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

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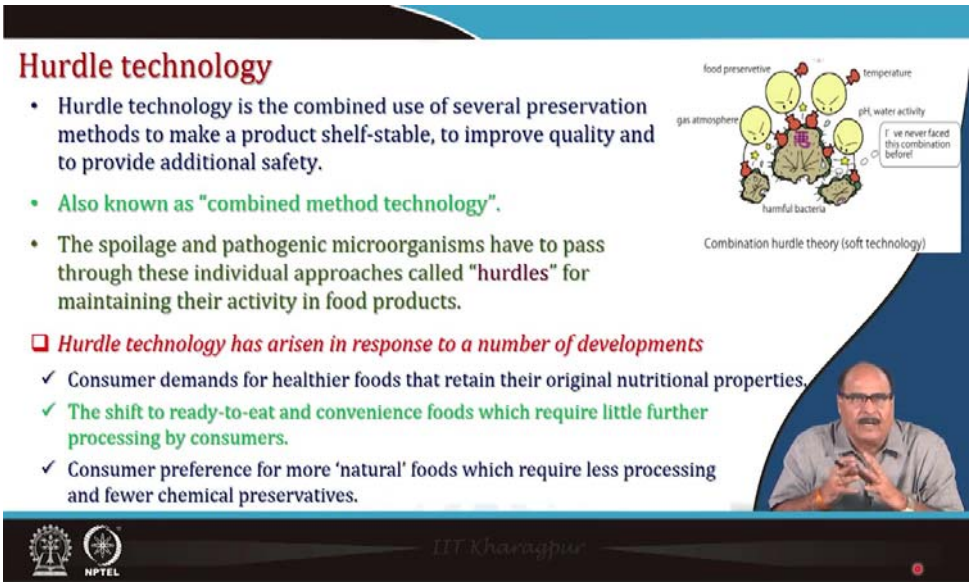
Lecture 22
Hurdle Technology Concepts

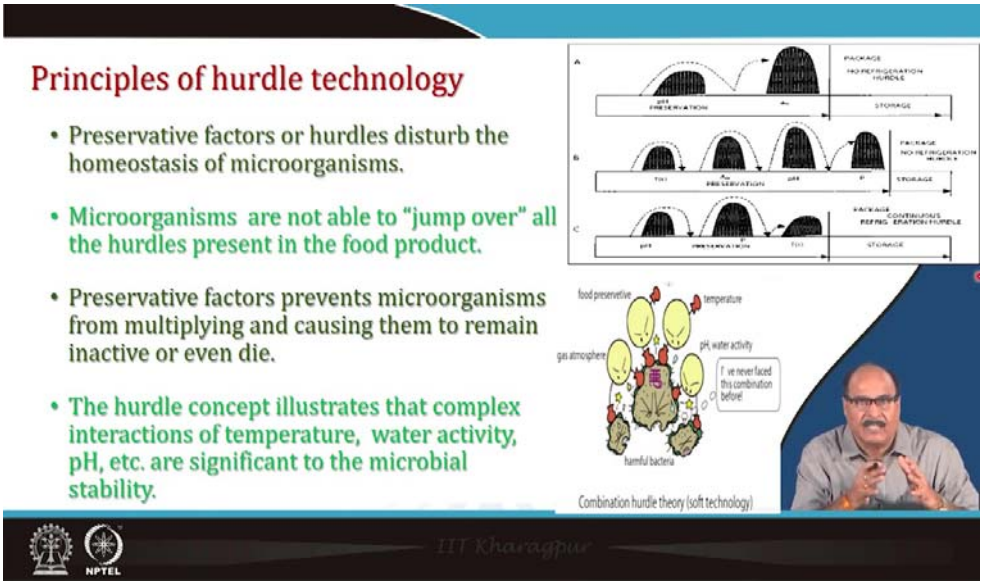
The concepts in this lecture covers various aspects of hurdle technology, types and effects of hurdles, effects of certain hurdles or microorganisms, non-thermal hurdle techniques, and effects of hurdle on product quality.



Hurdle technology

Hurdle technology is the combined use of several preservation methods to make a product shelf-stable, to improve quality and to provide additional safety. It is also known as "combined method technology". The spoilage and pathogenic microorganisms have to pass through these individual approaches called "hurdles" for maintaining their activity in food products.

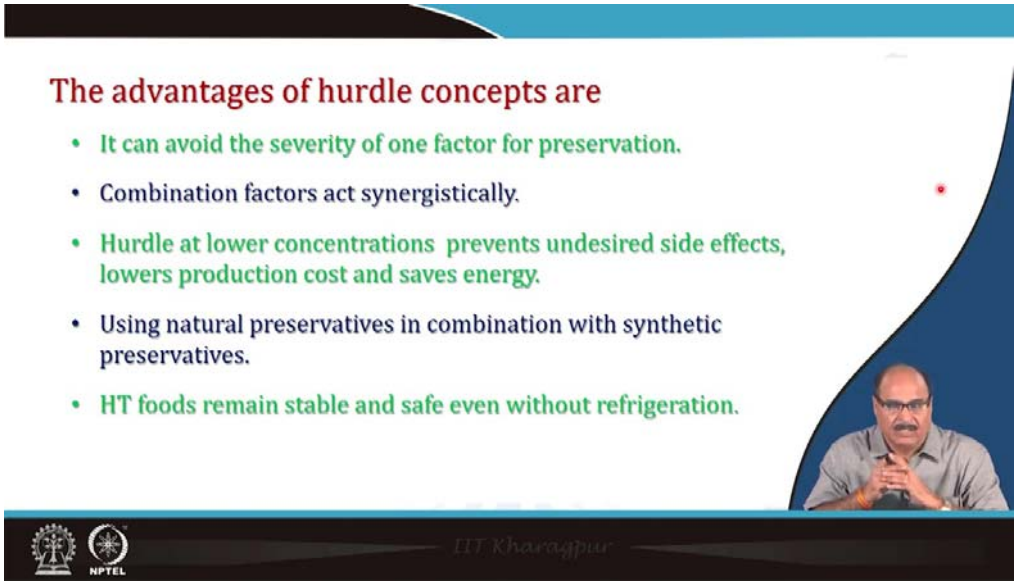
Hurdle technology has arisen in response to a number of developments. Now, consumer demands for healthier foods that retain the original nutritional properties, there is a shift to ready to eat and convenience foods, which require little further processing by the consumers and consumers preference for more natural foods, which require less processing and fewer chemical preservatives. So, these are the drivers for the hurdle technology.

