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

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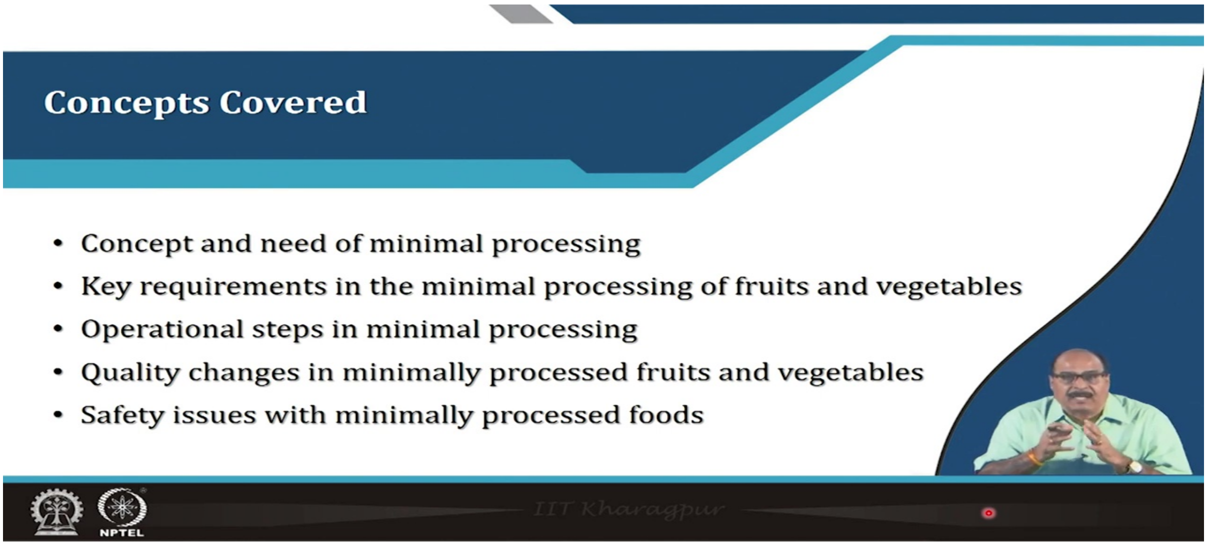
Lecture 21

Minimal Processing

In this lecture various strategies for minimal processing and its application in fruits and vegetables are discussed.

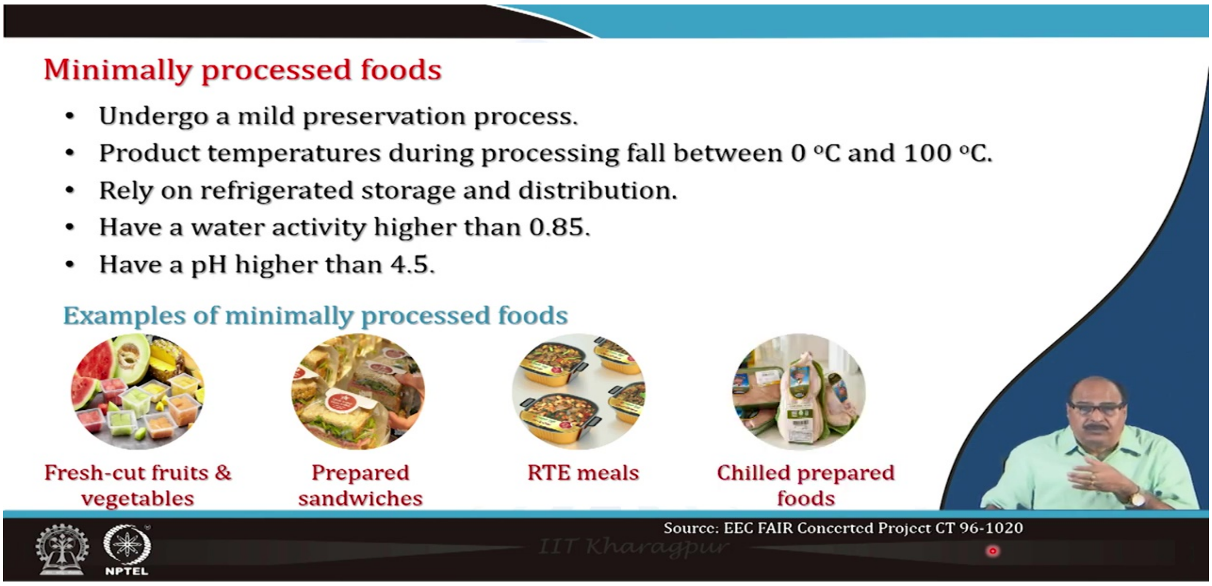


The topic covered in this lecture are Concept and need of minimal processing, key requirements in the minimal processing of fruits and vegetables, operational steps in minimal processing, quality changes in minimally processed fruits and vegetables, and safety issues with minimally processed foods.

Minimal Processing

Minimal processing may be defined as providing least possible treatment to achieve a defined purpose. Other definitions are, fresh produce subjected to different mild processing steps to obtain a fully edible and natural product while providing convenience and functionality to consumer and ensuring food safety. Minimally influence the quality characteristics of a food while at the same time giving the food sufficient self-life during its storage and distribution. Minimal processing should render the material as close as possible to its natural counterpart. The treatment given to the food material should be of minimum extent to get the desired value and shelf-life extension.

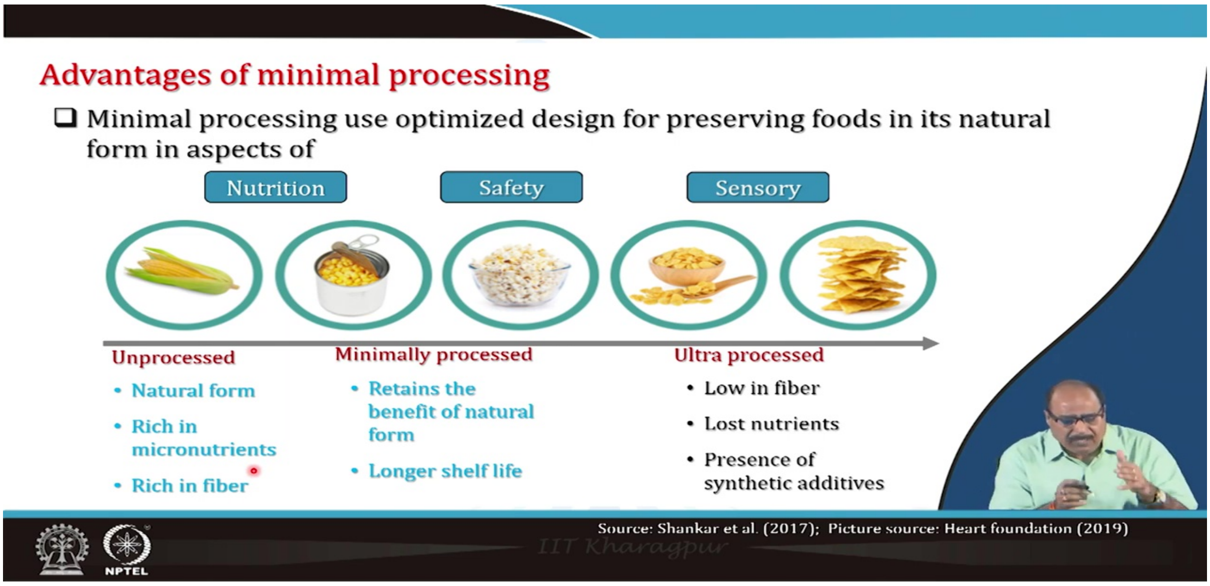
Minimally Processed Foods



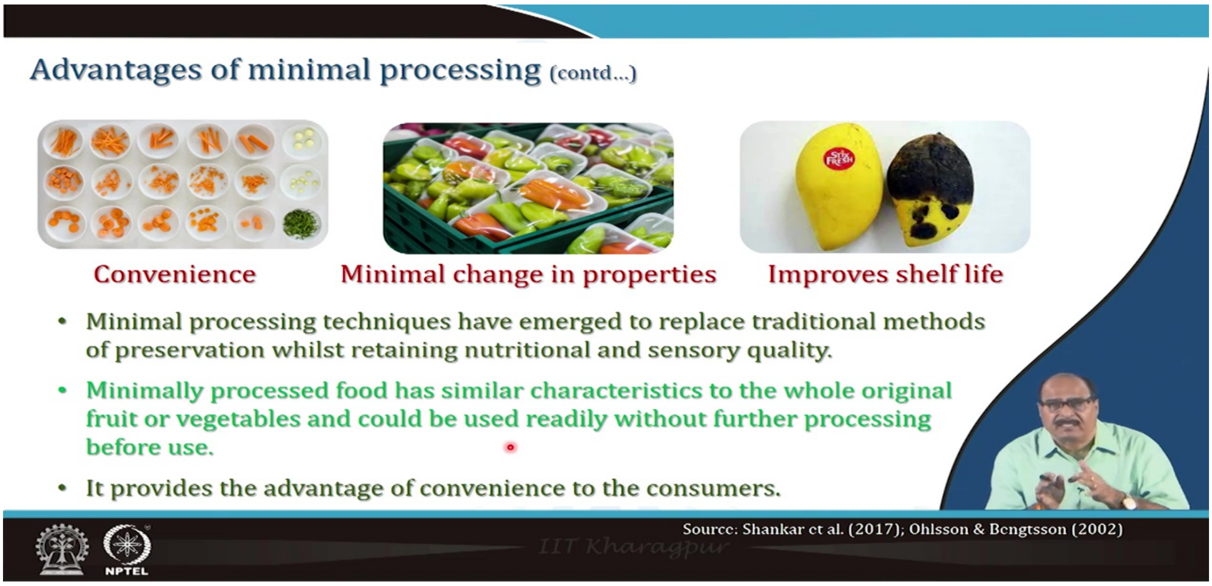
Minimally processed food undergoes a mild preservation process. The product temperature during processing falls between 0°C and 100°C. They rely on refrigerated storage and distribution. They have water activity higher than 0.85 and pH higher than 4.5. Examples of minimally processed foods may include fresh cut fruits and vegetables, prepared sandwich, ready to eat meals and chilled prepared foods.

