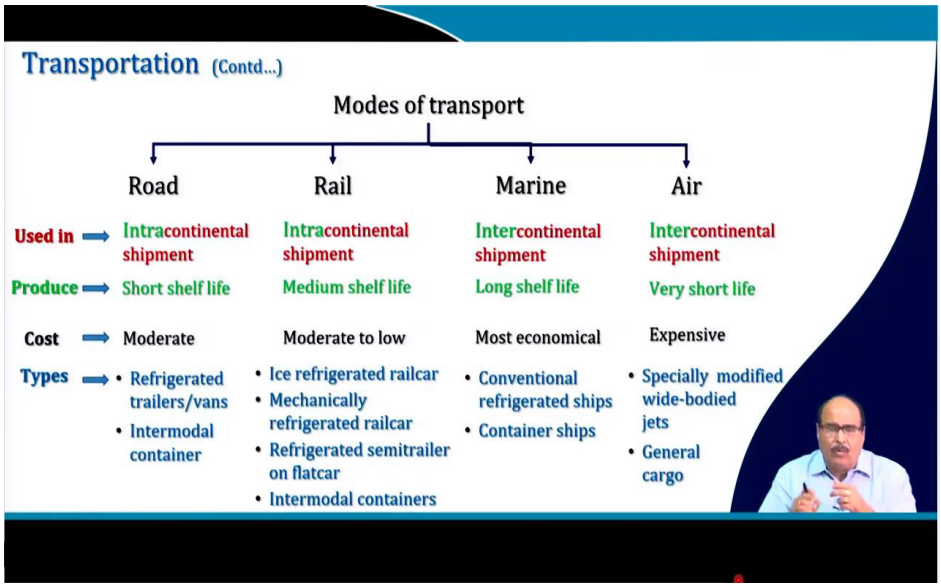
Transportation

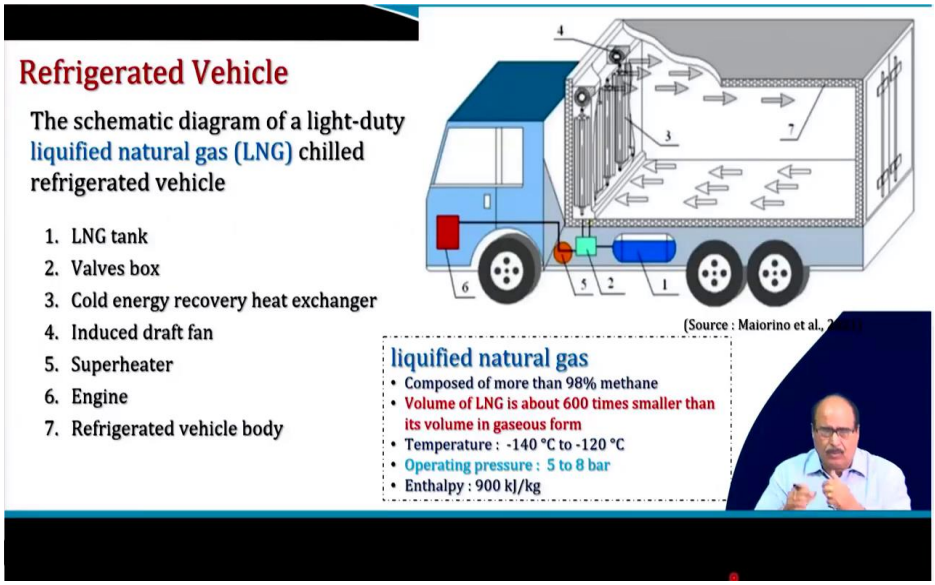
Fruits and vegetables are transported and thereby handled several times before they reach to the point of the sale. Proper selection, packaging, handling and maintenance of optimal temperature during all stages of distribution prevents physical damage and retards natural deterioration process. Quality losses of the produce are minimized during journey if the transport vehicles are well designed and properly constructed, if they are properly loaded with well pre-cooled produce, and the vehicle should be maintained at optimal temperature.



There is a gaining consumer's demand of fresh produce of good physical quality or appearance which is safe to eat. Quality loss is the result of improper handling, storage and transportation. Some issues in transportation are poor temperature management, lack of appropriate transport system, lack of refrigerated transport, poor loading and unloading practices and storage infrastructure. The recommendations to overcome the stated issues are creating awareness on proper transport system management, use horticultural value chain vision, provide financial incentives both in the terms of front and back ends, encourage investments, provide laws that give investors the assurance of security.

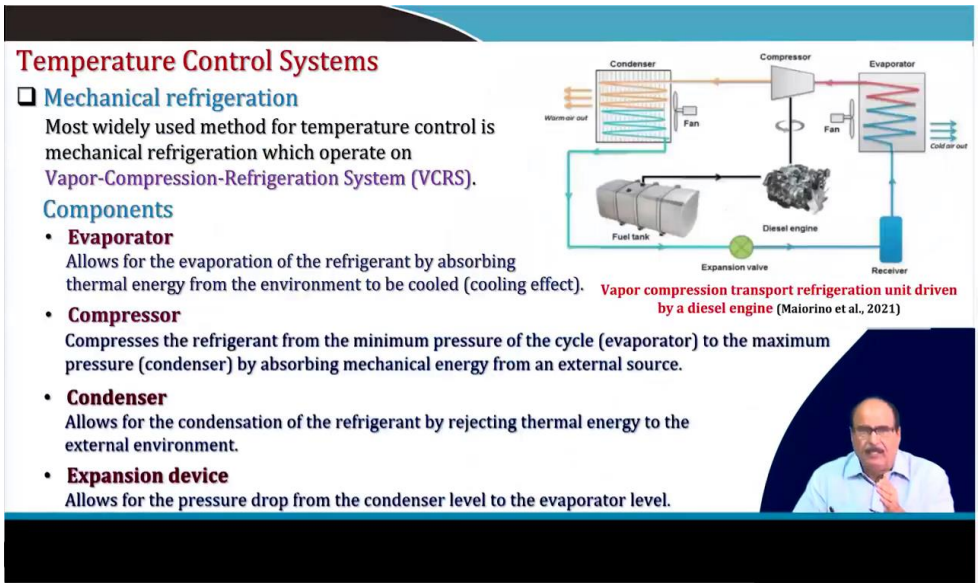
Different modes of transportation are rail, road, marine, and air. Roads are generally used in intra continental shipment, and the produce which has a short shelf life. It has a moderate cost of transport and the types of vehicle that are recommended for the road transportation included refrigerated trailer/vans and intermodal containers. A rail transport is also used for intracontinental shipment, and the communities which has medium shelf life. The cost of the transport is moderate to low and the types of vehicle recommended are ice refrigerated railcar, mechanically refrigerated railcar, refrigerated semitrailer on flatcar or intermodal containers. Marine and air transportation can also be used for the intercontinental shipments with produce having long shelf-life and very short-life, respectively. Marine transports are considered to be one of the most economical mode of transportation and the types of vehicles include conventional refrigerated ships and container ships. Conversely, air shipment is quiet expensive and it requires specially modified wide-bodied jets or general cargo.