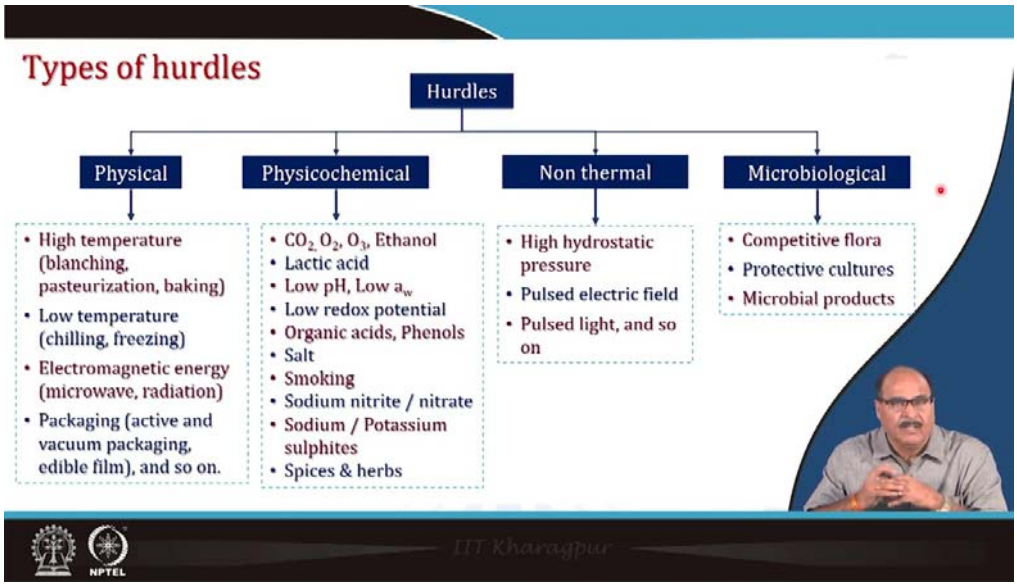


Principles of hurdle technology

Preservative factors or hurdles disturb the homeostasis of microorganisms. Microorganisms are not able to "jump over" all the hurdles present in the food product. Preservative factors prevents microorganisms from multiplying and causing them to remain inactive or even die. The hurdle concept illustrates that complex interactions of temperature, water activity, pH, etc. are significant to the microbial stability.

The advantages of hurdle concepts are that it can avoid the severity of one factor for preservation, combination factors act synergistically, hurdle at lower concentrations prevents undesired side effects, lowers production cost and saves energy. Using natural preservatives in combination with synthetic preservatives, HT foods remain stable and safe even without refrigeration.





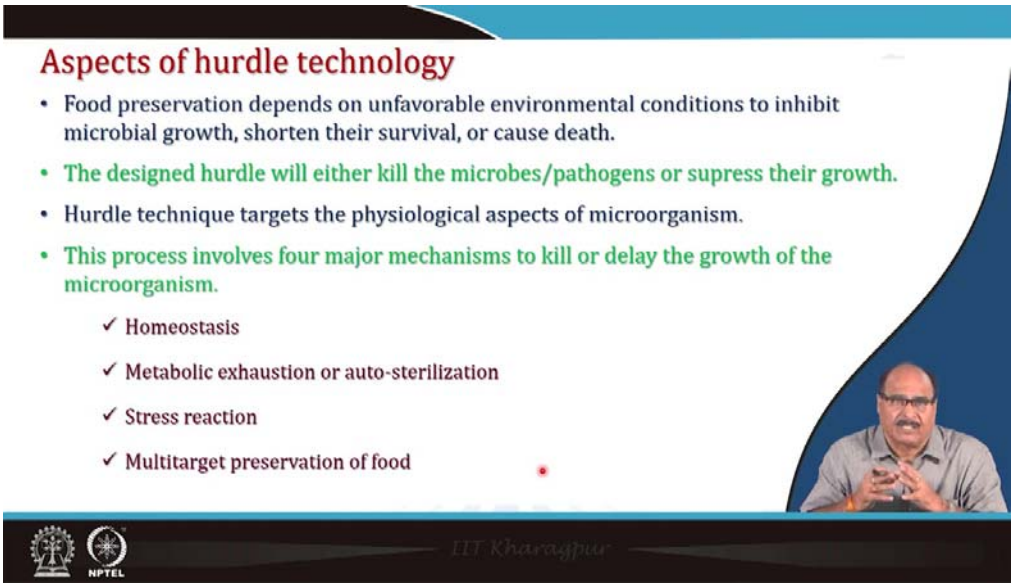
Types of hurdles

Physical: High temperature (blanching, pasteurization, baking), Low temperature (chilling, freezing), Electromagnetic energy (microwave, radiation), Packaging (active and vacuum packaging, edible film), and so on.

Physicochemical: CO_2, O_2, O_3, Ethanol, Lactic acid, Low pH, Low a_w, Low redox potential, Organic acids, Phenols, Salt, Smoking, Sodium nitrite/nitrate, Sodium / Potassium sulphites, Spices & herbs.

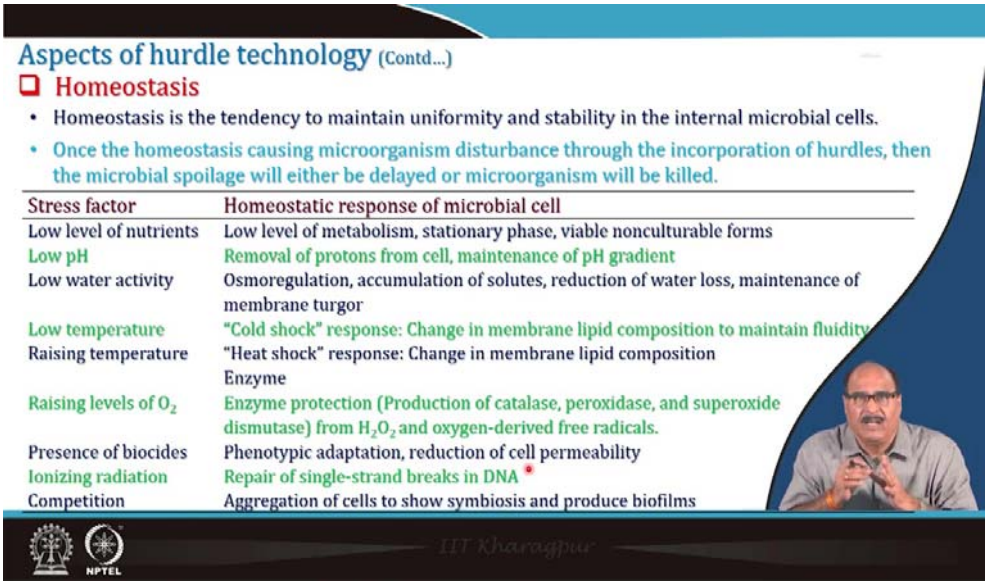
No-thermal: High hydrostatic pressure, Pulsed electric field, Pulsed light, and so on.

Microbiological: Competitive flora, Protective cultures, Microbial products.



Aspects of hurdle technology

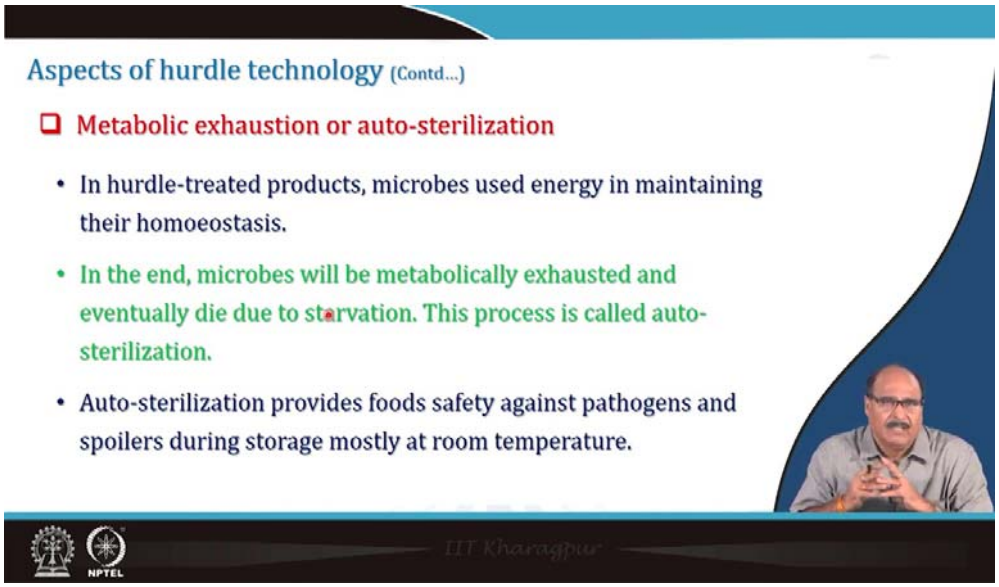
Food preservation depends on unfavorable environmental conditions to inhibit microbial growth, shorten their survival, or cause death. The designed hurdle will either kill the microbes/pathogens or supress their growth. Hurdle technique targets the physiological aspects of microorganism. This process involves four major mechanisms to kill or delay the growth of the microorganism, which include homeostasis, metabolic exhaustion or auto sterilization, stress reaction and multi target preservation of food.