Advantages of Minimal Processing

Minimal processing uses the optimized design for preserving foods in its natural form in aspect of its nutrition, safety and sensory characteristics.

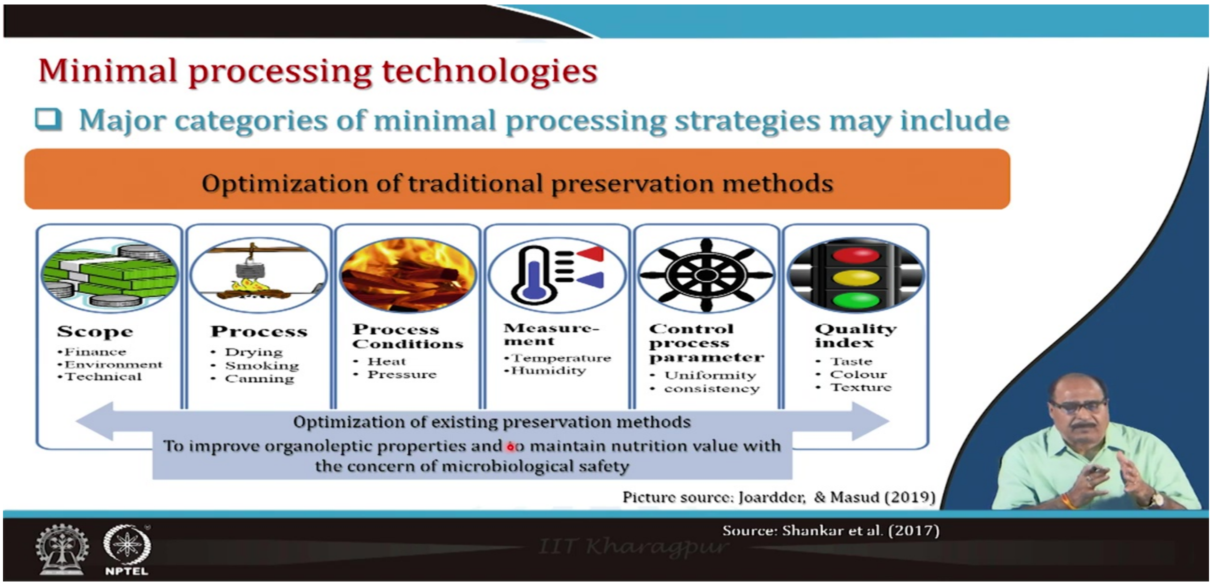


The figure shows the comparison of unprocessed, minimally processed food and ultra processed foods. Unprocessed food is in its natural form, rich in micronutrients, fiber and other nutritional value. Minimally processed are subjected to some treatment, processing and packaging that they retain the benefits of its natural form while extending the shelf life. The ultra-processed foods are low in fiber, nutrients and has added synthetic additives depending on the processing technology and methods of processing.

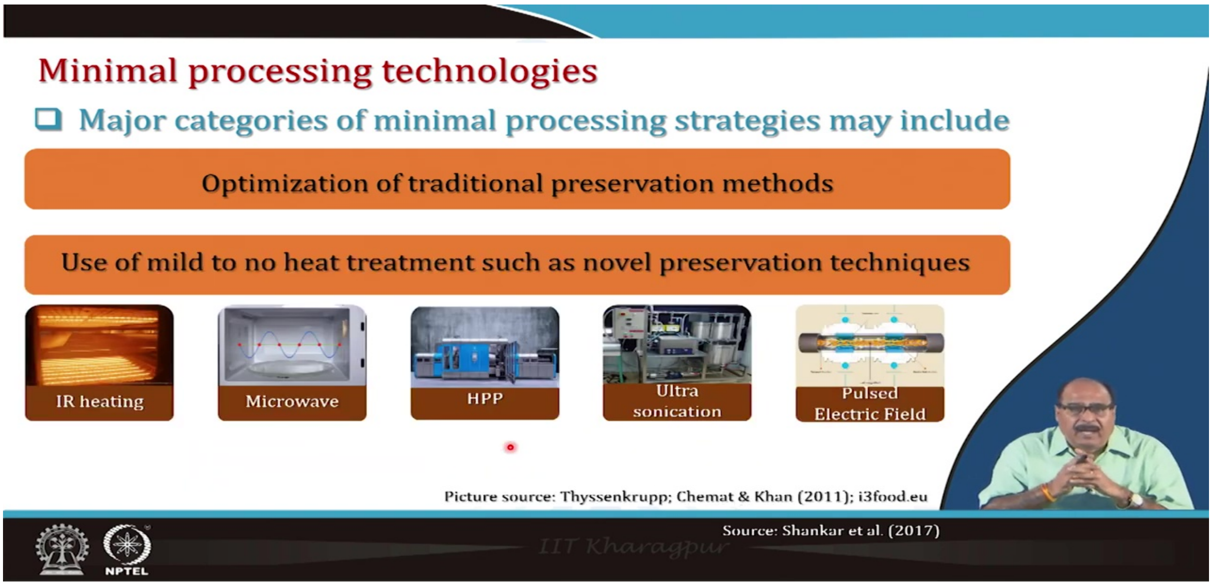


Minimal processing techniques have emerged to replace traditional methods of preservation whilst retaining nutritional and sensory quality. Minimally processed food has similar characteristics to the whole original fruit or vegetables and could be used readily without further processing before use. It provides the advantage of convenience to the consumers.

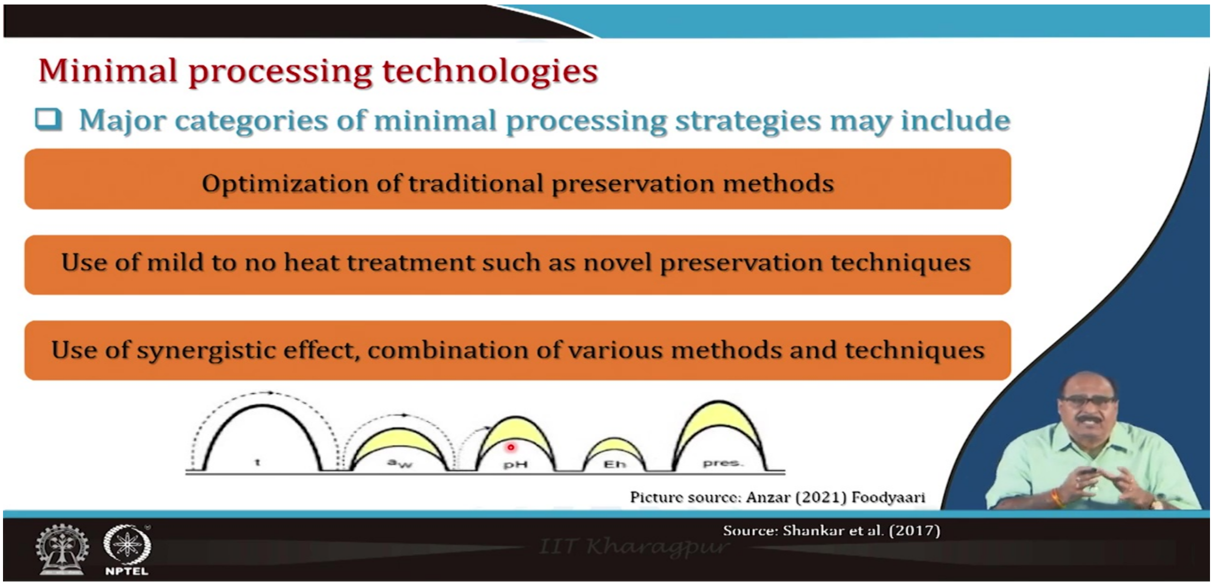
Minimal Processing Technologies



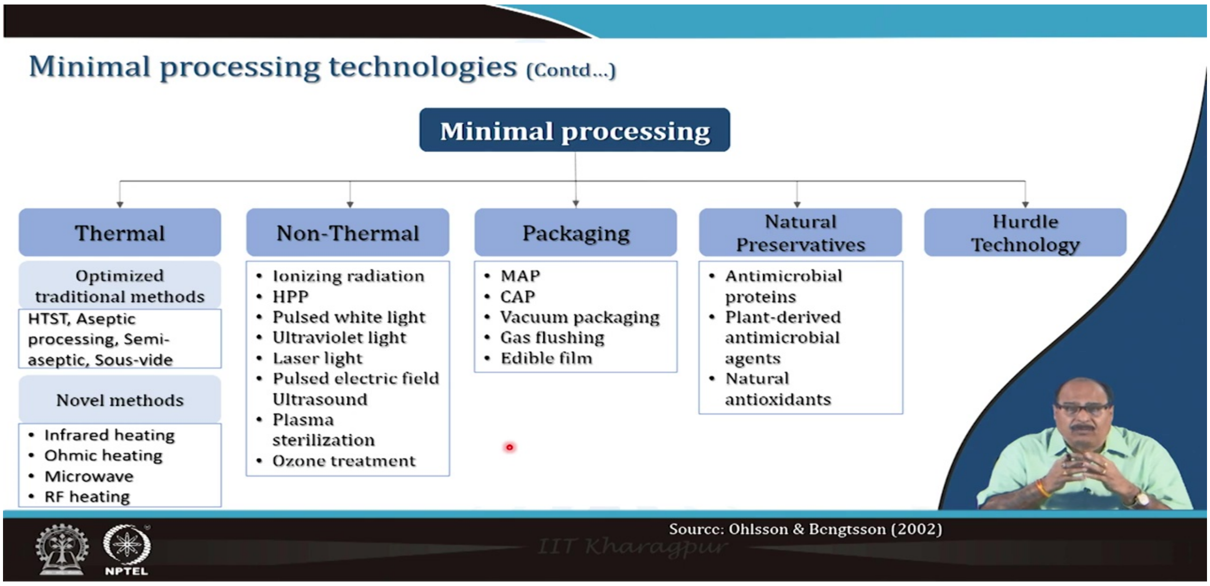
Major categories of the minimal processing strategies may include optimization of the traditional preservation methods. The traditional processing methods are optimized in such a way to get minimum possible conditions such as low heat, pressure, low salt concentration, et cetera to improve organoleptic properties and to maintain nutrition value with the concern of microbiological safety.