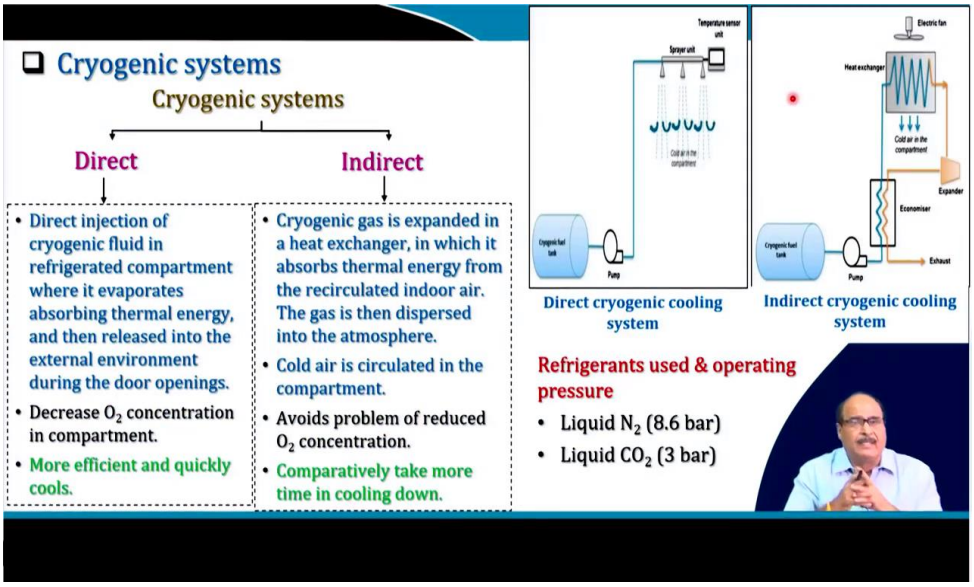




Refrigerated vehicles

The schematic diagram of a light duty liquefied natural gas chilled refrigerated vehicle is shown in the figure. It has one LNG tank provided with valve boxes, a cold energy recovery heat exchanger, induced draft fans that helps in blowing the cold air into the vehicle, superheater, engine, and refrigerated vehicle body. The liquefied natural gas is composed of more than 98 % methane. The volume of LNG is about 600 time is smaller than its value in gaseous form. Its temperature generally varies from -140 ℃ to -120 ℃, operating pressure from 5 to 8 bar and enthalpy is 900 kJ/kg.





Temperature control systems

Most widely used method for temperature control is mechanical refrigeration which operate on Vapor-Compression-Refrigeration Cycle (VCRS). It has different components as follows:

(1) Evaporator: Allows for the evaporation of the refrigerant by absorbing thermal energy from the environment to be cooled (cooling effect).

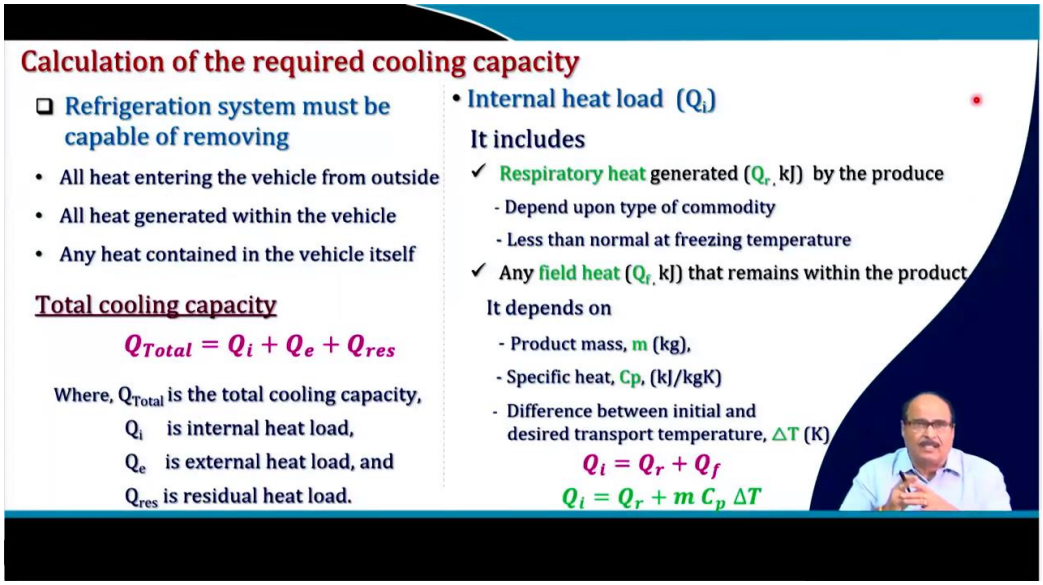
(2) Compressor: Compresses the refrigerant from the minimum pressure of the cycle (evaporator) to the maximum pressure (condenser) by absorbing mechanical energy from an external source.

(3) Condenser: Allows for the condensation of the refrigerant by rejecting thermal energy to the external environment.

(4) Expansion device: Allows the pressure drop from the condenser level to the evaporator level.

Cryogenic system

Cryogenic system may be direct or indirect system. In the direct system, direct injection of cryogenic fluid in refrigerated compartment where it evaporates absorbing thermal energy, and then released into the external environment during the door openings. So, there is a decrease O_2 concentration in the compartment and it is more efficient and it cools the commodity quickly. Conversely, in indirect system, cryogenic gas is expanded in a heat exchanger, in which it absorbs thermal energy from the recirculated indoor air. The gas is then dispersed into the atmosphere. Cold air is circulated in the compartment that avoids problem of reduced oxygen concentration. But it takes comparatively more time in cooling down.



Calculation of the required cooling capacity

The refrigeration system must be capable of removing the all heat entering the vehicle from outside, all heat generated within the vehicle, and any heat contained in the vehicle.