Homeostasis

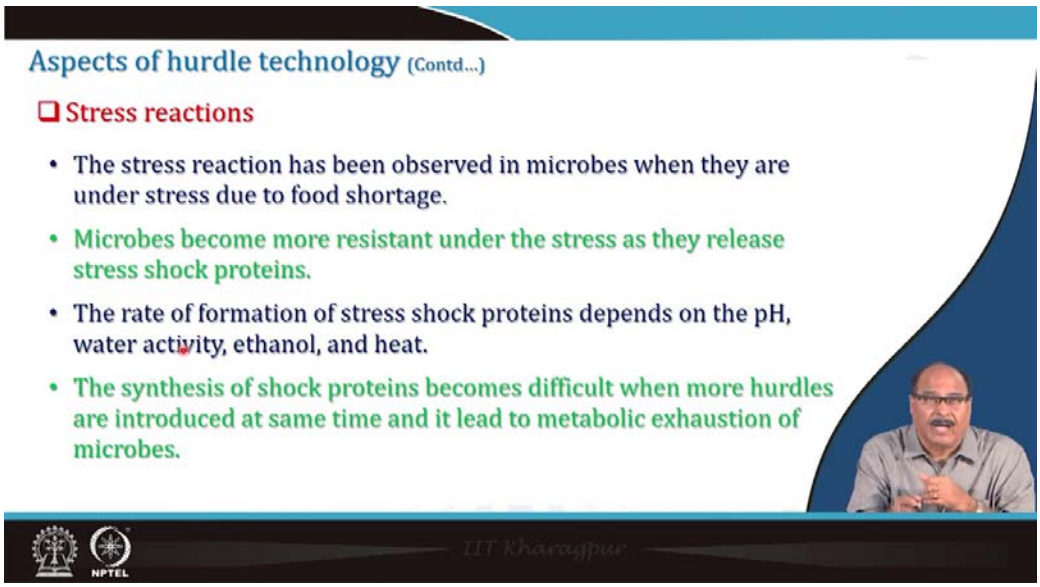
Homeostasis is the tendency to maintain uniformity and stability in the internal microbial cells. Once the homeostasis causing microorganism disturbance through the incorporation of hurdles, then the microbial spoilage will either be delayed or microorganism will be killed. The table shows the several stress factors and their homeostatic response of microbial cells. For example, low level of nutrients may cause low level of metabolism, stationary phase,

viable nonculturable forms; lower water activity is may cause osmoregulation, accumulation of solutes, reduction of water loss or maintenance of membrane turgor. Raising levels of oxygen may result in the enzyme protection life production of catalase, peroxidase, super oxide dismutase from hydrogen peroxide and oxygen derived free radicals. Low water activity or even a low pH it may result into the removal of protons from the cell maintenance of the pH gradient. Similarly, ionizing radiation may result in repair of single strand breaks in DNA.



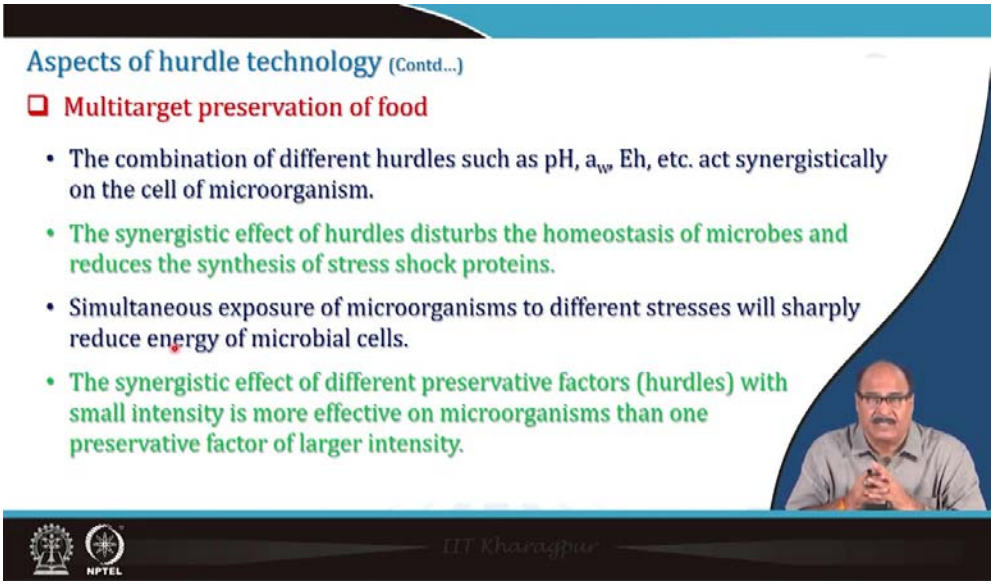
Metabolic exhaustion or auto-sterilization

In hurdle-treated products, microbes used energy in maintaining their homoeostasis. In the end, microbes will be metabolically exhausted and eventually die due to starvation. This process is called auto-sterilization. Auto-sterilization provides foods safety against pathogens and spoilers during storage mostly at room temperature.



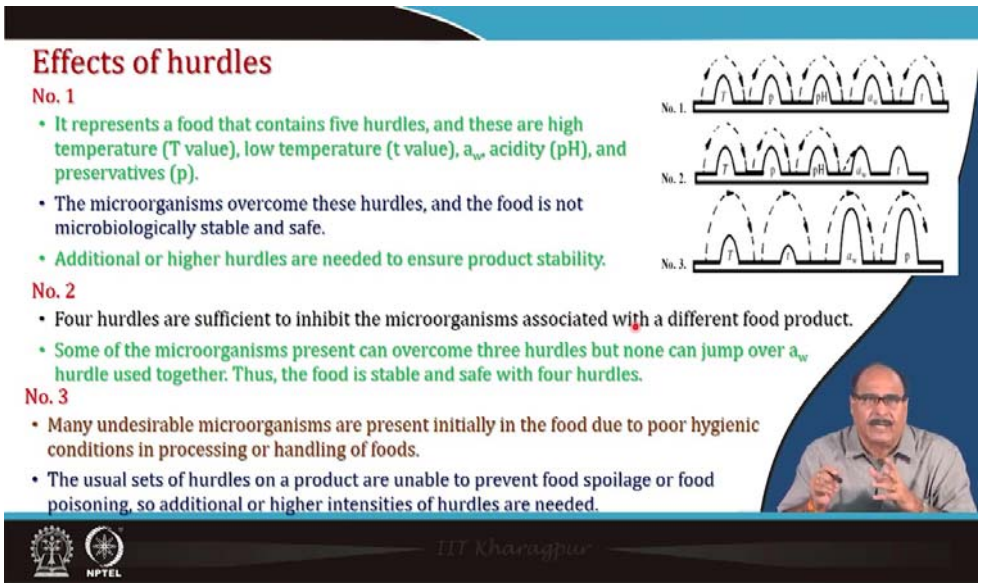
Stress reaction

The stress reaction has been observed in microbes when they are under stress due to food shortage. Microbes become more resistant under the stress as they release stress shock proteins. The rate of formation of stress shock proteins depends on the pH, water activity, ethanol, and heat. The synthesis of shock proteins becomes difficult when more hurdles are introduced at same time and it lead to metabolic exhaustion of microbes.