It uses mild to no heat treatment such as novel preservation techniques like infrared heating, microwave heating, high pressure processing, ultrasonication, pulsed and electric field processing. These are the novel advanced thermal technologies or non-thermal technologies which can be used to reduce the severity of the processes and get better nutritional properties.

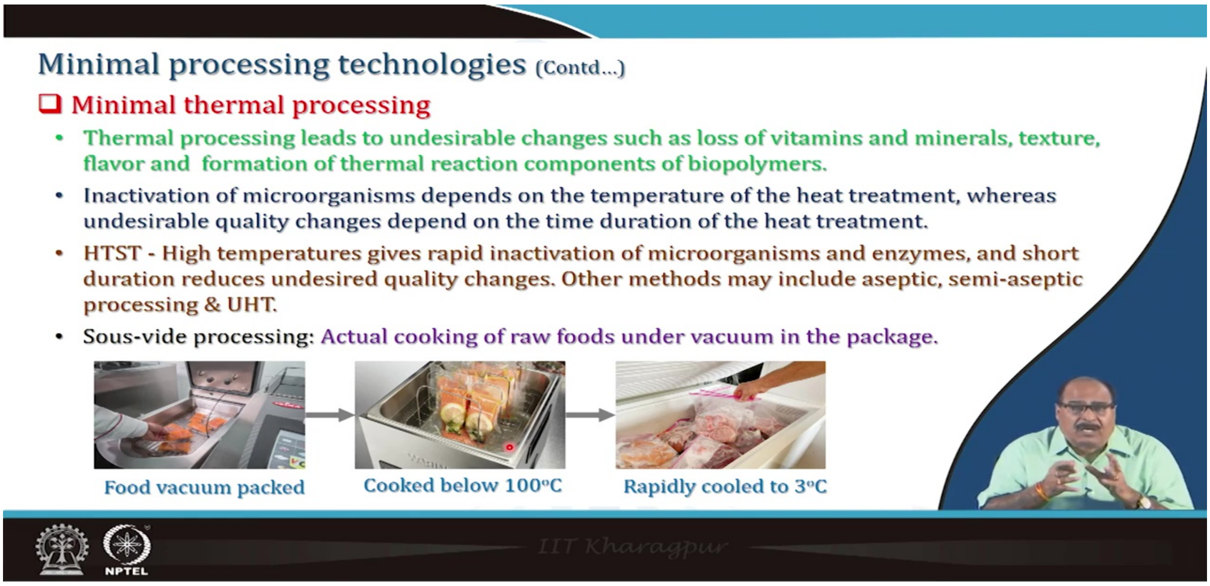


It uses synergistic effect that is the combination of various methods and techniques. The figure shows the concept of hurdle technology in which various preservation techniques like temperature, water activity, pH, oxidation reduction potentials, various chemicals and pressure are used in combination to reduce the severity of the process to extend the shelf life while having better nutritional value.



Minimal processing technologies may be thermal technologies like optimized traditional methods or novel thermal methods. Optimized traditional thermal methods includes high temperature short time methods, aseptic processing, semi aseptic processing, or sous-vide. Novel thermal technologies include infrared heating, ohmic heating, microwave heating, and radiofrequency heating. Non-thermal technologies are ionizing radiation, high pressure processing, pulsed white light, ultraviolet light, laser light, pulsed electric field, ultra sound, plasma sterilization, ozone treatment, etc. Packaging involves modified atmosphere packaging, control atmosphere packaging/Storage, vacuum packaging, gas flushing, edible film, edible coating, etc. Use of natural preservative like antimicrobial proteins, plant derived antimicrobial agents and natural antioxidants can also be categorized as minimal processing. Hurdle technology is combination of different preservation technologies.

Minimal Thermal Processing: Traditional Methods

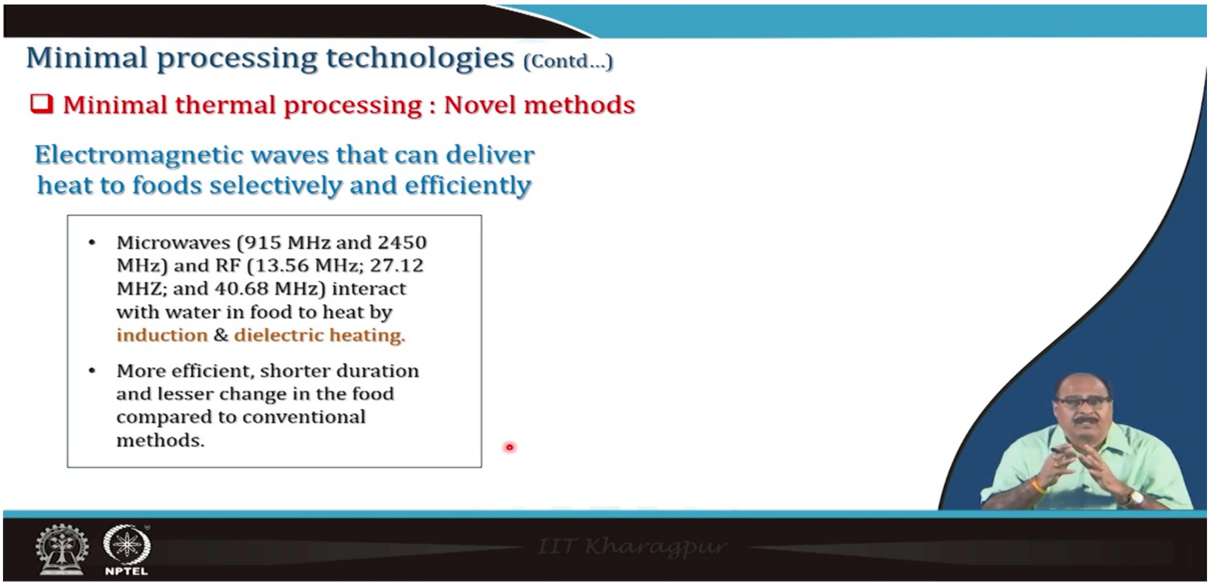


Thermal processing leads to undesirable changes such as loss of vitamins and minerals, texture, flavor and formation of thermal reaction components of biopolymers. Inactivation of microorganisms depends on the temperature of the heat treatment, whereas undesirable quality changes depend on the time duration of the heat treatment. In HTST, high temperatures gives rapid inactivation of microorganisms and enzymes, and short duration reduces undesired quality changes. Other methods may include aseptic, semi-aseptic processing & UHT. Sous-vide processing is actual cooking of raw foods under vacuum in the package.

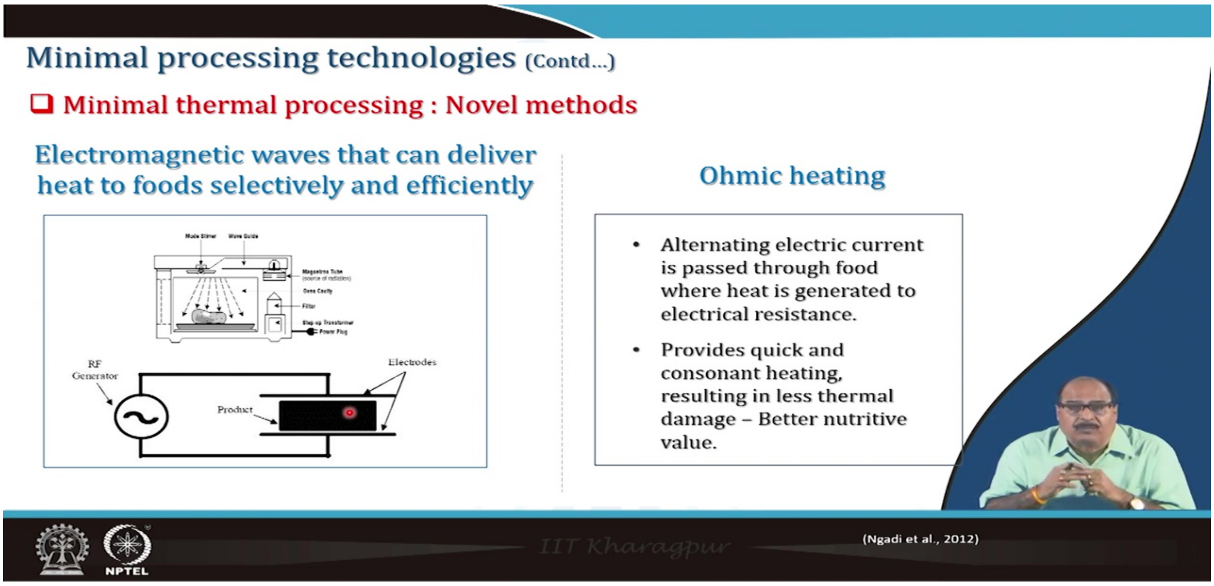
At high temperature and short time heating, the rate of the bacterial inactivation is very fast, but the nutrient destruction is comparatively low due to difference in the Z value of microbes and nutrients. The Z value of the microorganism is less compared to Z value of the vitamins price. This property is taken into advantage in the HTST processes, aseptic methods and ultra-high temperature processing.