Total cooling capacity,

$$Q_{Total} = Q_i + Q_e + Q_{res}$$

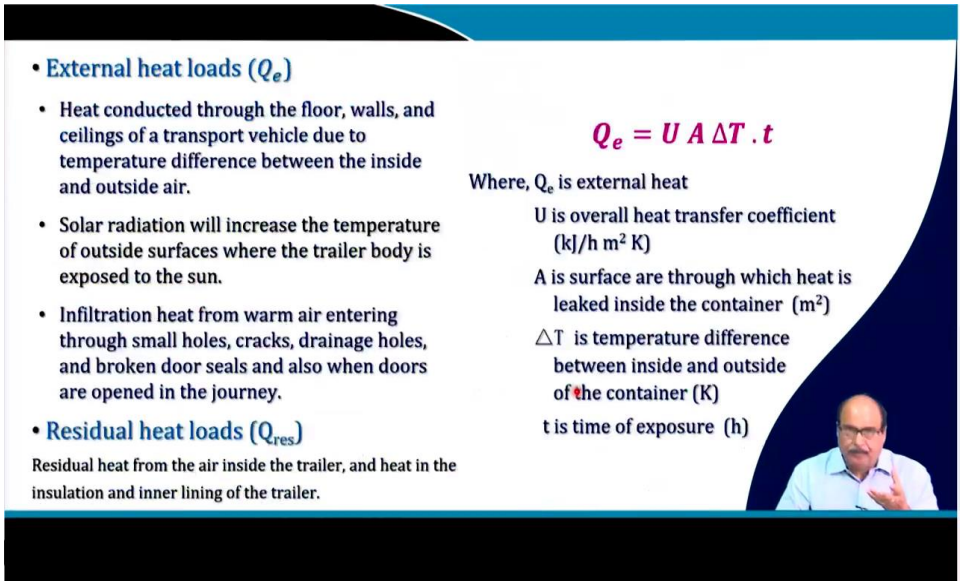
Where, Q_{Total} is the total cooling capacity, Q_i is internal heat load, Q_e is external heat load, and Q_{res} is residual heat load.

$$Q_i = Q_r + Q_f$$

$$Q_i = Q_r + m\,C_p\,\Delta T$$

The internal heat load (Q_i) is the respiratory heat generated (Qr, kJ) by the produce that depends upon type of commodity. It is less than normal at freezing temperature. Any field

heat (Q_f, kJ) that remains within the product. It depends on the product mass, m (kg), specific heat, C_p, (kJ/kgK), and difference between initial and desired transport temperature, ΔT (K).



External heat load (Q_e)

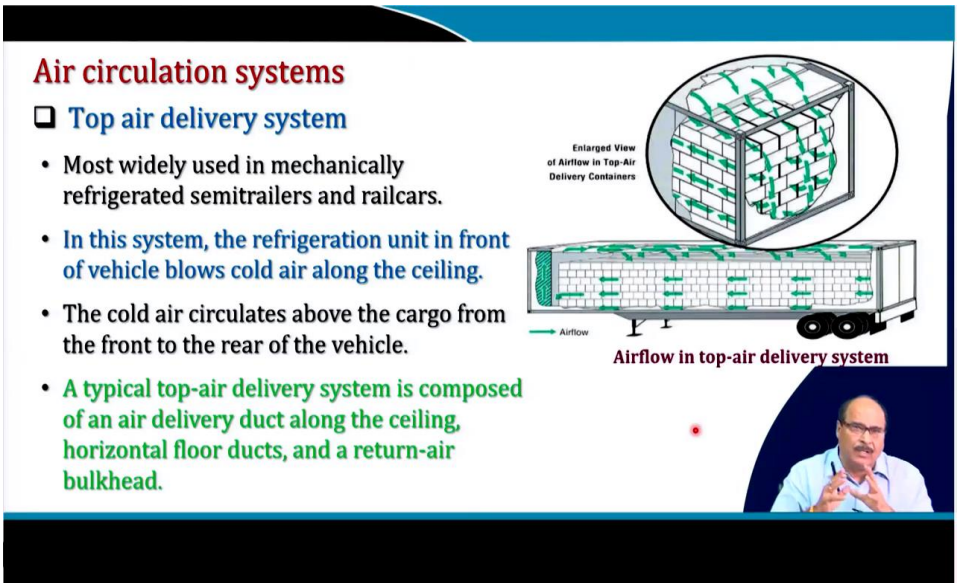
It is the heat conducted through the floor, walls and ceilings of a transport vehicle due to temperature difference between the inside and outside air. Solar radiation will increase the temperature of outside surfaces where the trailer body is exposed to the sun. Infiltration heat from warm air entering through small holes, cracks, drainage holes, and broken door seals and also when doors are opened during the journey may heat up the vehicle.

$$Q_e = U\ A\ \Delta T\ .\ t$$

Where, Q_e is external heat, U is overall heat transfer coefficient (kJ/h m^2 K), A is surface are through which heat is leaked inside the container (m_2), ΔT is temperature difference between inside and outside of the container (K), t is time of exposure (h).

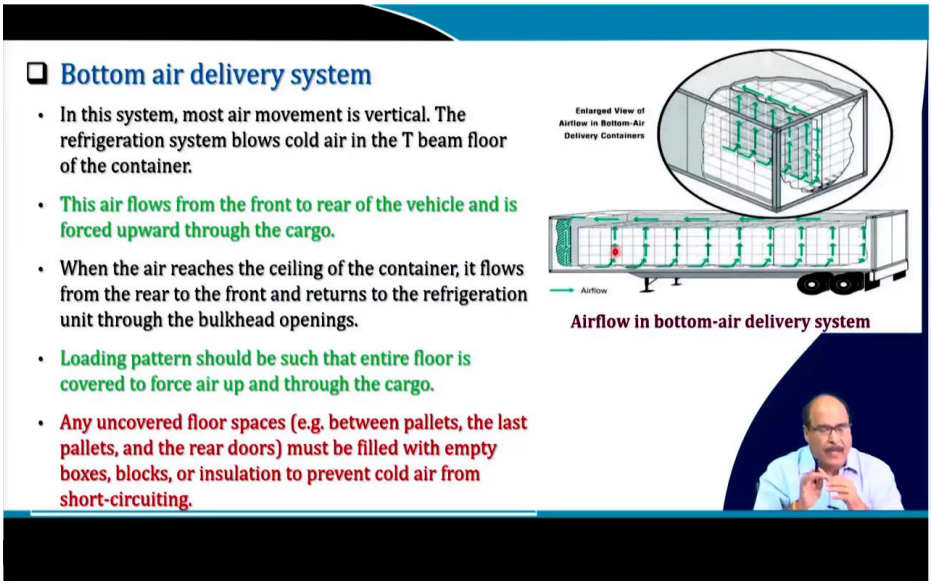
Residual heat load (Q_{res})

Residual heat from the air inside the trailer, and heat in the insulation and inner lining of the trailer.