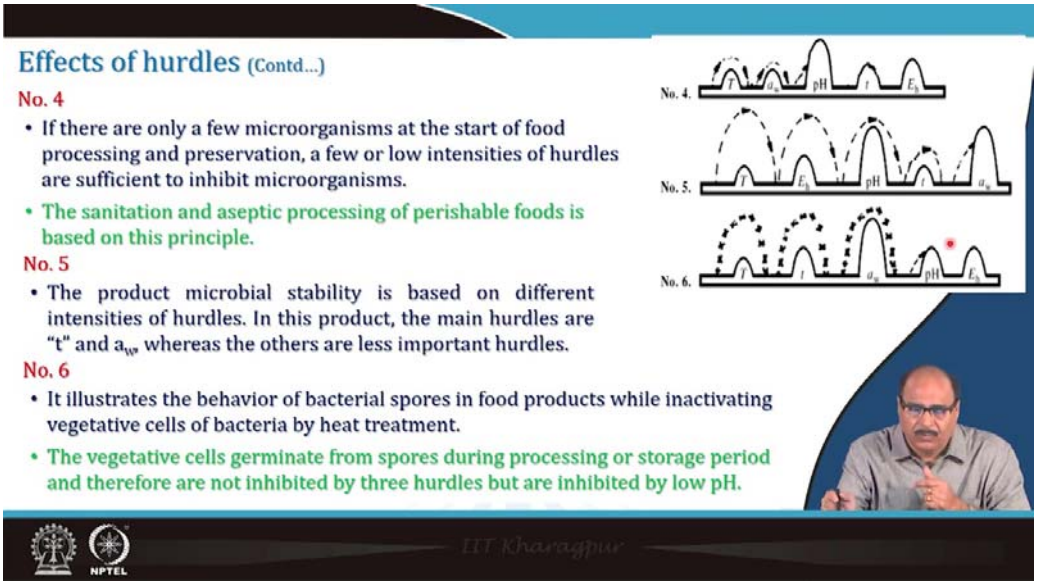
Multitarget preservation of food

The combination of different hurdles such as pH, aw, Eh, etc. act synergistically on the cell of microorganism. The synergistic effect of hurdles disturbs the homeostasis of microbes and reduces the synthesis of stress shock proteins. Simultaneous exposure of microorganisms to different stresses will sharply reduce energy of microbial cells. The synergistic effect of different preservative factors (hurdles) with small intensity is more effective on microorganisms than one preservative factor of larger intensity.

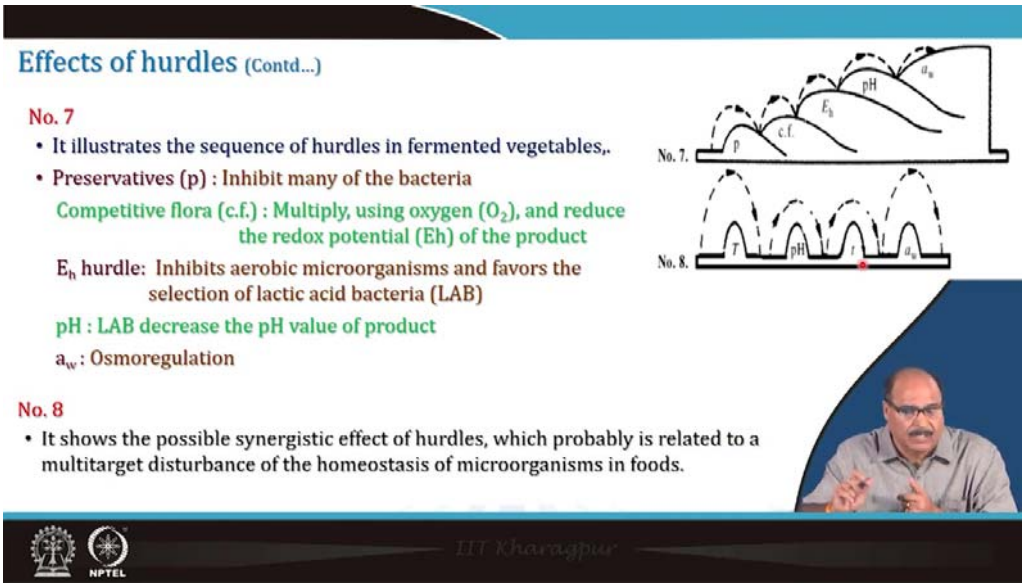


Effect of hurdles

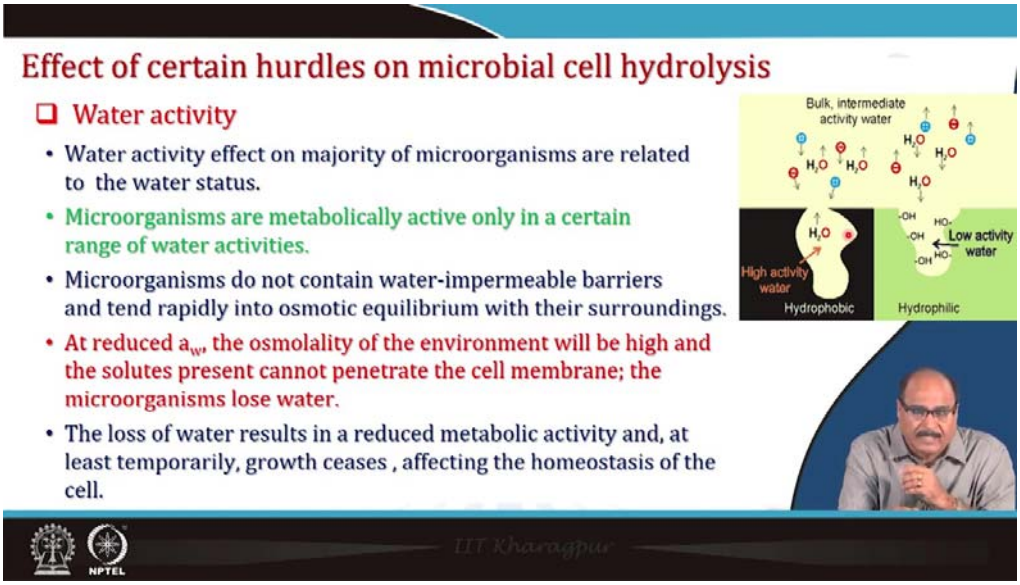
The image no. 1 represents a food that contains five hurdles, and these are high temperature (T value), low temperature (t value), aw, acidity (pH), and preservatives. The microorganisms overcome these hurdles, and the food is not microbiologically stable and safe. Additional or higher hurdles are needed to ensure product stability. The image no. 2 represents four hurdles are sufficient to inhibit the microorganisms associated with a different food product. Some of the microorganisms present can overcome three hurdles but none can jump over aw hurdle used together. Thus, the food is stable and safe with four hurdles. The image no. 3 represents many undesirable microorganisms are present initially in the food due to poor hygienic conditions in processing or handling of foods. The usual sets of hurdles on a product are unable to prevent food spoilage or food poisoning, so additional or higher intensities of hurdles are needed.