Minimal Thermal Processing: Novel Methods

Electromagnetic Heating



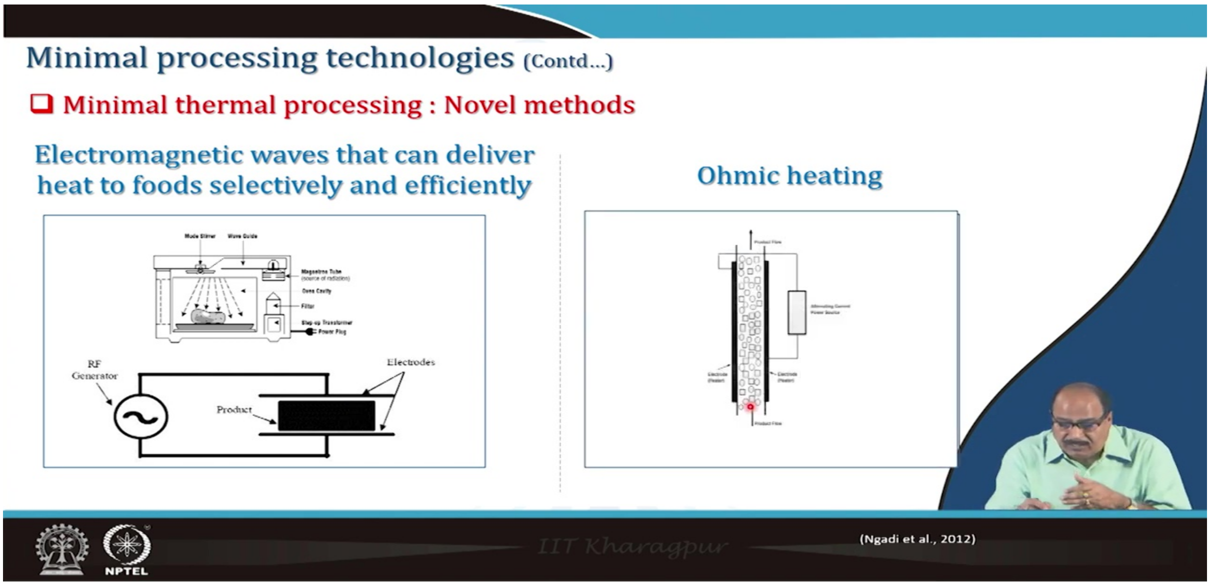
Electromagnetic waves deliver heat to food selectively and effectively like microwaves and radiofrequency waves. Microwaves (915 MHz and 2450 MHz) and RF (13.56 MHz; 27.12 MHZ; and 40.68 MHz) interact with water in food to heat by induction and dielectric heating, which is also known as volumetric/ internal heating. This type of heating is more efficient, takes lesser duration and causes lesser change in the food compared to conventional methods.



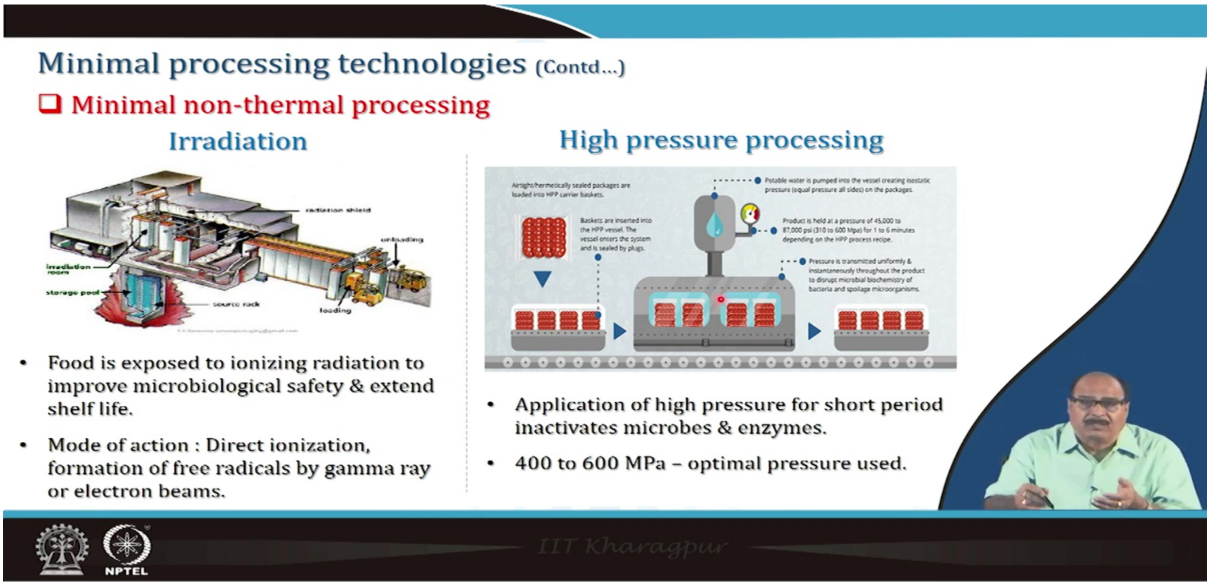
The figure shows the schematic diagram of a microwave and RF heater. The microwaves are generated by the magnetron and distributed to the oven cavity via the wave guide. The microwave reaches the food kept in the oven cavity and causes dielectric heating. In case of the RF heater, the food is placed between two electrodes, where RF is generated.

Ohmic Heating

In ohmic heating, alternating electric current is passed through food where heat is generated to electrical resistance. Provides quick and consonant heating, resulting in less thermal damage and thus providing better nutritive value.



The figure provided shows the schematic diagram of ohmic heating set up. It consists of two electrodes that provides the alternating electric current. The food product is placed or passed through the gap between the two electrodes.



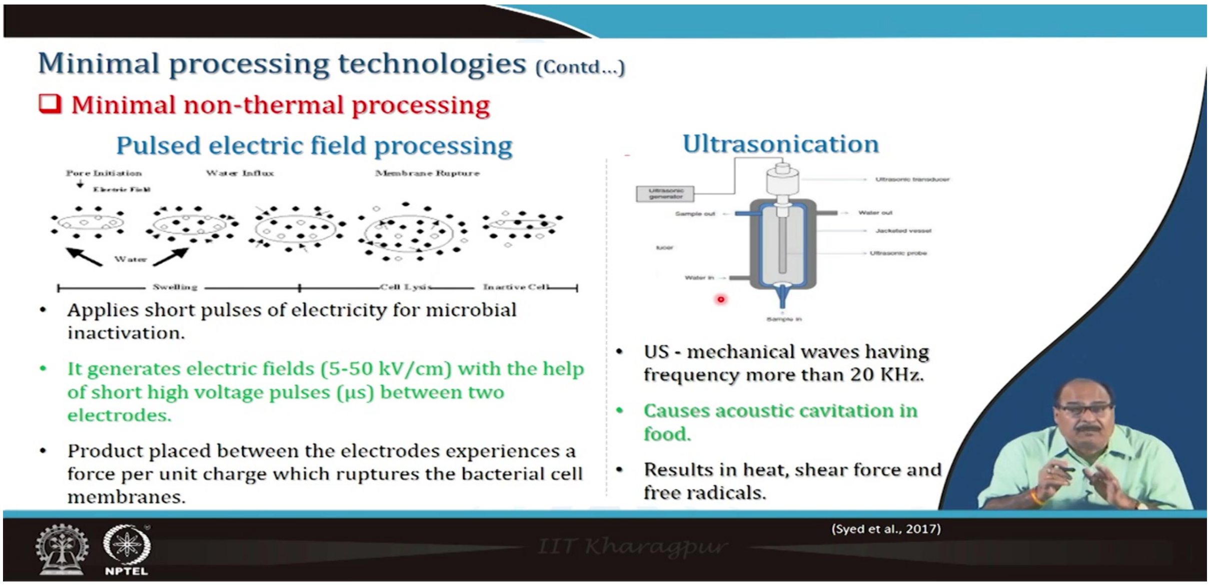
Irradiation

In irradiation technology, food is exposed to ionizing radiation to improve microbiological safety and extend shelf life. Mode of action of this technology is direct ionization of fresh produce and formation of free radicals by gamma ray or electron beams, which kills the pathogenic microbes without affecting the produce quality. The figure shows the source rack, storage pool, irradiation room, radiation and loading, unloading stations of an irradiation plant.

High Pressure Processing

One of the emerging non thermal techniques that has wide application as minimal processing is high pressure processing. In this, the fresh produce or food is applied with high hydrostatic pressure of about 400 to 600 mega Pascal. Application of high pressure for short period inactivates microbes & enzymes.

The figure shows the HPP process. The food material is packed airtight or hermetically sealed and loaded into HPP carrier baskets. The baskets are inserted into the HPP vessel. The vessel enters the system and is sealed by plugs. Potable water is pumped into the vessel creating isocratic pressure (equal pressure on all sides) on the packages. Product is held at the pressure of 45,000 to 87,000 psi (310 to 600 Mpa) for 1 to 6 minutes depending on the HPP process recipe. Pressure is transmitted uniformly and instantaneously throughout the product to disrupt microbial biochemistry of bacteria and spoilage microorganisms.

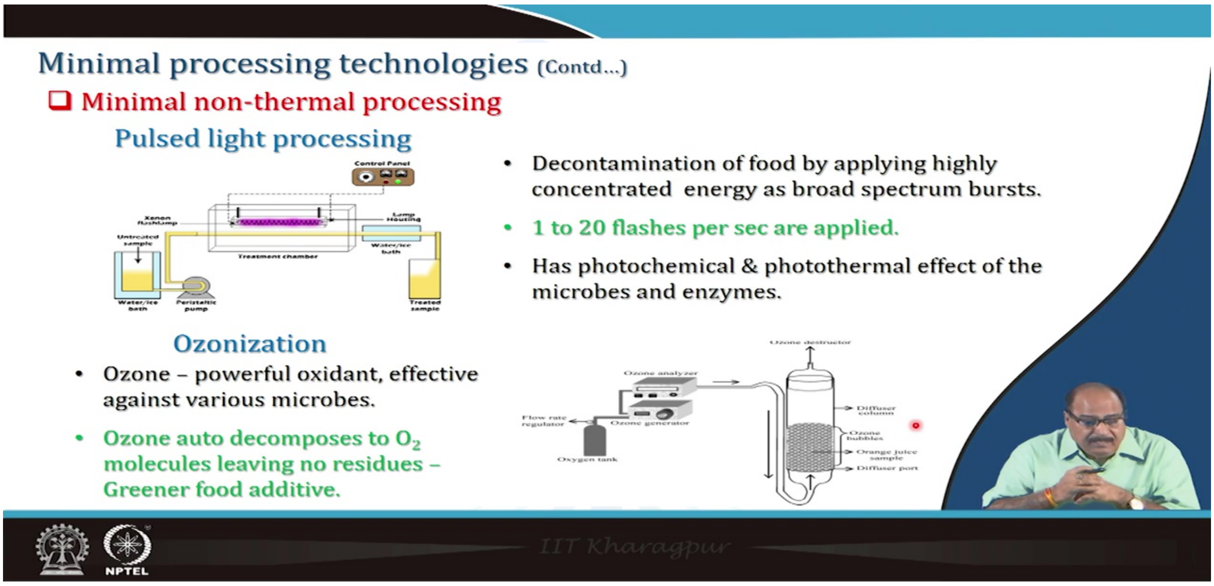


Pulsed Electric Field

Pulsed electric field processing applies short pulses of electricity for microbial inactivation. It generates electrical fields (5 – 50 kV/cm) with the help of short high voltage pulses (μs) between two electrodes. Product placed between the electrode experiences a force per unit charge which ruptures the bacterial cell membranes. Treatment of fruits with PEF has also shown to improve the juice extractability, thus allowing rupture of fruit cell walls with minimal pressure. This prevents nutritional losses and bio-actives losses as extraction happens at minimum pressure as opposed to regular pressure, which generates heat. The figure shows the process of pore initiation on the bacterial cell wall by electrical field. This causes inflex of water into the cells, followed by swelling, rupture and inactivation of cells.