Air circulation system

Top air delivery system is the most widely used in mechanically refrigerated semitrailers and railcars. In this system, the refrigeration unit in front of the vehicle blows cold air along the ceiling. The cold air circulates above the cargo from the front to the rear of the vehicle. A typical top air delivery system is comprised of an air delivery duct along the ceiling, horizontal floor duct, and a return-air bulkhead.

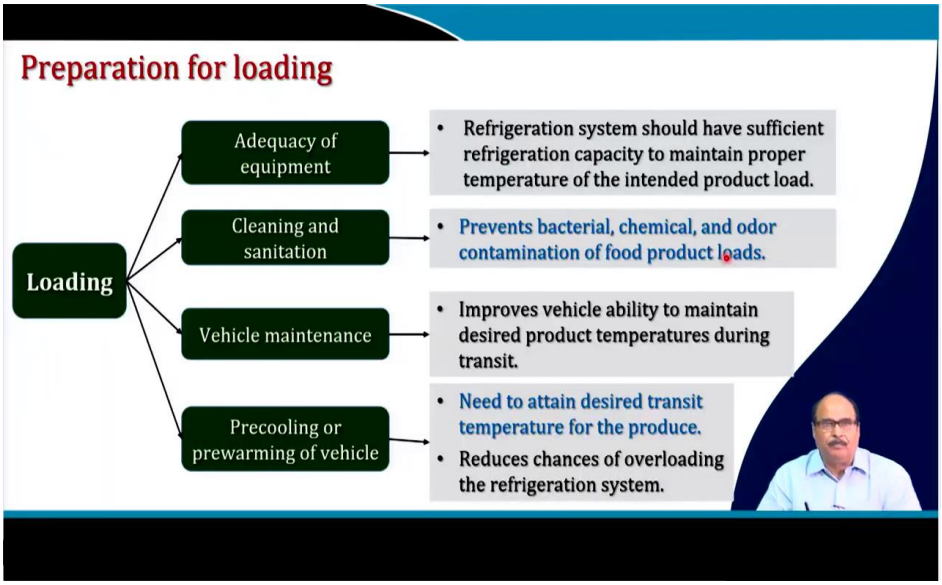


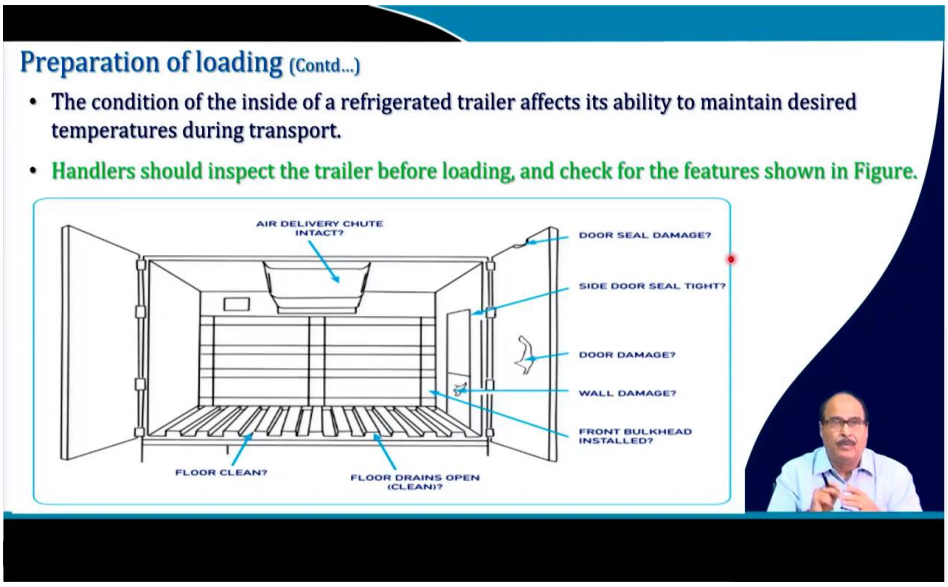
Bottom air delivery system

In this system the most air movement is vertical, the refrigeration system blows cold air in the T beam floor of the container. This air flows from the front to rear of the vehicle and is forced upward through the cargo.

When the air reaches the ceiling of the container, it flows from the rear to the front and returns to the refrigeration unit through the bulkhead openings. The loading pattern should be such that entire floor is covered to force air up and through the cargo. Any uncovered floor

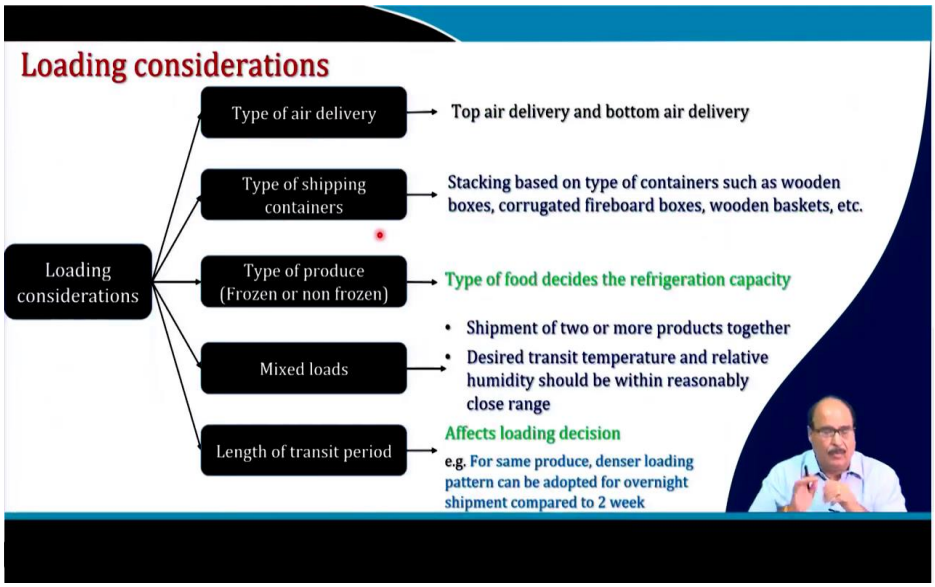
space, for example, between pellets, the last pellet and the real doors must be filled with empty boxes, blocks or insulation to prevent cold air from short-circuiting to have better efficiency of the system.