The image no. 4 signifies that if there are only a few microorganisms at the start of food processing and preservation, a few or low intensities of hurdles are sufficient to inhibit microorganisms. The sanitation and aseptic processing of perishable foods is based on this principle. The image no. 5 represents that the product microbial stability is based on different intensities of hurdles. In this product, the main hurdles are "t" and aw, whereas the others are less important hurdles. The image no. 6 represents that it illustrates the behavior of bacterial spores in food products while inactivating vegetative cells of bacteria by heat treatment. The vegetative cells germinate from spores during processing or storage period and therefore are not inhibited by three hurdles but are inhibited by low pH.



The image no. 7 illustrates the sequence of hurdles in fermented vegetables. Preservatives (p): Inhibit many of the bacteria, Competitive flora (c.f.): Multiply, using oxygen (O_2), and reduce the redox potential (Eh) of the product, E_h hurdle: Inhibits aerobic microorganisms and favors the selection of lactic acid bacteria (LAB), pH: LAB decrease the pH value of product, a_w: Osmoregulation. The image no. 8 shows the possible synergistic effect of hurdles, which probably is related to a multi-target disturbance of the homeostasis of microorganisms in foods.

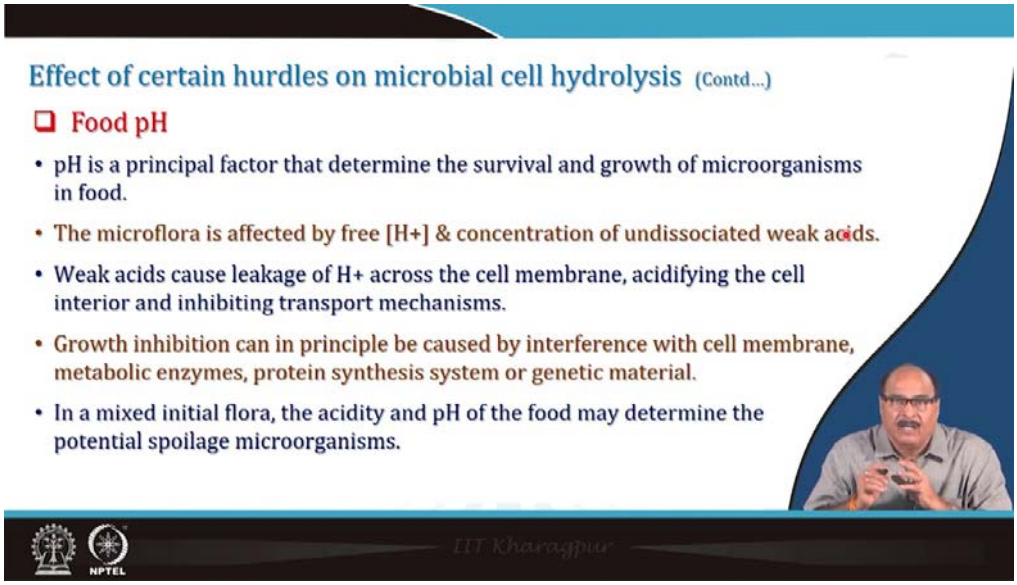


Effect of certain hurdles on microbial cell hydrolysis

Water activity

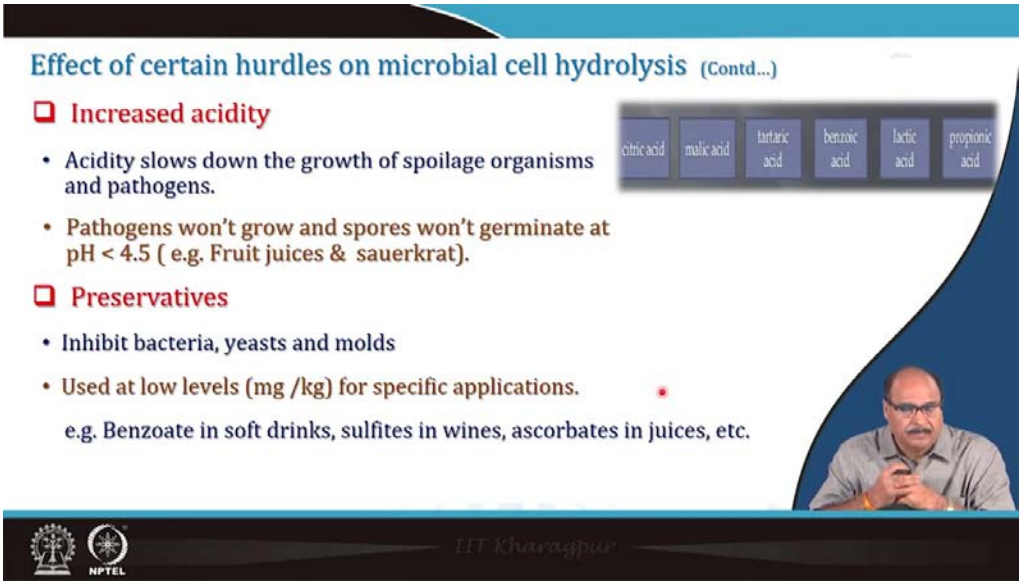
Water activity effect on majority of microorganisms are related to the water status. Microorganisms are metabolically active only in a certain range of water activities. Microorganisms do not contain water-impermeable barriers and tend rapidly into osmotic equilibrium with their surroundings. At reduced a_w, the osmolality of the environment will be

high and the solutes present cannot penetrate the cell membrane; the microorganisms lose water. The loss of water results in a reduced metabolic activity and, at least temporarily, growth ceases, affecting the homeostasis of the cell.



Food pH

pH is a principal factor that determine the survival and growth of microorganisms in food. The microflora is affected by free [H+] & concentration of undissociated weak acids. Weak acids cause leakage of H+ across the cell membrane, acidifying the cell interior and inhibiting transport mechanisms. Growth inhibition can in principle be caused by interference with cell membrane, metabolic enzymes, protein synthesis system or genetic material. In a mixed initial flora, the acidity and pH of the food may determine the potential spoilage microorganisms.