Ultrasonication

Ultrasonication involves mechanical waves having frequency more than 20 kilohertz. This causes acoustic cavitation in food and results in heat, shear force and free radical formation. This also used to improve the juice extractability of fruits. The figure shows the ultrasonic generator which consists of an ultrasonic transducer and ultrasound probe. The ultrasound probe generates and transfers the ultrasound into the food materials. The sample enters from the bottom of the chamber and exists at the top of the chamber. The chamber is double jacketed to circulate water for temperature regulation.



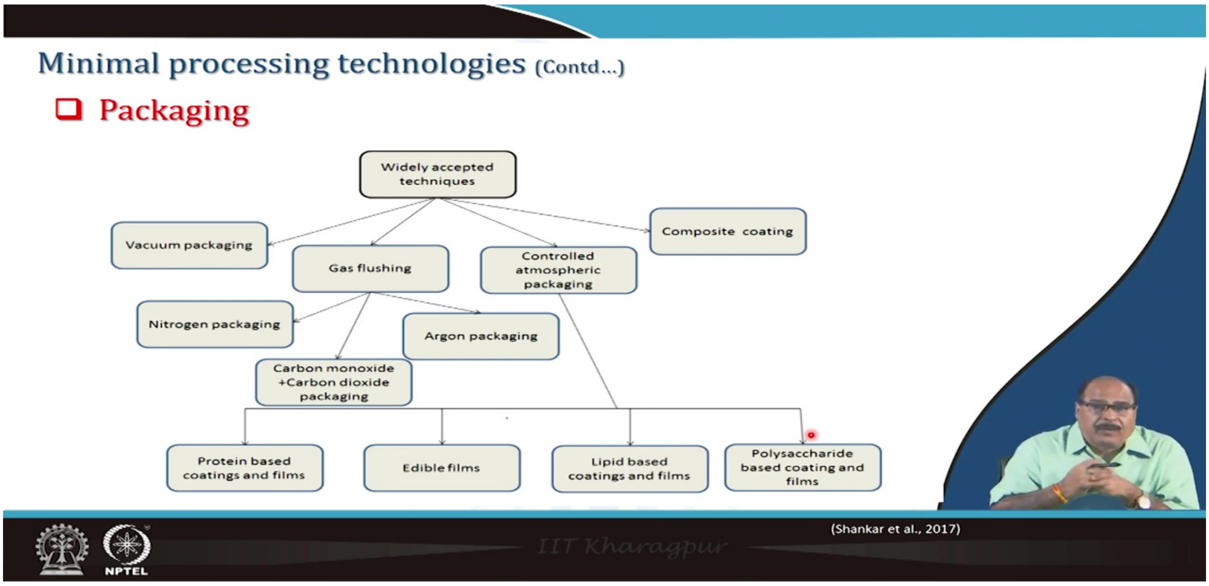
Pulsed Light Processing

In pulsed light processing, decontamination of food is achieved by applying highly concentrated energy as broad spectrum bursts. About 1 to 20 flashes per sec are applied to the food material. It has photochemical & photothermal effect of the microbes and enzymes. The pulsed light processing setup consists of a treatment chamber equipped with xenon flash lamp, through which the product is passed through for the treatment.

Ozonation

Ozone is a powerful oxidant and shown to be effective against various microbes. When applied on food material it auto decomposes to O_2 molecules leaving no residues. Ozonation is considered as greener food additive that has been permitted by FDA. The setup consists of an ozone generator that generates ozone. It is passed through an analyzer and then to a diffusion chamber where the food material is placed. Ozone passes through the product disinfecting it and moves out to ozone destructor.

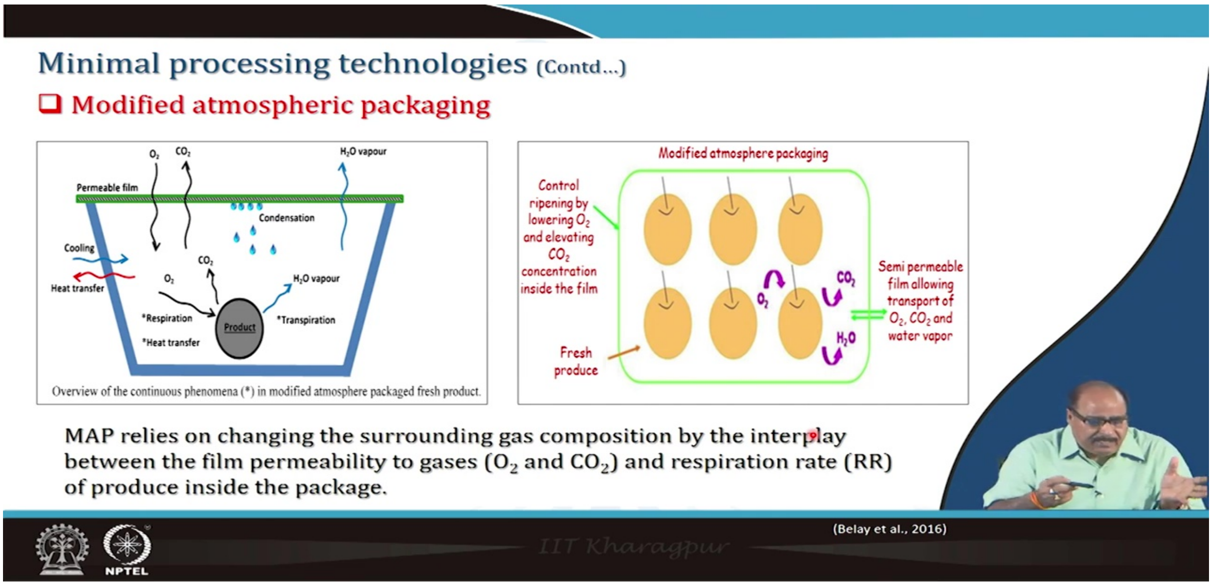
Packaging



Other than processing, different packaging intervention is also accepted as type of minimal processing strategies, especially for the whole produces. Widely accepted packaging techniques are vacuum packaging, gas flushing packaging like nitrogen packaging, argon packaging or carbon monoxide and carbon dioxide packaging. Other method is controlled atmosphere packaging where the packaging environments atmosphere composition is controlled and maintained to a particular ratio. Other type is composite coating of the produce. The coatings used may be protein-based films, edible films, lignin based coating films or polysaccharide based coating films.

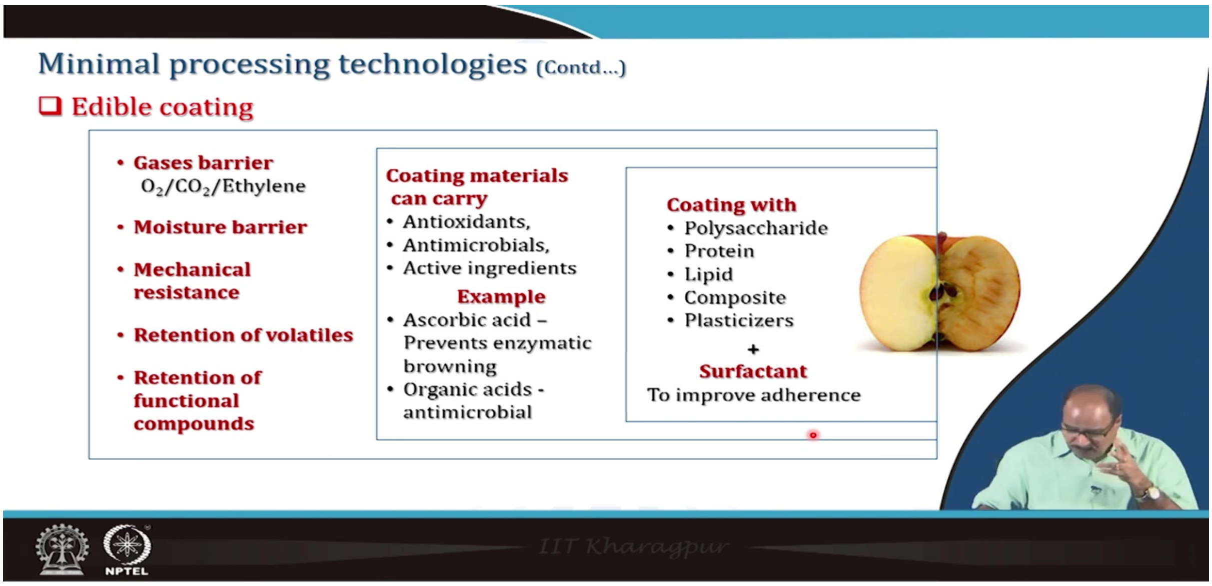
Modified Atmospheric Packaging

MAP relies on the changing the surrounding gas composition by interplay between the film permeability to gases (O_2 and CO_2) and respiration rate of the product inside the package



