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

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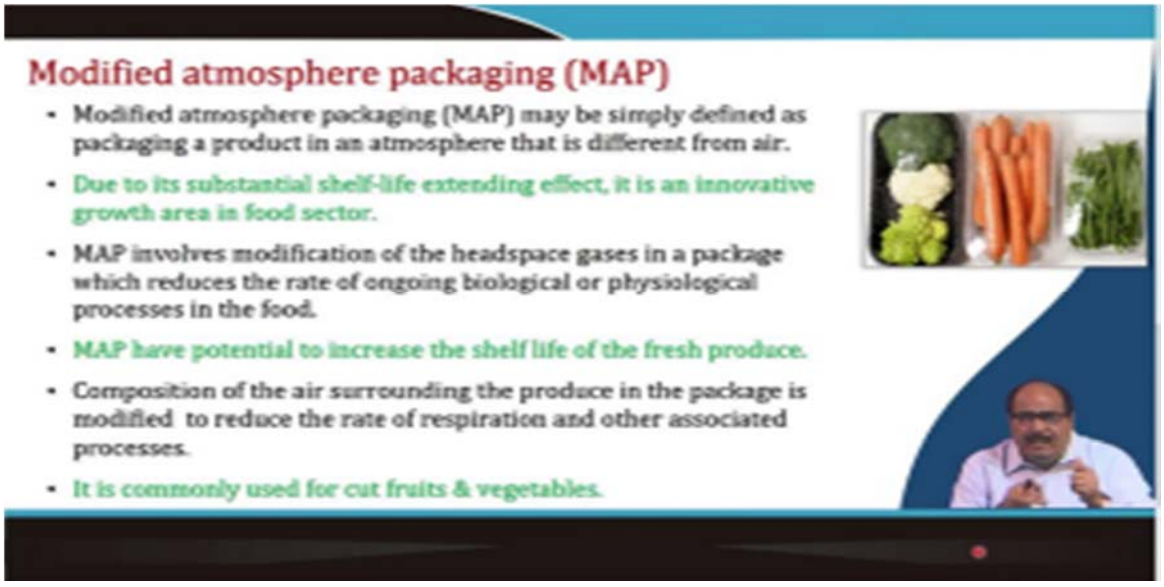
Lecture 54
Modified Atmosphere Packaging

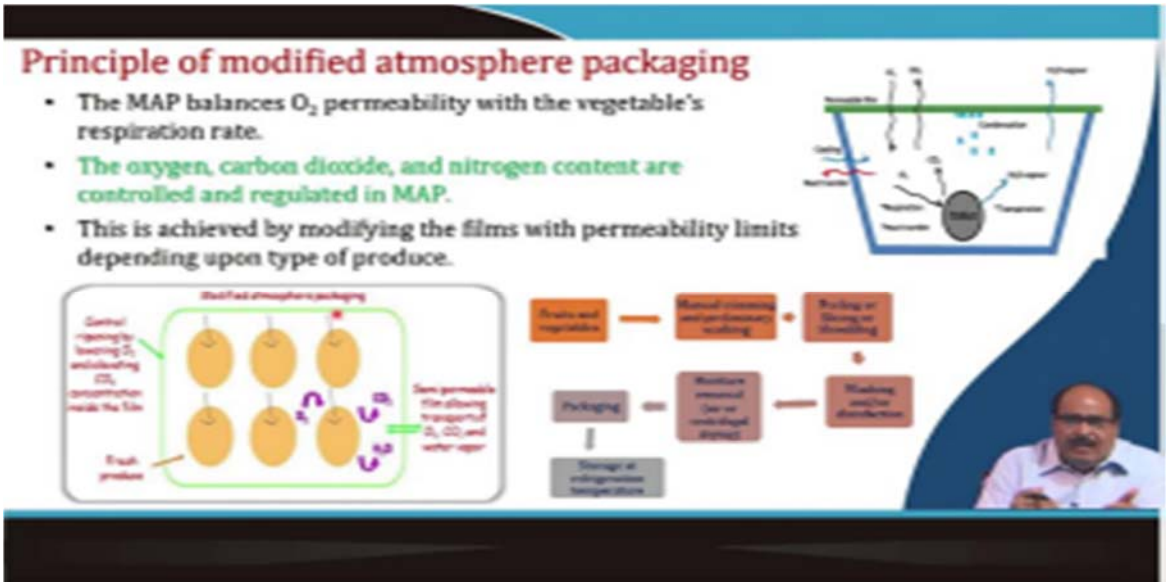
This lecture covers modified atmospheric packaging of horticultural and plantation crop produces including the methods and systems, their advantages and disadvantages, requirements of the packaging materials for modified atmosphere packaging of fresh produce and its effect on nutritional quality, and the concepts of equilibrium humidity packaging.