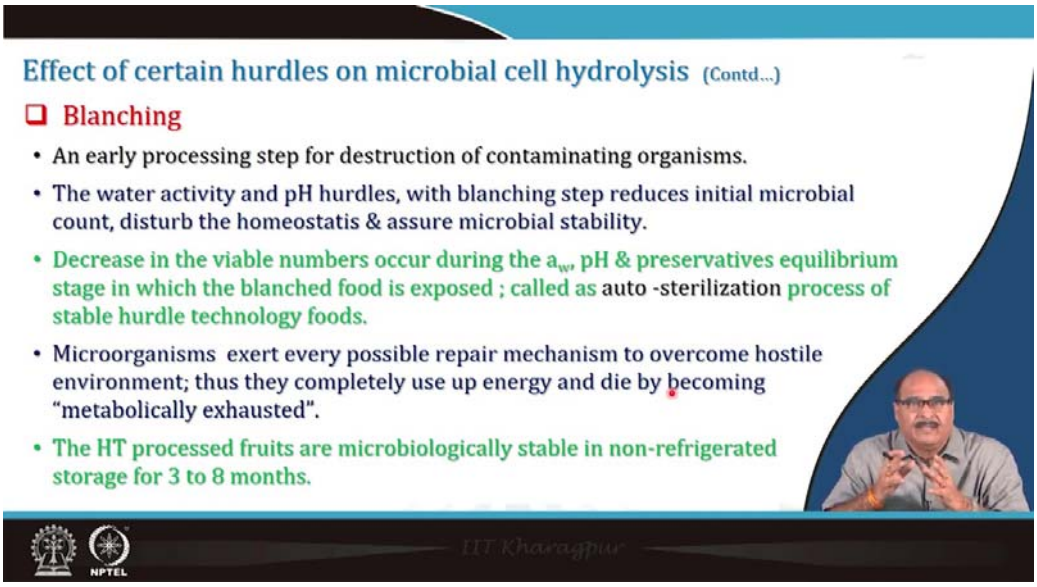


Increased acidity

Acidity slows down the growth of spoilage organisms and pathogens. Pathogens won't grow and spores won't germinate at pH < 4.5 (e.g. Fruit juices & sauerkraut).

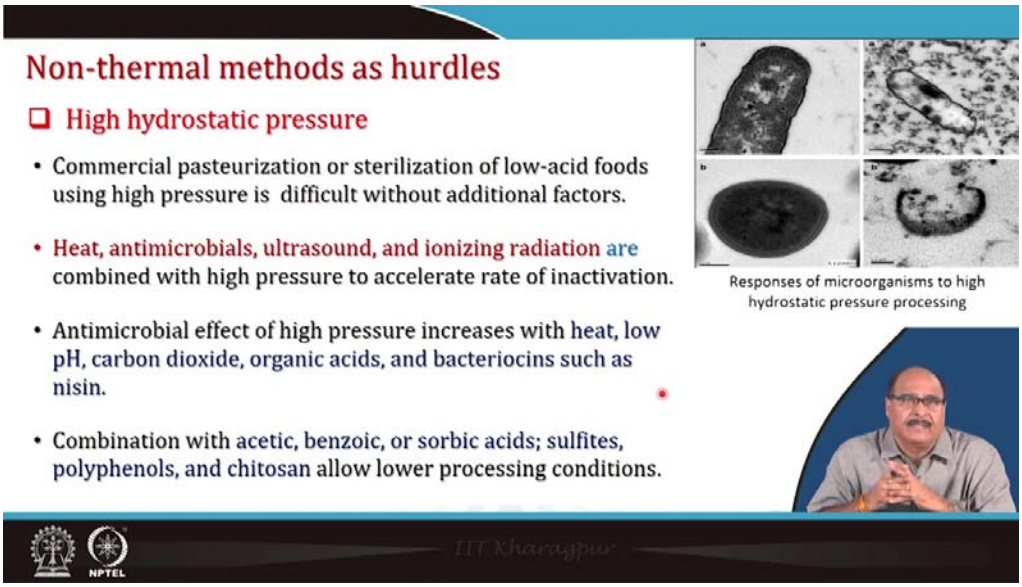
Preservatives

Preservatives inhibit bacteria, yeasts and molds, used at low levels (mg/kg) for specific applications, e.g. Benzoate in soft drinks, sulfites in wines, ascorbates in juices, etc.



Blanching

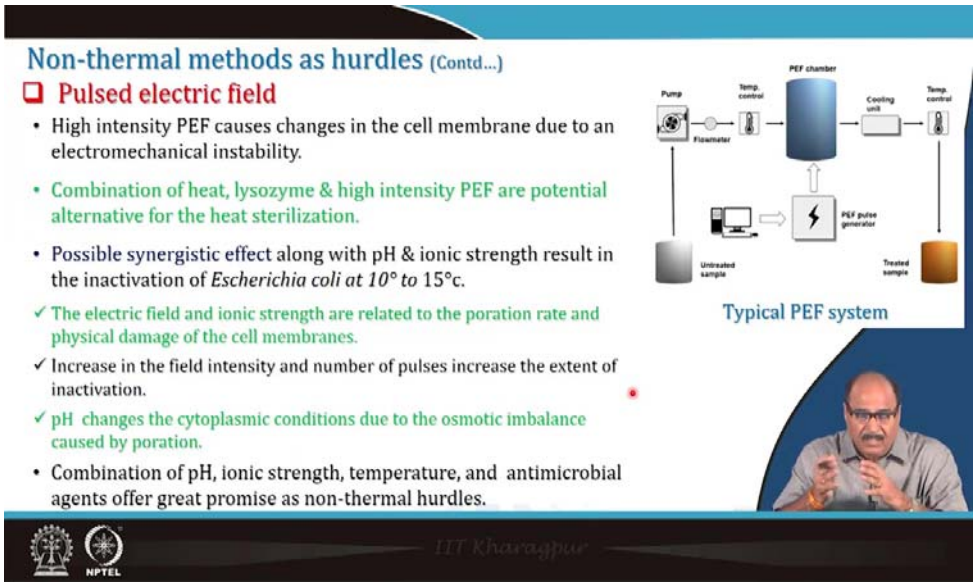
An early processing step for destruction of contaminating organisms. The water activity and pH hurdles, with blanching step reduces initial microbial count, disturb the homeostatis & assure microbial stability. Decrease in the viable numbers occur during the a_w, pH & preservatives equilibrium stage in which the blanched food is exposed; called as auto - sterilization process of stable hurdle technology foods. Microorganisms exert every possible repair mechanism to overcome hostile environment; thus they completely use up energy and die by becoming "metabolically exhausted". The HT processed fruits are microbiologically stable in non-refrigerated storage for 3 to 8 months.



Non-thermal methods as hurdles

High hydrostatic pressure

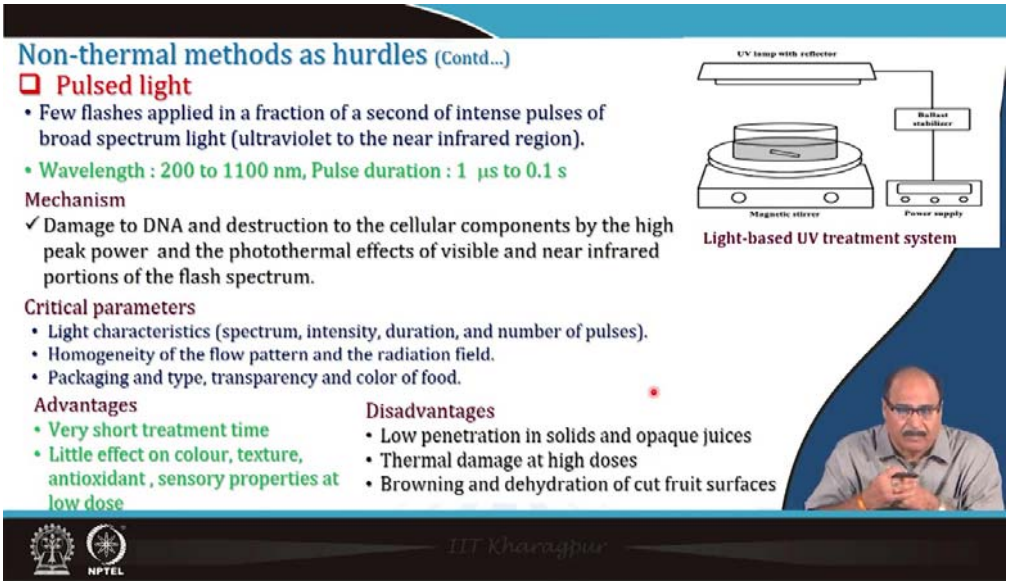
Commercial pasteurization or sterilization of low-acid foods using high pressure is difficult without additional factors. Heat, antimicrobials, ultrasound, and ionizing radiation are combined with high pressure to accelerate rate of inactivation. Antimicrobial effect of high pressure increases with heat, low pH, carbon dioxide, organic acids, and bacteriocins such as nisin. Combination with acetic, benzoic, or sorbic acids; sulfites, polyphenols, and chitosan allow lower processing conditions.