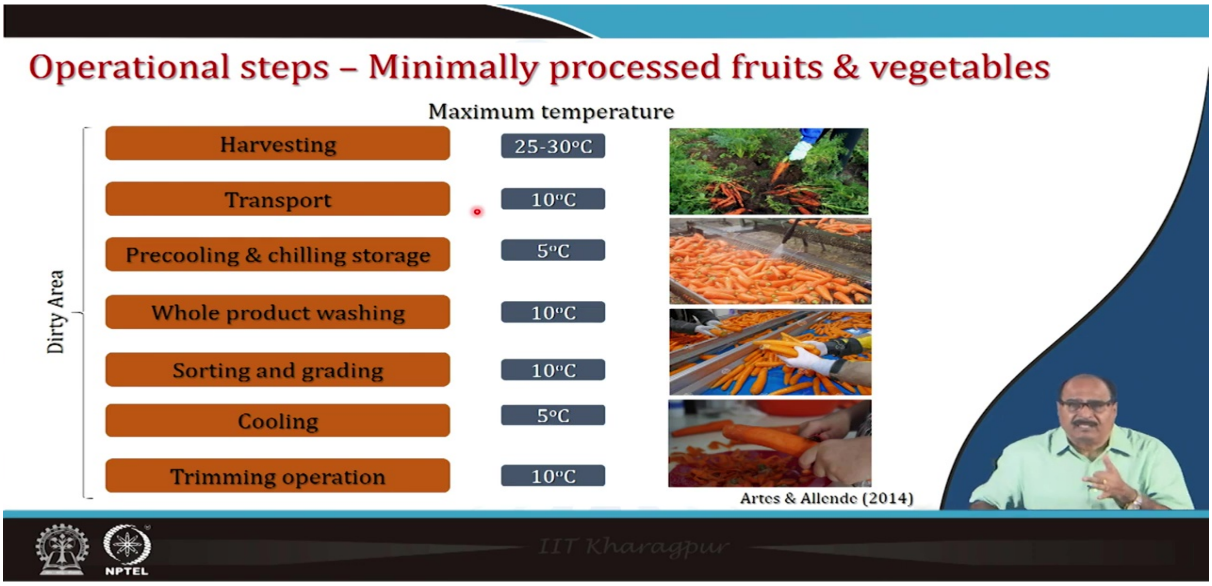
As shown in the figure provided, MAP of fresh produce allows the produce to breath by permitting O_2 and CO_2 transmission. It also allows transmission of water vapor outside to prevent condensation and allows transpiration. It controls ripening by lowering O_2 and elevating CO_2 concentration inside film. Semi permeable film allows transport of O_2, CO_2 and water vapor.

Edible Coating



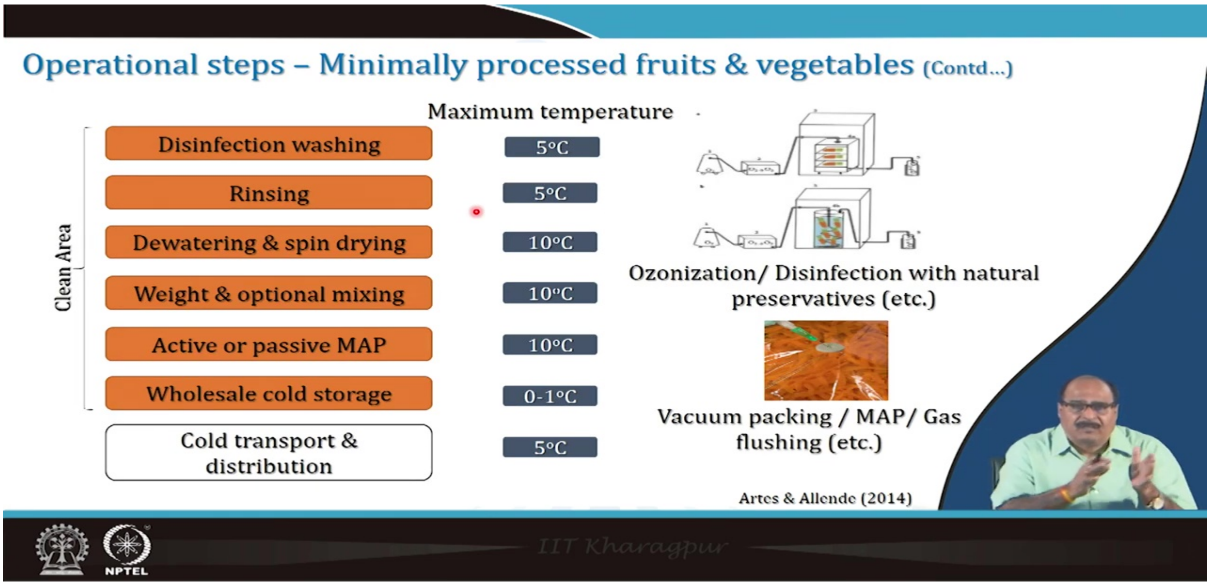
Edible coating includes coating of the produce with polysaccharide, protein, lipid, composite, plasticizers with a surfactant to improve the adherence. The coating material can carry antioxidant, antimicrobials or any active ingredients to provide additional functions, such as ascorbic acid to prevent enzymatic browning or organic acids to provide antimicrobial properties. The edible coating acts by improving barrier properties against O_2, CO_2 and ethylene, moisture barrier, mechanical resistance, by retention of volatiles and functional compounds.

Operational Steps – Minimally Processed Fruits & Vegetables



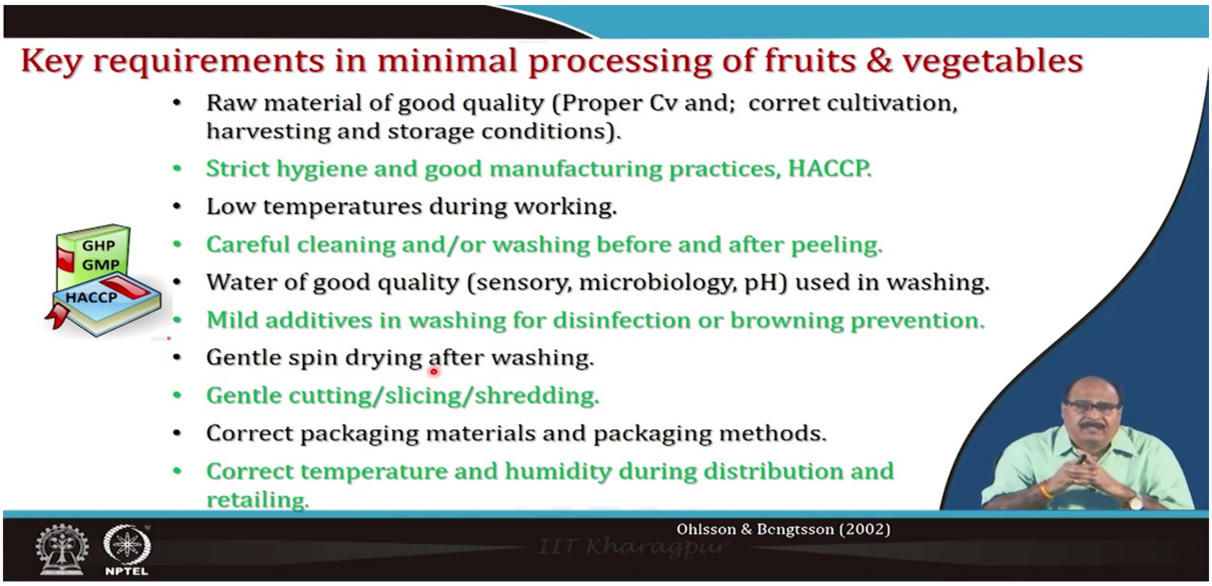
Operational steps of minimally processed fruits and vegetables includes harvesting, transport, pre-cooling, chilling storage, whole produce washing, sorting and grading, cooling and trimming operation. During these process operations the temperature should be maintained between 5 to 10 °C, except during harvesting where the temperature should be between 25 to 30 °C. The temperatures should be maintained in each and every step so that any possible destruction of the nutrients and change in the composition of nutrients bioactive in fruits and vegetable could be minimized.

After trimming operation, the produce enters the processing area which is a clean area. The produce is disinfected either by convention washing with disinfectants or by ozonation or by using natural preservatives. The disinfection step is followed by rinsing, dewatering and spin drying, weight and optional mixing. After processing it is packaged by active or passive modified atmosphere packaging or vacuum packaging or gas flushing before wholesale or cold storage and distribution.

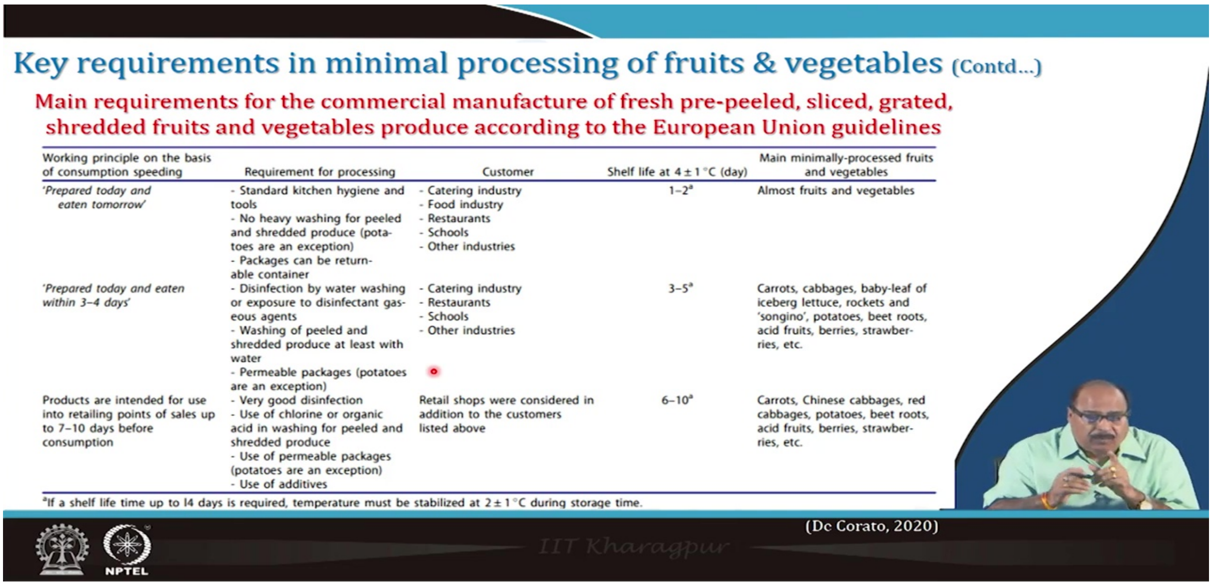


The temperature should be maintained at maximum allowable limit during different operational steps to get better quality. The temperature should be maintained between 5 to 10°C at every step except during cold storage where it should be stored at temperature 0 to 1°C for long term storage without quality losses.