Modified atmosphere packaging (MAP)

Modified atmosphere packaging (MAP) may be simply defined as packaging a product in an atmosphere that is different from air. Due to its substantial shelf-life extending effect, it is an innovative growth area in food sector. MAP involves modification of the headspace gases in a

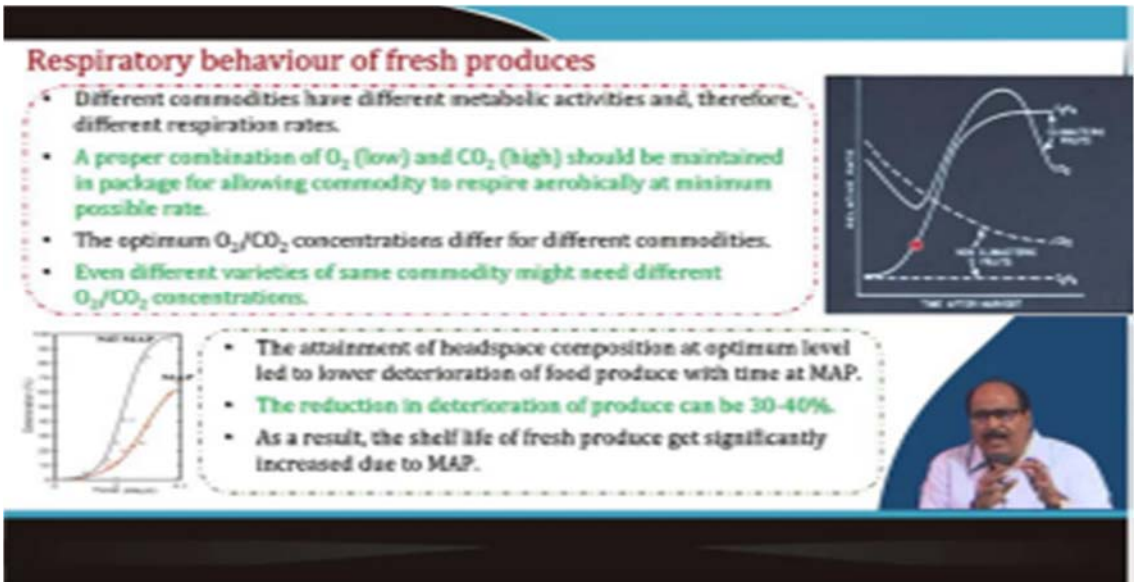
package which reduces the rate of ongoing biological or physiological processes in the food. MAP have potential to increase the shelf life of the fresh produce. Composition of the air surrounding the produce in the package is modified to reduce the rate of respiration and other associated processes. It is commonly used for cut fruits & vegetables or even whole fruits and vegetables.



Principle of modified atmosphere packaging

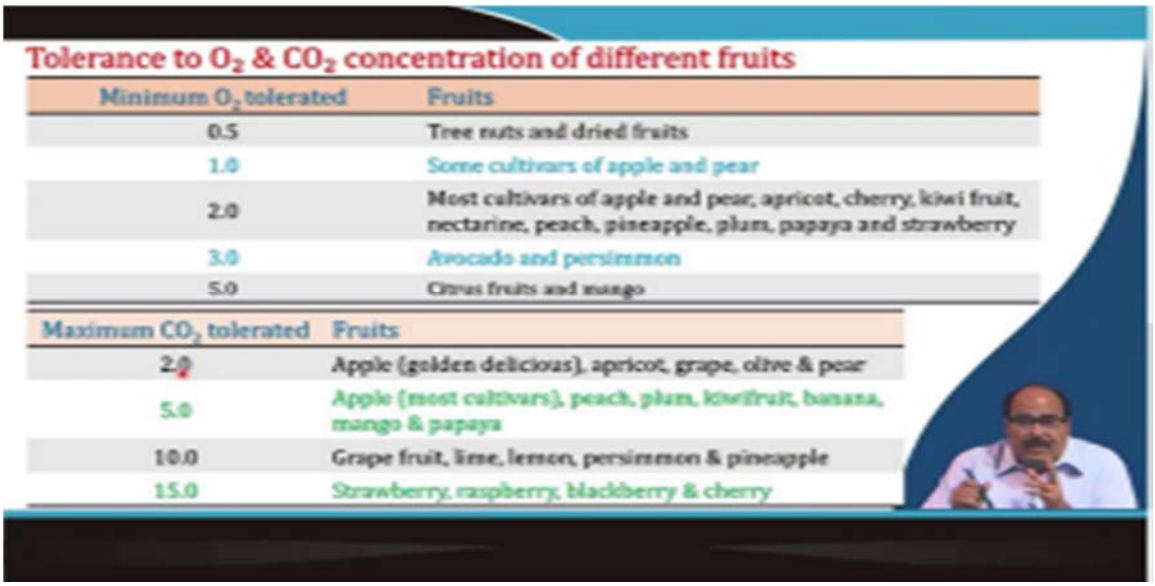
MAP basically balances the oxygen permeability with the vegetables respiration rate. So, as shown in a thumb setup, permeable and semi permeable materials are used, which selectively allows in and out of the gases such as O_2, CO_2 and water vapour and therefore it maintains a proper desired level of composition of these gases, i.e. the oxygen, carbon dioxide and nitrogen content are controlled and regulated inside the packet and this is achieved by modifying the film with its permeability limit depending upon the type of the produce, because different produces have different rate of respiration as well as their requirements for O_2 and CO_2 etc. might be different.