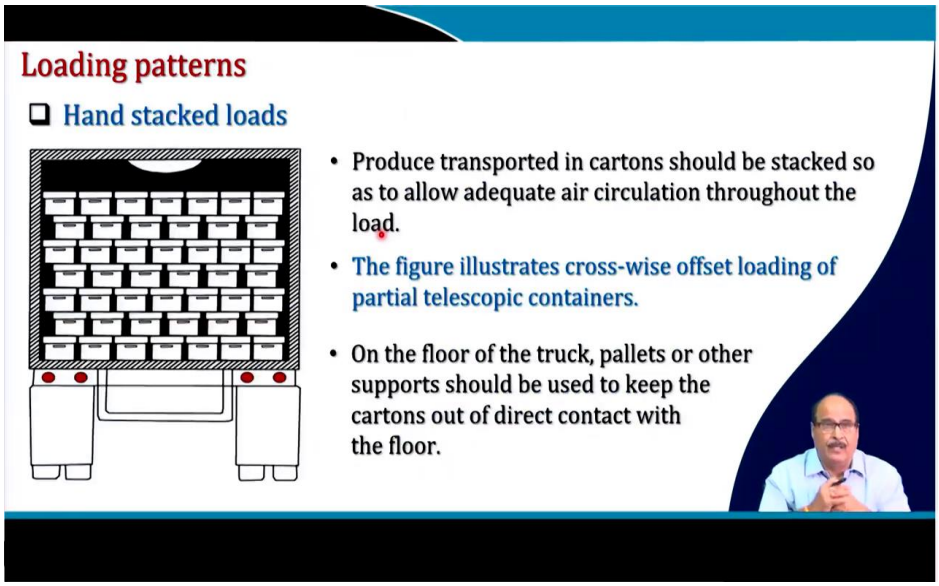
Preparation for loading

The refrigeration system should have sufficient refrigeration capacity to maintain proper temperature of the intended product load. The vehicle should be inspected for proper sanitation to prevent the bacterial, chemical and other contamination of the food product loads. Vehicle maintenance improves vehicle ability to maintain desired product temperature during transit. There is a needs to attain desired transit temperature for the produce. It reduces chances of overloading the refrigeration system. The condition of the inside of the refrigerated trailer affects its ability to maintain the desired temperature during the transit. Therefore, handlers should inspect the trailer before loading and check out the various features like the presence of air delivery chute, no damage of the door seal, tightness of the side door seal, installation of bulkhead, and cleanliness of the floor and floor drains.



Loading considerations

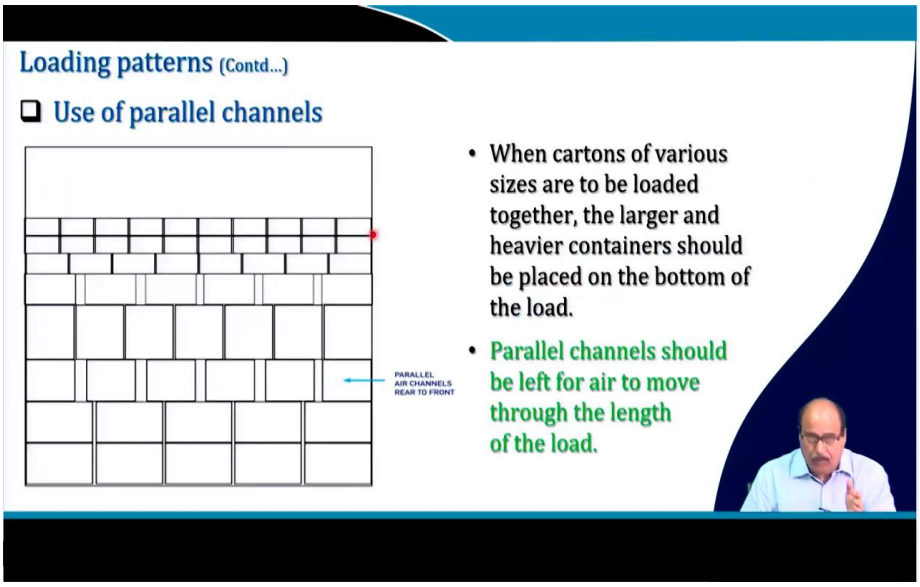
Some loading considerations should be taken like the type of air delivery (i.e. top air delivery or bottom air delivery), type of shipping containers (eg. stacking based on the type of containers such as wooden boxes, corrugated fiberboard boxes, or wooden baskets), type of the produce (i.e. frozen or non-frozen produce). The type of food decides the refrigeration capacity. The shipment consisting of two or more produce together must have the desired transit temperature and relative humidity, within reasonably close range. And the length of transit period affects the loading decision, for example, for same produce, denser loading pattern can be adopted for overnight shipment compared to 2 weeks.



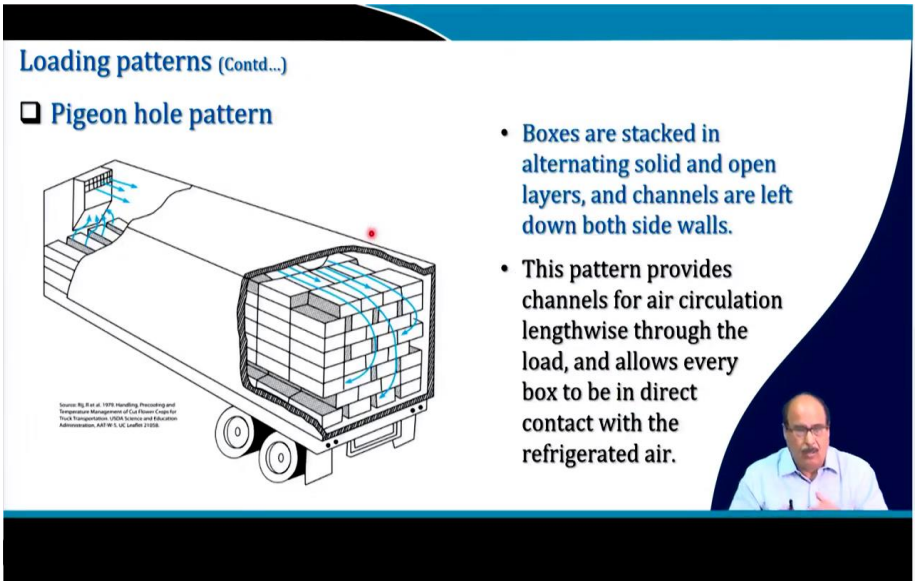
Loading patterns

In hand stacked loads produce transported in cartons should be stacked so as to allow adequate air circulation throughout the load. The figure illustrates cross-wise offset loading