Key Requirement in Minimal Processing of Fruits and Vegetables



The key requirement in minimal processing of fruits and vegetable are Raw material of good quality of proper cultivar, correct cultivation, harvesting and storage conditions. Strict hygiene and good manufacturing practices, HACCP. Low temperatures during working. Careful cleaning and/or washing before and after peeling. Water of good quality (sensory, microbiology, pH) used in washing. Mild additives in washing for disinfection or browning prevention. Gentle spin drying after washing. Gentle cutting/slicing/shredding. Correct packaging materials and packaging methods. Correct temperature and humidity during distribution and retailing.

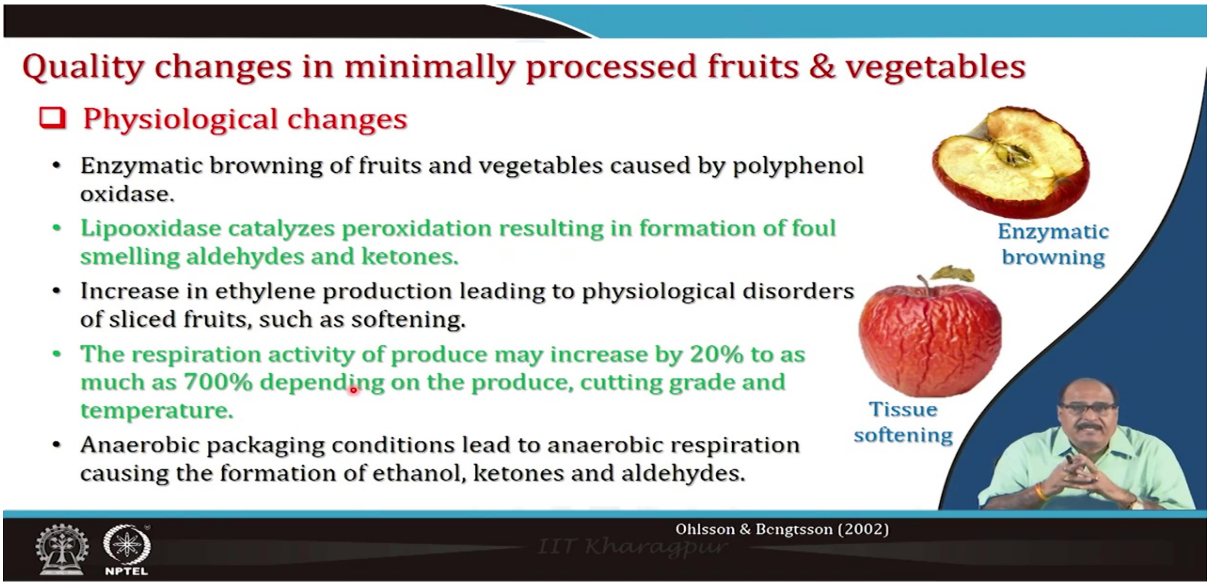


Working principle on the basis of consumption speeding	Requirement for processing	Customer	Shelf life at 4 ± 1 °C (day)	Main minimally-processed fruits and vegetables
'Prepared today and eaten tomorrow'	- Standard kitchen hygiene and tools - No heavy washing for peeled and shredded produce (potatoes are an exception) - Packages can be returnable container	- Catering industry - Food industry - Restaurants - Schools - Other industries	1–2[a]	Almost fruits and vegetables
'Prepared today and eaten within 3–4 days'	- Disinfection by water washing or exposure to disinfectant gaseous agents - Washing of peeled and shredded produce at least with water - Permeable packages (potatoes are an exception)	- Catering industry - Restaurants - Schools - Other industries	3–5[a]	Carrots, cabbages, baby-leaf of iceberg lettuce, rockets and 'songino', potatoes, beet roots, acid fruits, berries, strawberries, etc.
Products are intended for use into retailing points of sales up to 7–10 days before consumption	- Very good disinfection - Use of chlorine or organic acid in washing for peeled and shredded produce - Use of permeable packages (potatoes are an exception) - Use of additives	Retail shops were considered in addition to the customers listed above	6–10[a]	Carrots, Chinese cabbages, red cabbages, potatoes, beet roots, acid fruits, berries, strawberries, etc.

[a] If a shelf life time up to 14 days is required, temperature must be stabilized at 2 ± 1 °C during storage time.

Main requirements for the commercial manufacture of fresh pre-peeled, sliced, grated, shredded fruits and vegetables produce according to the European Union guidelines are provided as follows. There should be standard kitchen hygiene and tools, no heavy washing for peeled and shredded produce (potatoes are an exception), packages can be returnable containers for 'prepared today and eaten tomorrow' types of food. It is applicable to almost all fruits and vegetables. The shelf life of such products at 4 °C is 1 to 2 days. The customers are mainly catering industry, food industry, restaurants, schools and other industries. For foods that are prepared today and eaten within 3 to 4 days, the requirements for processing are disinfection by water washing or exposure to disinfectant gaseous agents, washing of peeled and shredded produce at least with water and permeable packages. At 4 °C they can be stored for 3 to 5 days. It includes carrots, cabbages, baby leaf of iceberg lettuce, rockets, and songino potatoes, beet roots, acid fruits, berries and strawberries, and the customers are catering industries, restaurants, schools and other industries. For products that are intended for use into retailing points of sales up to 7 to 10 days before consumption, the requirements are very good disinfectant, use of chlorine or organic acid in washing for peeled and shredded produce, use of permeable packages and used of additives. Such process is applicable for carrots, Chinese cabbages, red cabbages, potatoes, beet roots, acid fruits, berries, and strawberries and at 4 °C they can be stored for 6 to 10 days. The customers for these products are the retail shops mainly.

Quality Changes in Minimally Processed Fruits and Vegetables

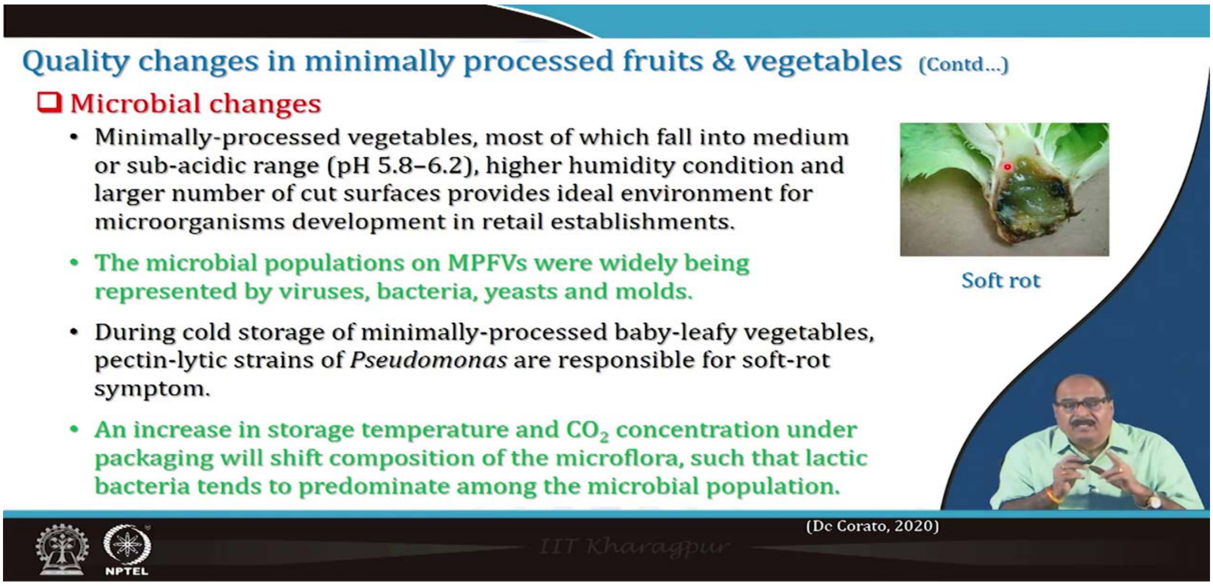


Physiological Changes

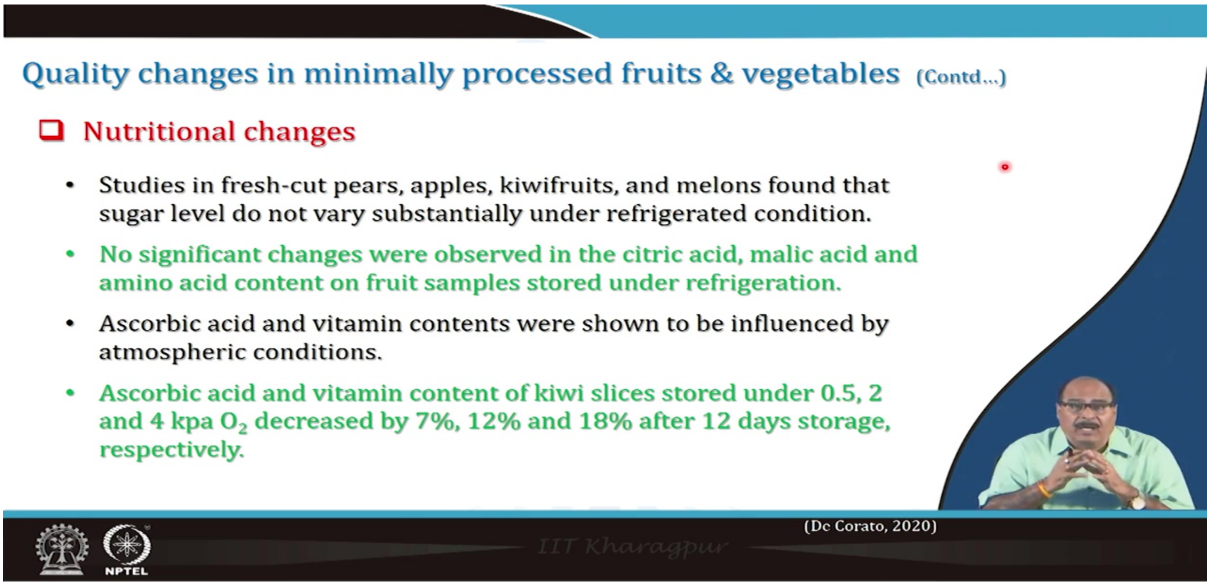
In minimally processed fruits and vegetables there will be physiological changes such as enzymatic browning caused by polyphenol oxidase enzymes. Lipooxidase catalyzes peroxidation resulting in the formation of foul-smelling aldehydes and ketones. There will be increase in ethylene production, ethylene production leading to physiological disorders of sliced fruits, such as softening. The respiration activity of produce may increase by 20% to as much as 700% depending on the produce, cutting grade and temperature. Anaerobic packaging conditions lead to anaerobic respiration causing the formation of ethanol, ketones and aldehydes. Physiological effects such as enzymatic browning and tissue softening are shown in the figure provided.