However, it is very important to control the proper conditions inside the packaging material and there should be proper balance between the humidity inside the packet and outside the packet. So, the fruit and vegetables after the harvesting are subjected to the usual pre-treatment processes such as cleaning, washing, grading, sorting and finally packaging and storage.



Respiratory behaviour of fresh produces

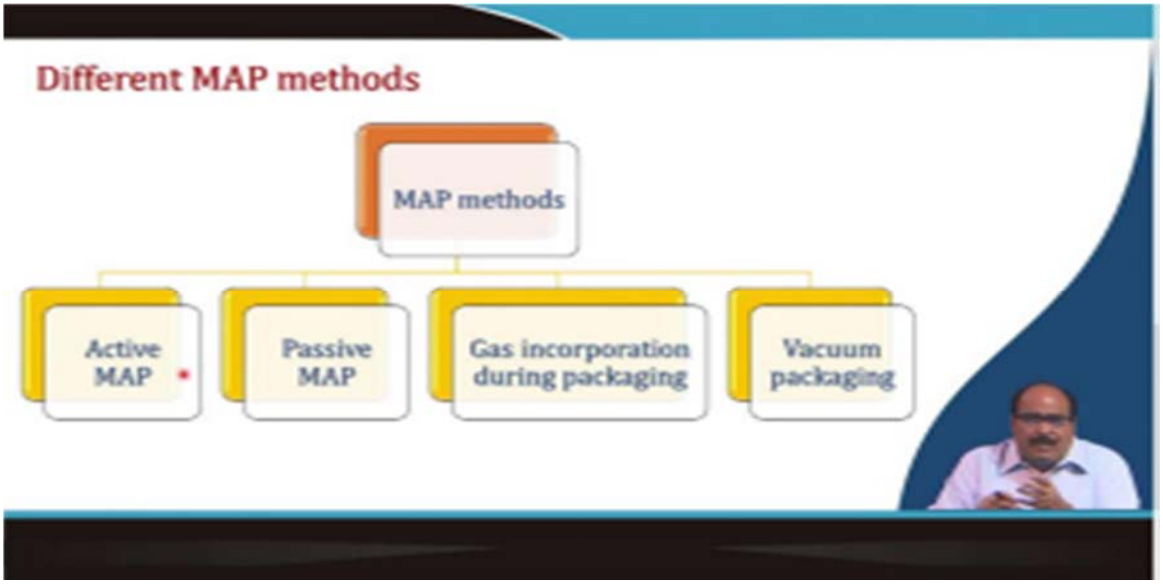
Different commodities have different metabolic activities and, therefore, different respiration rates. A proper combination of O_2 (low) and CO_2 (high) should be maintained in package for allowing commodity to respire aerobically at minimum possible rate. The optimum O_2/CO_2 concentrations differ for different commodities. Even different varieties of same commodity might need different O_2/CO_2 concentrations. The attainment of headspace composition at optimum level led to lower deterioration of food produce with time at MAP. The reduction in deterioration of produce can be 30-40%.