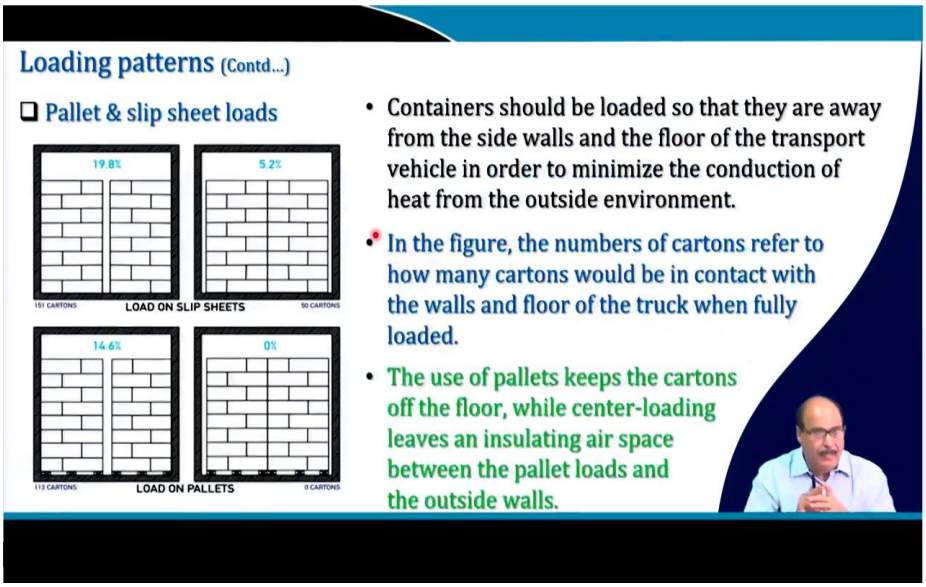
of the parcel telescopic containers. On the floor of the truck pellets or other support should be used to keep the cartoons out of the direct contact with the floor.



Use of proper channels when cartons of various sizes are to be loaded together, the larger and heavier containers should be placed on the bottom of the load. Parallel channels should be left for the air to move through the length of the load.

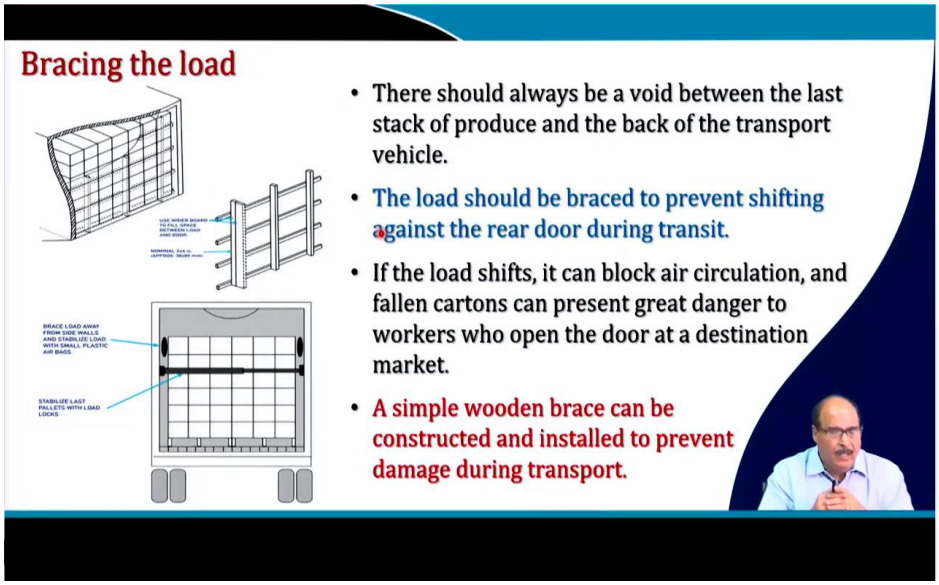


Pigeon hole pattern has boxes stacked in alternating solid and open layers and channels are left down both sidewalls. This pattern provides channel for proper air circulation that is air circulation lengthwise through the load and it allows every box to be in direct contact with the refrigerated air.