Microbial Changes

Minimally-processed vegetables, most of which fall into medium or sub-acidic range (pH 5.8–6.2), higher humidity condition and larger number of cut surfaces provides ideal environment for microorganisms development in retail establishments. The microbial populations on MPFVs were widely being represented by viruses, bacteria, yeasts and molds. During cold storage of minimally-processed baby-leafy vegetables, pectin-lytic strains of *Pseudomonas* are responsible for soft-rot symptom. An increase in storage temperature and CO_2 concentration under packaging will shift composition of the microflora, such that lactic bacteria tend to predominate among the microbial population. Soft rot due to microbial action is shown in the figure provided.

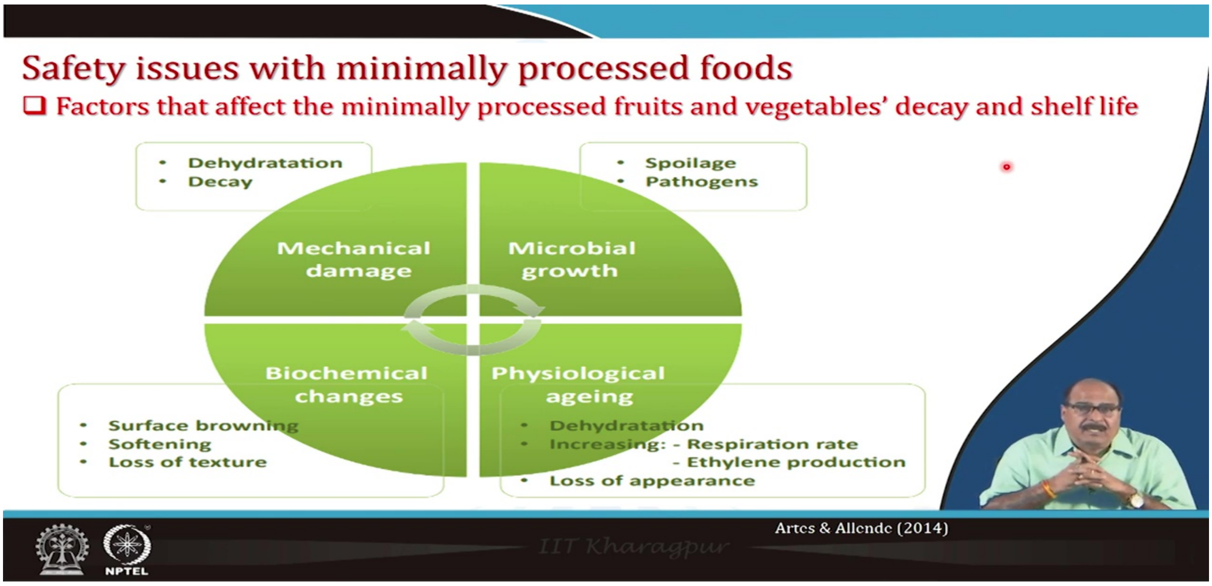


Nutritional Changes

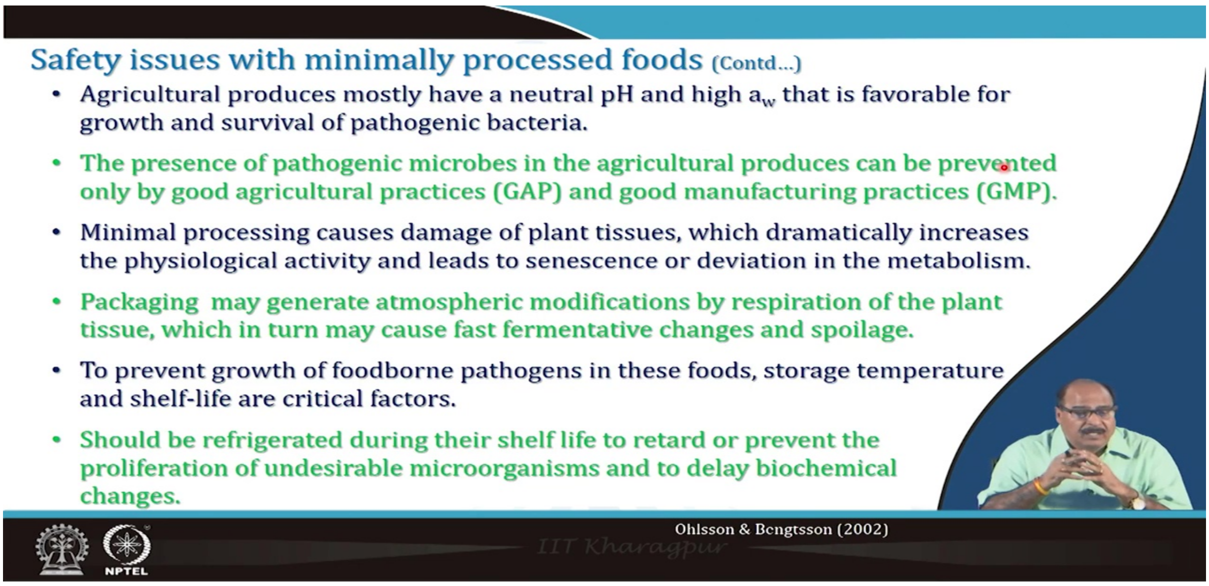


Studies in fresh-cut pears, apples, kiwifruits, and melons found that sugar level do not vary substantially under refrigerated condition. No significant changes were observed in the citric acid, malic acid and amino acid content on fruit samples stored under refrigeration. Ascorbic acid and vitamin contents were shown to be influenced by atmospheric conditions. Ascorbic acid and vitamin content of kiwi slices stored under 0.5, 2 and 4 kpa O_2 decreased by 7%, 12% and 18% after 12 days storage, respectively.

Safety Issues with Minimally Processed Foods

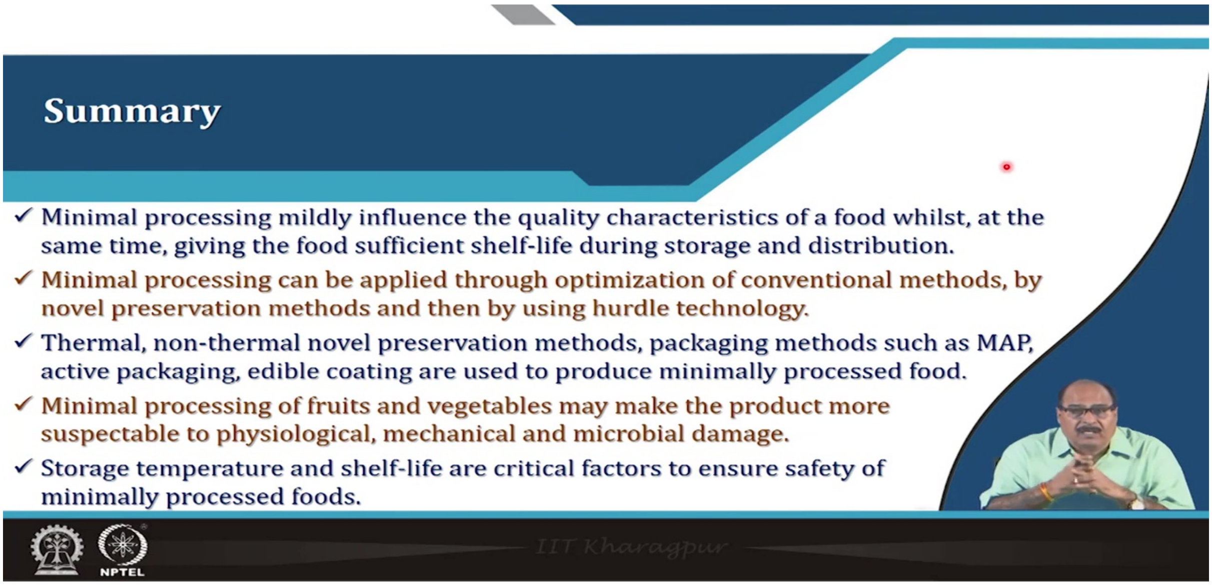


Factors that affect the minimally processed fruits and vegetables decay and shelf life are due to mechanical damage that could lead to dehydration and decay and it may act as a vector for microbial growth or oxidation as enzymes may get released. Other safety issue is microbial growth like growth of spoilage organisms and pathogens growth. Physiological aging leads to dehydration, increase in respiration rate, ethylene production and loss of appearance due tissue softening. Biochemical changes include surface browning, softening and loss of texture.



Agricultural produces mostly have a neutral pH and high-water activity that is favorable for the growth and survival of the pathogenic bacteria. The presence of pathogenic microbes in the agricultural produces can be prevented only by good agricultural practices (GAP) and good manufacturing practices (GMP). Minimal processing causes damage to plant tissues, which dramatically increases the physiological activity and lead to senescence or deviation in the metabolism. Packaging may generate atmospheric modification by respiration of the plant tissue, which in turn may cause fast fermentative changes and spoilage. MAP / CAP or other types of packaging should be used to ensure absence of anaerobic respiration which will lead to fermentation and spoilage of the fruits and vegetables. To prevent the growth of foodborne pathogen in these foods, storage temperature and shelf lives are critical factors. The produces should be refrigerated during their shelf life to retard or prevent the proliferation of undesirable microorganisms and to delay biochemical changes.

Summary



Minimal processing mildly influences the quality characteristics of a food whilst, at the same time, giving the food sufficient shelf-life during storage and distribution. Minimal processing can be applied through optimization of conventional methods, by novel preservation methods and then by using hurdle technology. Thermal, non-thermal novel preservation methods, packaging methods such as MAP, active packaging, edible coating are used to produce minimally processed food. Minimal processing of fruits and vegetables may make the product more suspectable to physiological, mechanical and microbial damage. Storage temperature and shelf-life are critical factors to ensure safety of minimally processed foods.

The reference for further reading is provided in the slide.