Pulsed electric field

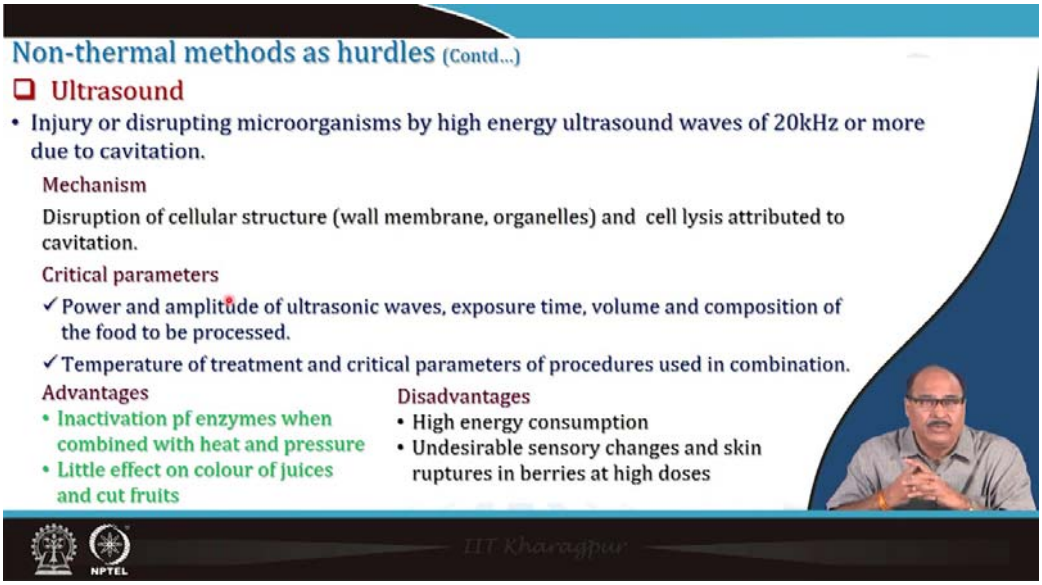
High intensity PEF causes changes in the cell membrane due to an electromechanical instability. Combination of heat, lysozyme & high intensity PEF are potential alternative for the heat sterilization. Possible synergistic effect along with pH & ionic strength result in the

inactivation of Escherichia coli at 10 to 15 °C. The electric field and ionic strength are related to the poration rate and physical damage of the cell membranes. Increase in the field intensity and number of pulses increase the extent of inactivation. pH changes the cytoplasmic conditions due to the osmotic imbalance caused by poration. Combination of pH, ionic strength, temperature, and antimicrobial agents offer great promise as non-thermal hurdles.



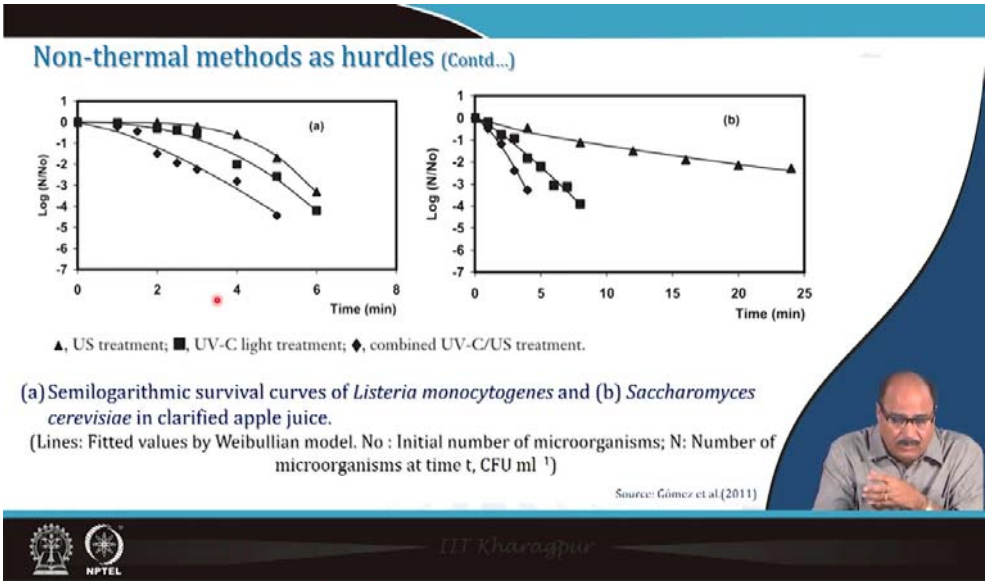
Pulsed light

Few flashes applied in a fraction of a second of intense pulses of broad spectrum light (ultraviolet to the near infrared region) having the wavelength: 200 to 1100 nm, and pulse duration: 1 μs to 0.1 s. The mechanism behind this is the damage to DNA and destruction to the cellular components by the high peak power and the photothermal effects of visible and near infrared portions of the flash spectrum. The critical parameters are light characteristics (spectrum, intensity, duration, and number of pulses), homogeneity of the flow pattern and the radiation field, and packaging and type, transparency and color of food. The advantages are very short treatment time, little effect on colour, texture, antioxidant, sensory properties at low dose. The disadvantages of this process are the low penetration in solids and opaque juices, thermal damage at high doses, and browning and dehydration of cut fruit surfaces.