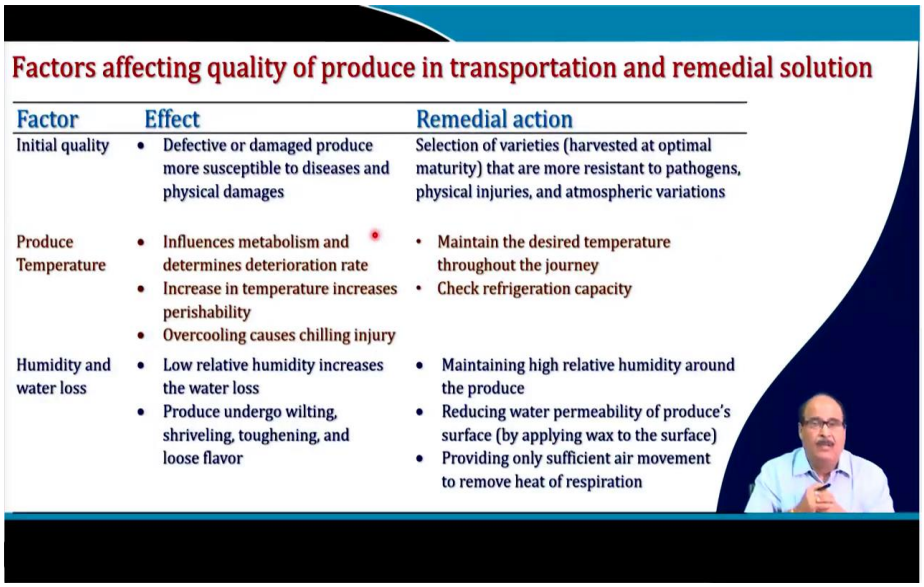
Pallets and slip sheet loads

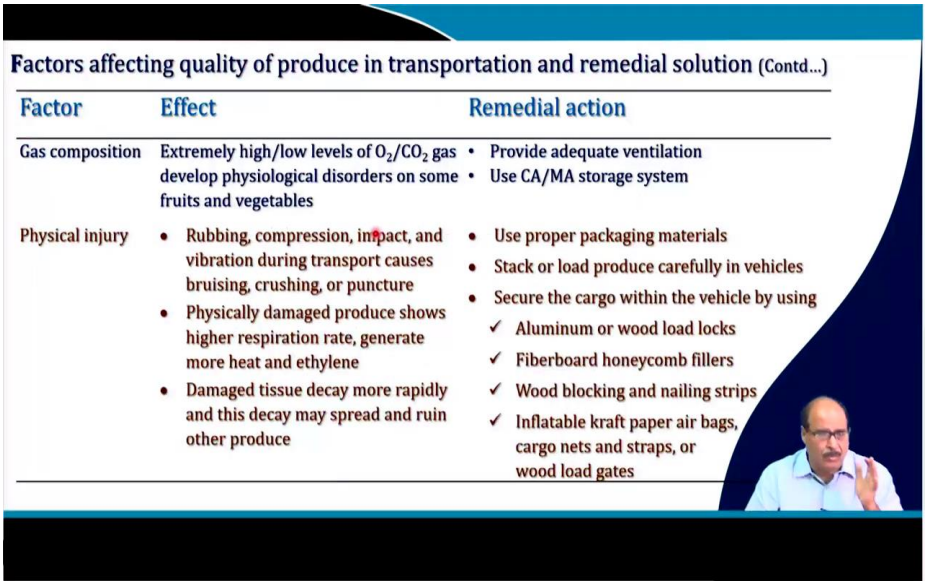
The containers should be loaded so that they are away from the sidewalls and the floor of the transport vehicle in order to minimize the conduction of heat from the outside environment. The use of pellets keeps the cartons off the floor while center-loading leaves an insulating air space between the pallet loads and the outside walls.



Bracing the load

There should always be a void between the last stack of produce and the back of the transport vehicle. The load should be braced to prevent sifting against the rear door during transit. If the load shifts, it can block air circulation and fallen cartons can present a great danger to the workers who open the door at the destination market. A simple wooden brace can be constructed and installed to prevent damage during the transportation.





Factors affecting quality of the produce in transportation and the remedial solution

(1) **Initial quality:** Defective or damaged produce are more susceptible to disease and physical damage. So, selection of varieties (harvested at optimal maturity) that are more resistant to pathogens, physical injuries, and atmospheric variations should be done.

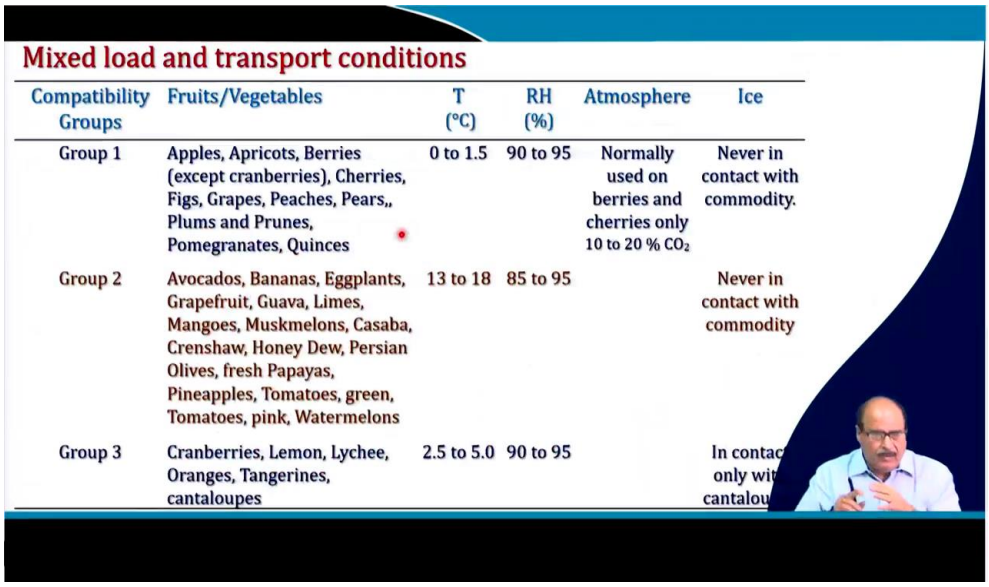
(2) **Produce temperature**: It influences the metabolism and determines deterioration rate. Increase in temperature increases perishability and overcooling causes chilling injury. Hence, it must be ensured that a desired temperature is maintained throughout the journey and subsequently check refrigeration capacity.

(3) **Humidity and water loss:** Low relative humidity increases the water loss and produce undergoes wilting, shriveling, toughening, and loose flavor. Therefore, high relative humidity around the produce should be maintained. Water permeability of the

produce's surface can be reduced by applying wax to the surface or providing only sufficient air movement to remove heat up respiration.

(4) **Gas composition:** Extremely high/low levels of O_2/CO_2 gas can develop physiological disorders on some fruits and vegetables. This can be prevented by providing adequate ventilation or by using CA/MA storage system.

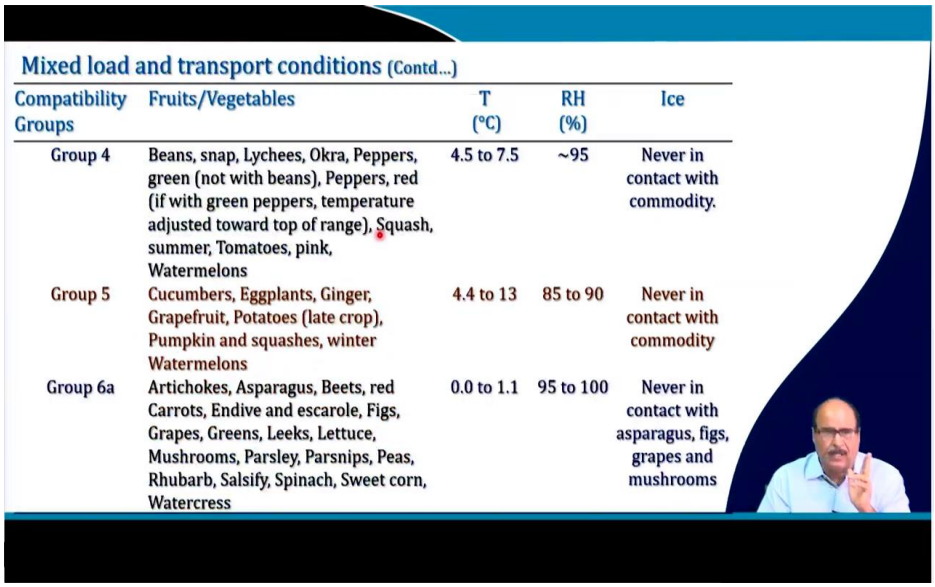
(5) **Physical injuries:** Rubbing, compression, impact, and vibration during transport causes bruising, crushing, or puncture. Physically damaged produce shows higher respiration rate, generate more heat and ethylene. Damaged tissue decay more rapidly and this decay may spread and ruin other produce. It can be averted by using proper packaging materials, stacking or loading produce carefully in the vehicles, and secure the cargo within the vehicle by using aluminum or wood load locks, Fiberboard honeycomb fillers, wood blocking and nailing strips, inflatable kraft paper air bags, cargo nets and straps, or wood load gates.