Tolerance to O_2 & CO_2 concentration of different fruits

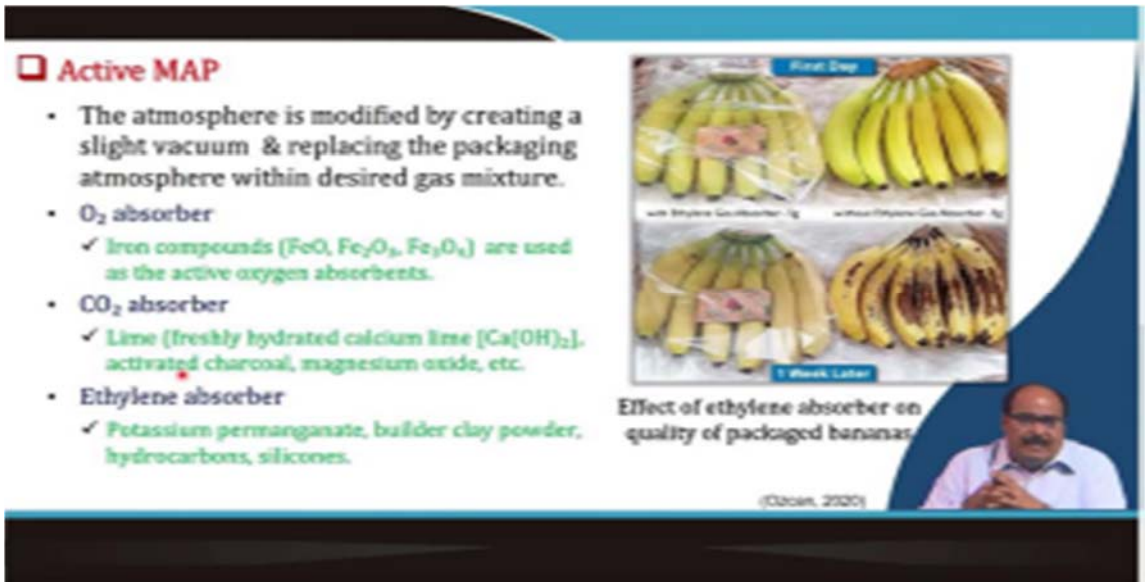
The table represents the minimum O_2 tolerated and maximum CO_2 tolerated by different fruits. For example, the minimum O_2 tolerated level for tree nuts and dried fruits is 0.5%, for some cultivars of apple and pear is 1.0%, most cultivars of apple and pear, apricot, cherry, kiwi fruit, peach, pineapple, plum, papaya strawberry is 2.0% etc. Similarly, the maximum carbon dioxide tolerated for apple, apricot, grape, olive, and pear is 2.0%, for peach, plum, kiwifruit, banana,

mango & papaya, it is 5.0%, grape fruit, lime, lemon, persimmon & pineapple, it is 10%, for strawberry, raspberry, blackberry & cherry can tolerate up to 15%.



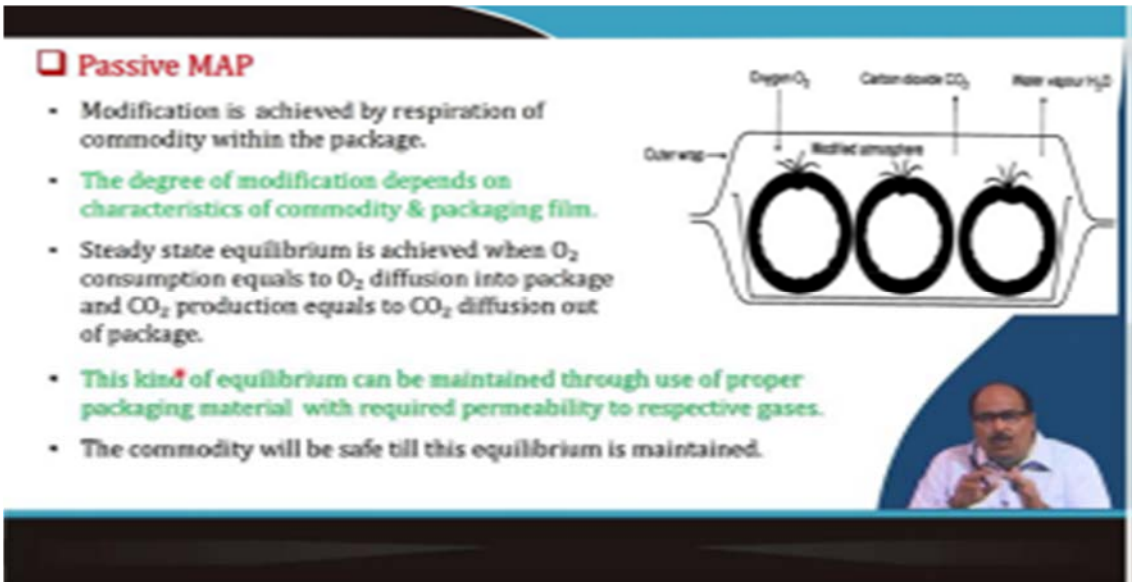
Different MAP methods

Different types of MAP methods are active modified atmosphere packaging, passive modified atmosphere packaging, gas incorporation during packaging or vacuum packaging. In fact, vacuum packaging is also a type of modified atmosphere packaging where oxygen is completely removed or sometimes nitrogen flushing is used.