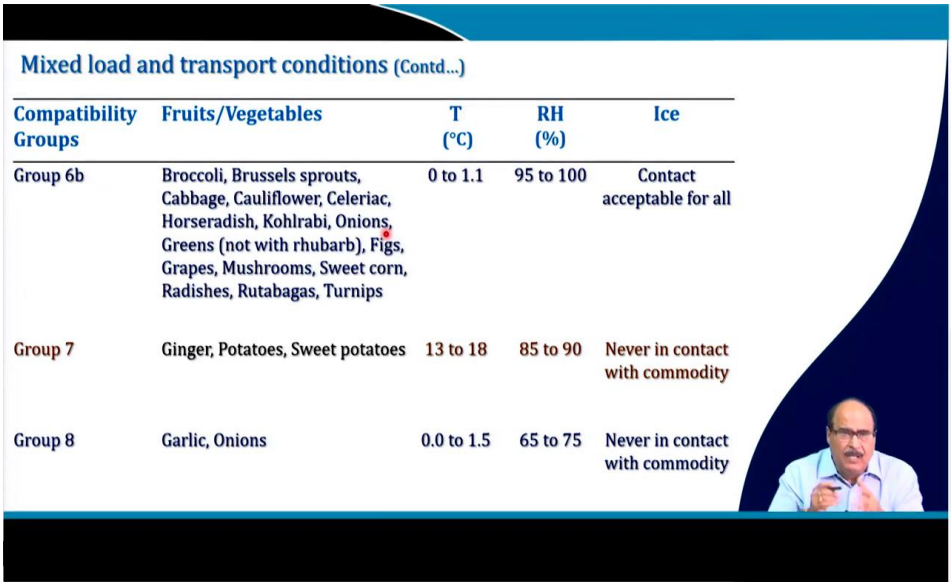


Mixed load and transport conditions

Different groups require different temperature, relative humidity during transportation like group 1 consisting of apple, apricot, berries, cherries, fig, grapes, peaches, pears, plums, prunes, pomegranates and quinces require 0 to 1.5 ℃ temperature and 90 to 95 % relative humidity. The atmosphere that is normally used on berries and cherries are 10 to 20 % CO_2. The commodities in this group should never be brought in contact with the ice.

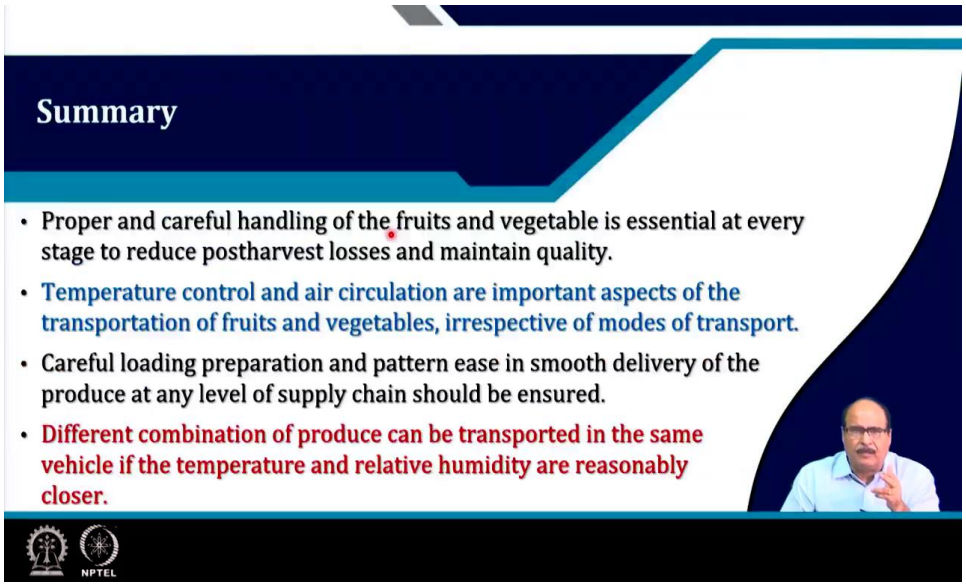
Similarly, in the group 2, there are avocado, banana, olive, fresh papaya, pineapple, tomato, green tomato, pink, watermelon, etc. The required temperature is around 13 to 18 ℃, relative humidity 85 to 95 %. The commodities should never come in contact with the ice. Group 3 comprises of cranberries, lemon, lychee, oranges, tangerines, and cantaloupes. The required temperature 2.5 to 5 ℃ and 90 to 95 % relative humidity.





Group 4 consists of beans, snap, lychees, okra, peppers, green (not with beans), peppers, red (if with green peppers, temperature adjusted toward top of range), squash, summer, tomatoes, pink, watermelons. They require a temperature of 4.5 to 7.5 ℃ and relative humidity around 95 %. In group 5 consists of Cucumbers, Eggplants, Ginger, Grapefruit, Potatoes (late crop), Pumpkin and squashes, winter Watermelons. The required temperature is 4.4 to 13 ℃ and relative humidity 85 to 90 %. Group 6a contain the artichokes, asparagus, beets, red carrots, endive and escarole, figs, grapes, greens, leeks, lettuce, mushrooms, parsley, parsnips, peas, rhubarb, salsify, spinach, sweet corn, watercress. The required temperature is 0 to 1.1 ℃ and relative humidity 95 to 100 %. Similarly, group 6b comprises of broccoli, brussels sprouts, cabbage, cauliflower, celeriac, horseradish, kohlrabi, onions, greens (not with rhubarb), figs, grapes, mushrooms, sweet corn, radishes, rutabagas, turnips. the required temperature is 0 to 1.1 ℃ and relative humidity 95 to 100%. Ice contact is acceptable for all commodities groups. Group 7 consists of Ginger, Potato, and Sweet Potato, which require comparatively higher temperature i.e. 13 to 18 ℃, relative humidity 85 to 90 %. They should never be in contact

with ice. In the group 8, there is Garlic and onion which requires temperature about 0 to 1.5 ℃, relative humidity around 65 to 75 %.



In summary, proper and careful handling of fruits and vegetable is essential at every stage to reduce post-harvest losses and maintain quality. Temperature control and air circulation are important aspects of the transportation of fruits and vegetables, irrespective of modes of transport. Careful loading preparation and pattern ease in the smooth delivery of the produce at any level of supply chain. Different combinations of produce can be transported in the same vehicle product if the temperature and relative humidity are reasonably closer.

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