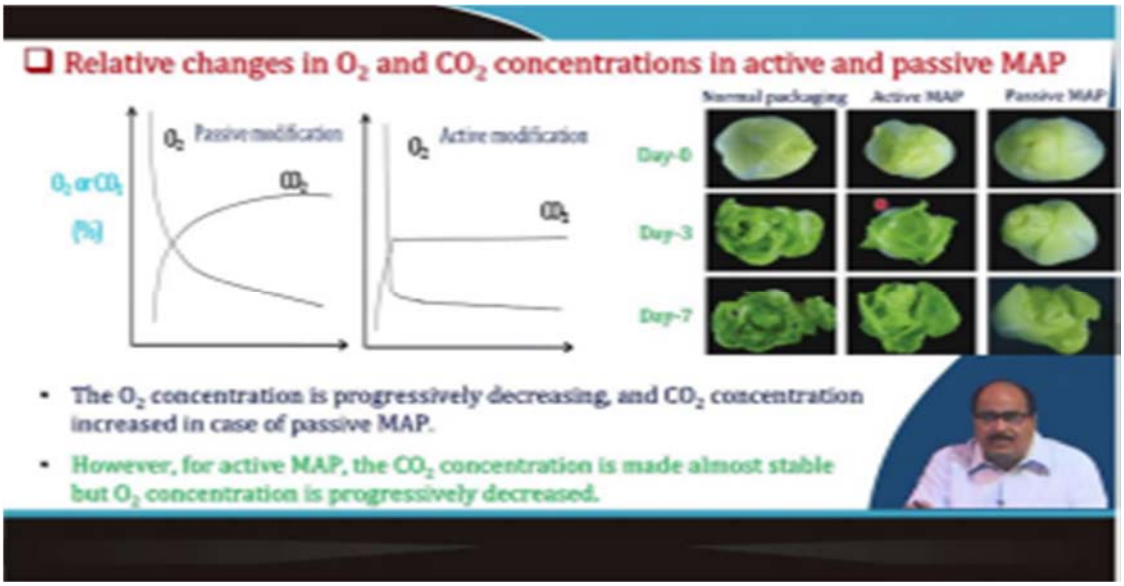
Active MAP

In active MAP, The atmosphere is modified by creating a slight vacuum & replacing the packaging atmosphere within desired gas mixture. The iron compounds (FeO, Fe_2O_3, Fe_3O_4) are used as the active oxygen absorbents. The CO_2 absorbers are used are lime (freshly hydrated calcium lime [$Ca(OH)_2$], activated charcoal, magnesium oxide, etc. The ethylene absorbers used are potassium permanganate, builder clay powder, hydrocarbons, and silicones.



Passive MAP

Modification is achieved by respiration of commodity within the package. The degree of modification depends on characteristics of commodity & packaging film. Steady state equilibrium is achieved when O_2 consumption equals to O_2 diffusion into package and CO_2 production equals to CO_2 diffusion out of package. This kind of equilibrium can be maintained through use of proper packaging material with required permeability to respective gases. The commodity will be safe till this equilibrium is maintained.



Relative changes in O_2 and CO_2 concentrations in active and passive MAP

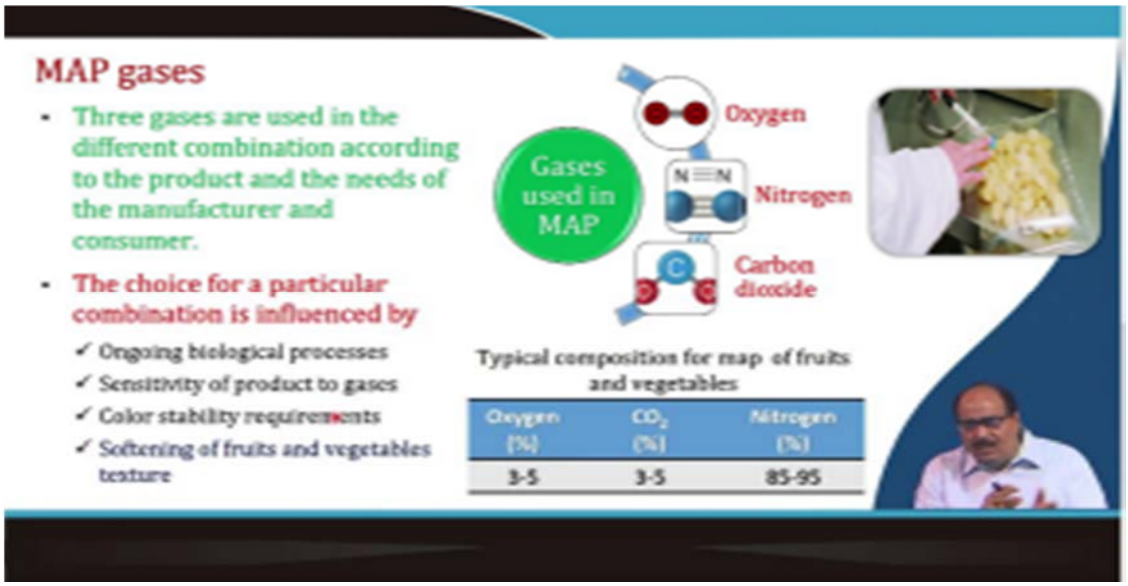
The figure shows the variation in physiological changes of food products in a normal packaging, active modified atmosphere packaging and passive modified atmosphere packaging at day 0, day 3 and day 7. In active modified atmosphere packaging, scavengers, emitters, and scrubbers are used. So, the desired atmosphere is achieved at a faster rate. The O_2 concentration is progressively decreasing, and CO_2 concentration increased in case of passive MAP. However, for active MAP, the CO_2 concentration is made almost stable but O_2 concentration is progressively decreased.

Gas incorporation during packaging

It involves the flushing with the mixture of gases. The air inside the package is replaced with inert gas nitrogen, or mixture of gases (nitrogen, CO_2) before packaging and sealing in barrier materials. So, the material is filled into the package, placing in the chamber, closing the chamber, evacuation of air (oxygen is completely removed), then gas injection and nitrogen flushing is done, then sealing, releasing the vacuum, and finally the modified atmosphere package is achieved.

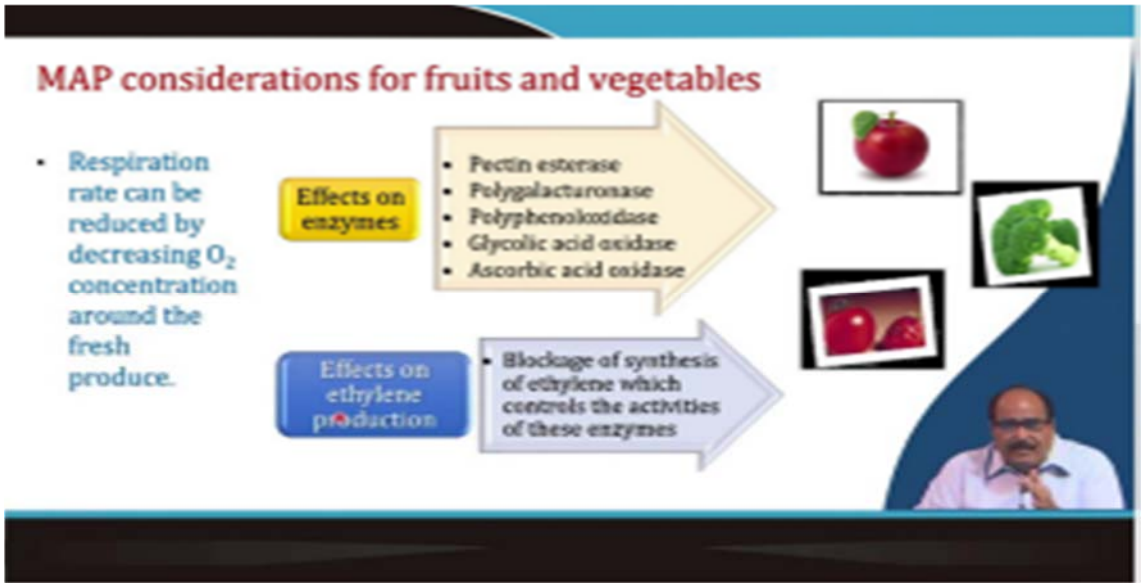
Vacuum packaging

In vacuum packaging, the air is mechanically removed from the package before it is sealed.



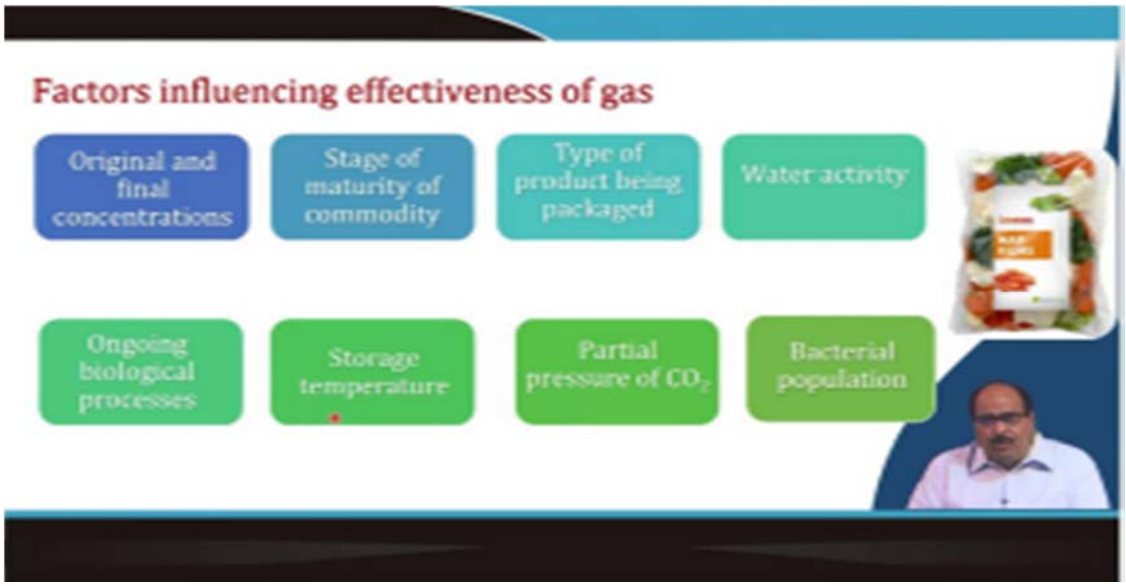
MAP gases

Three gases such as O_2, CO_2, and N_2 are used in the different combination according to the product and the needs of the manufacturer and consumer. The compositions for MAP of fruits and vegetables are as O_2: 3-5%, CO_2: 3-5%, and N_2: 85-95%. The choice for a particular combination is influenced by ongoing biological processes, sensitivity of product to gases, color stability requirements, and softening of fruits and vegetables texture.



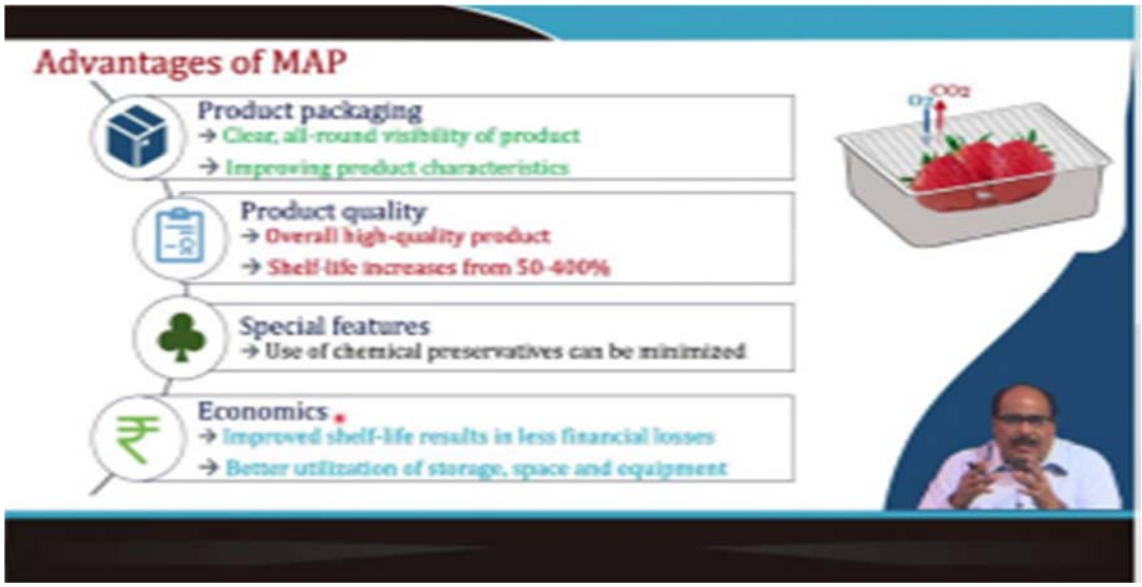
MAP considerations for fruits and vegetables

Respiration rate can be reduced by decreasing O_2 concentration around the fresh produce. Pectin esterase, polygalacturonase, polyphenoloxidase, glycolic acid oxidase, ascorbic acid oxidase are the active enzymes and many of these continue because of the continuation of the life in the fruit, physiological process, and respiratory behaviour. The effects on ethylene production can be described as blockage of synthesis ethylene which control the activities of these enzymes.



Factors influencing effectiveness of gas

The factors influencing the effectiveness of gas include original and final concentrations of the gases, stage of maturity of commodity, type of product being packaged, water activity, ongoing biological processes, storage temperature, partial pressure of carbon dioxide, and bacterial population.



Advantages of MAP

Firstly, product packaging (clear all round visibility of the product and it improve the product characteristics), secondly, product quality (overall high quality product, shelf-life increases from 50-400%), thirdly, special features (use of chemical preservatives can be minimized), and economics (Improved shelf-life results in less financial losses and better utilization of storage, space and equipment).

Disadvantages of MAP

Firstly, product packaging (increased package volume leads to poor retail display and added transport cost etc, benefits of MAP are lost upon package leakage), secondly, product quality (product safety is not fully established), thirdly, special features (temperature control is required different products need a different gas composition and this becomes a complicated material that is one time only one specific commodity can be stored special equipment and training is required), and economics (cost of analytical equipment to measure gas composition, cost of gas filling and other machinery & their maintenance).

Systems for gas packaging

Horizontal FFS machines for rigid and semi-rigid packages (Deep-draw machines) is suitable for the retail packaging of processed products, and nuts, etc. Horizontal and vertical FFS machines for flexible 'pillow-pack' pouches (Flow-pack machines) are mainly suitable for the retail packaging of snack foods, coffee, nuts, salads and fruits, etc. Vacuum chamber machines are suitable for both retail and catering packaging of nuts, and prepared meals, etc.

Gemella can be used for packaging of fruits, vegetables, salads and ready meals, etc. Fiberlam system can also be applied to fruit, vegetables, processed products, salads and ready meals, etc. Bag-in-Carton system is used for making consumer size packs of dry powders and granules such as coffee, tea and dried potato powder, etc. Bag-in-Box system has the advantage that a conventional unit pack can be produced and then gas is flushed.

Packaging material requirements

Integrity of sealing is important to maintain correct atmosphere in package. Package types (rigid or semi-rigid, lidded tray or flexible film pouch) help in choosing packaging materials. Polyethylene in packaging laminates can be specially treated to prevent condensation of water that fogs package and affects visibility of inside product. Microwaveability of packaging materials is an important factor to be considered in gas packaging, particularly in the case of RTE products.

Biodegradability and recyclability is a major challenge for the materials manufacture is the natural hydrophilic behavior of many bio-based polymers. The mechanical properties in terms of modulus and stiffness should not be very different to those of the conventional polymers. The compostability is highly dependent on the type & composition of the material.

Films used in MAP

The films which are used in modified atmosphere packaging may be polymeric film like LDPE, HDPE, Polypropylene, OPP, Metallized Polyester, EBA, PVC, Perforated, Micro Perforated, edible films like biopolymers, emulsion, laminates etc., smart packaging film material like temperature-responsive, ethylene absorber etc., anti-microbial like Wasabi-based polymers.

Function of MAP gases in preservation

The gases that are applied in MAP are basically O_2, CO_2 and N_2. N_2 has no specific preservative effect but functions mainly as a filler gas to avoid the collapse that takes place when CO_2 dissolves in the product. CO_2, because of its antimicrobial activity, is the most important component in applied gas mixtures. The different proposed mechanisms of antimicrobial action of CO_2 involving are lowering the pH of the food, cellular penetration followed by a decrease in the cytoplasmic pH of the cell, specific actions on cytoplasmic enzymes, and specific actions on biological membranes. The gas/product volume ratio and permeability of applied film for O_2 & CO_2 will influence amount of dissolved CO_2 & thus microbial inhibition of atmosphere.

Effect of MAP on nutritional quality of fruits and vegetables

There is a decrease in all phenolic compounds (anthocynanins, flavonols, etc.) in both skin and pulp of grape berries in CO2 enriched atmosphere due to anaerobiosis. Anaerobiosis can lead to unwanted browning and loss of anthocyanins. Low O_2 and high CO_2 enhances retention of ascorbate. But in fresh cut produce high CO_2 causes degradation of vitamin C. Lower O_2 &

enhanced CO_2 reduces loss of provitamin A. No changes in RTE oranges after 11 days at 4 °C in MAP (19% O_2 + 5% CO_2 and 3% O_2 + 25% CO_2).

Equilibrium humidity packaging

Fresh respiring in hermetically sealed packs leads to decreased O_2 and increased CO_2 and H_2O. Increased CO_2 can have inhibitory effect on microbes. However, decreased O_2 can increase risks of anerobic growth of microorganisms like fungi & some bacteria. Similarly, reduced H2O can lead to shriveling and drying of fresh produce. If a produce item's respiratory characteristics are properly matched to film permeability values, then a beneficial equilibrium MA (EMA) (high O_2 and high moisture) can be passively established. This is the concept of equilibrium humidity packaging.

The figure shows the experiment conducted in the laboratory. In improperly designed modified atmosphere package, there is a condensation of moisture, and spoilage of product. When the modified atmosphere is maintained properly, there is no accumulation of moisture observed. So, a study of the transpiration rate (TR) helps to quantify the rate of water evaporation from the fruit surface. And also helps to determine the water vapor transpiration rate required for the

packaging of the fruit.

So basically, equilibrium humidity packaging is can be used to extend the shelf life of fruits and vegetable considerably. If the equilibrium humidity is not maintained inside the water vapor will condense on the walls of the package, it will enhance the bacterial growth. So, to design EHP for the fruit and vegetable, it is essential to have the information and about the rate of water evaporation from produce surface and so, it should be balanced with the water vapor transmission rate of the packaging material and the rate of the water evaporation from the produce surface should be balanced with the water vapor transmission rate of the packaging film and the equilibrium humidity packaging should be maintained, so that there is no condensation of water inside.

The EMAs attained are influenced by (i) Produce respiration rate, (ii) Film permeability, (iii) Pack volume, surface area, fill weight, etc. Different humidity regulation techniques include packaging material like that perforated films, individual shrink wrapping, and enhanced permeable films, and moisture absorbers such as desiccators, humidity regulating trays or pads.

The principle of MAP technology is modifying the headspace composition which depends upon the permeability of film. MAP can be done via four methods viz. active, passive, gas incorporation during packaging and vacuum packaging. The MAP of produce can increase shelf life and preserve quality; however, it increases cost and additional facilitates is needed during functioning. The phenolic compounds and vitamin C get affected due to MAP, however, there is very little change in the carotenoids content.

These are the references used in this lecture. Thank you very much.