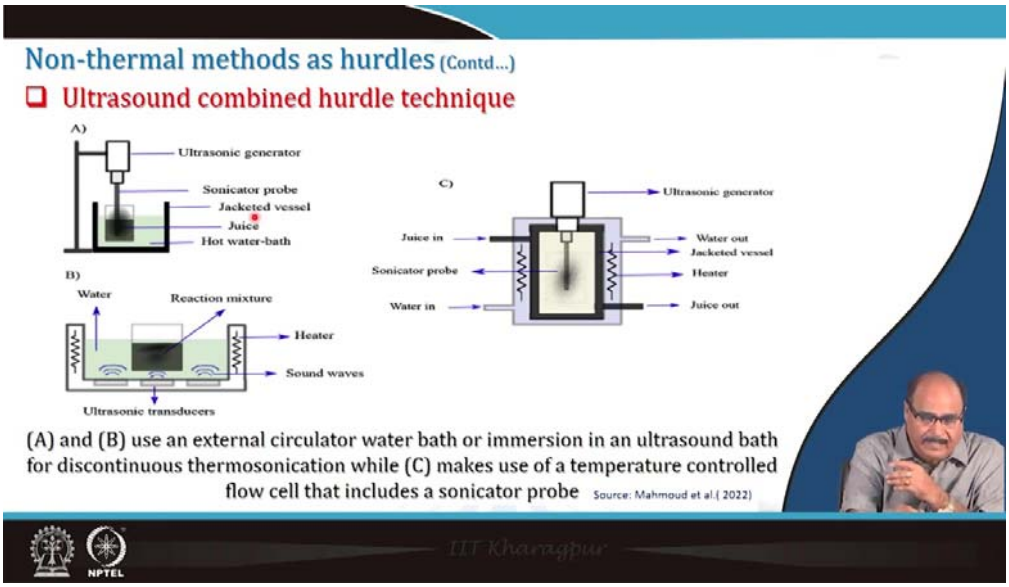


Ultrasound

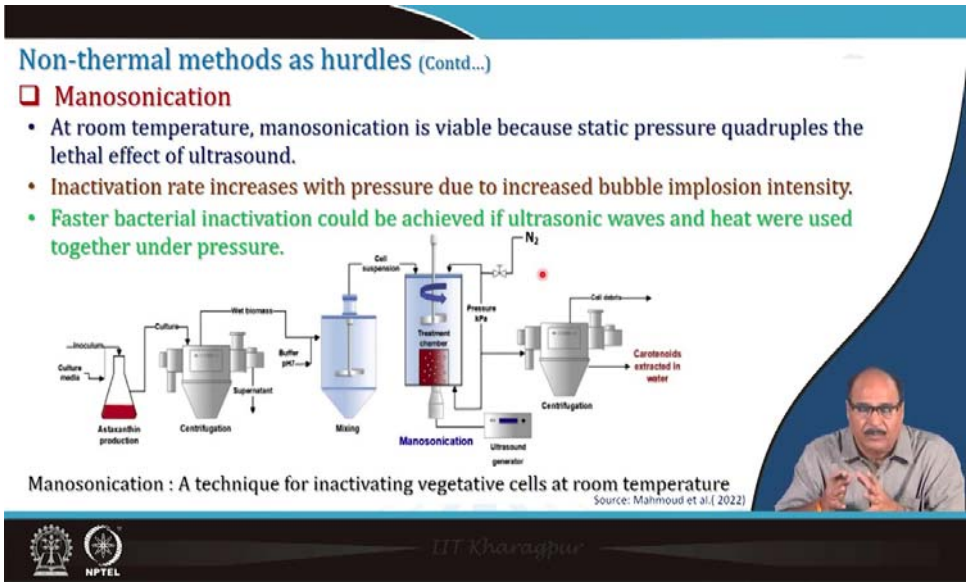
Injury or disrupting microorganisms by high energy ultrasound waves of 20 kHz or more due to cavitation. Disruption of cellular structure (wall membrane, organelles) and cell lysis attributed to cavitation. The critical parameters are power and amplitude of ultrasonic waves, exposure time, volume and composition of the food to be processed, temperature of treatment and critical parameters of procedures used in combination. It causes inactivation pf enzymes when combined with heat and pressure, and has little effect on colour of juices and cut fruits, but it requires a high energy consumption, and causes undesirable sensory changes and skin ruptures in berries at high doses.



These graphs show the semi logarithmic plots for (a) semilogarithmic survival curves of *Listeria monocytogenes* and (b) *Saccharomyces cerevisiae* in clarified apple juice. The combined US treatment and UV-C light treatment is effective in reducing the microbial load.

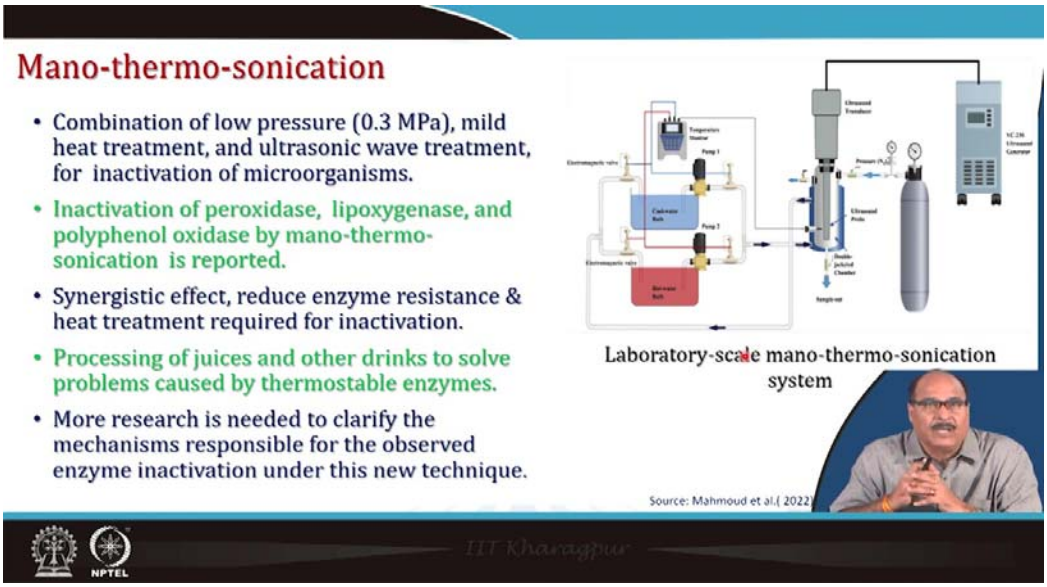


In these figures (A) and (B) use an external circulator water bath or immersion in an ultrasound bath for discontinuous thermosonication while (C) makes use of a temperature controlled flow cell that includes a sonicator probe.



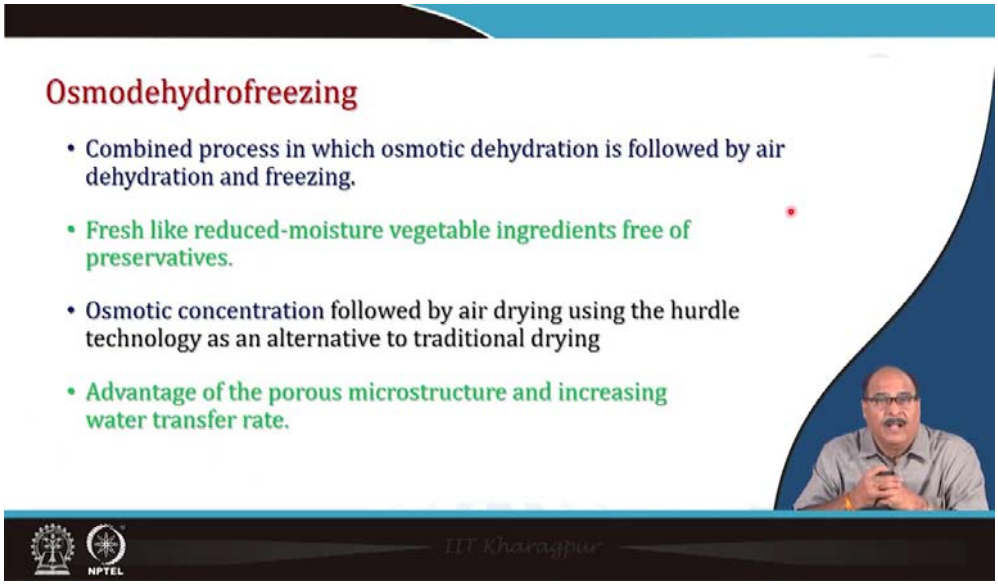
Manosonication

At room temperature, manosonication is viable because static pressure quadruples the lethal effect of ultrasound. Inactivation rate increases with pressure due to increased bubble implosion intensity. Faster bacterial inactivation could be achieved if ultrasonic waves and heat were used together under pressure. As shown in figure, astaxanthin is produced with a culture media and inoculum, followed by centrifugation. Then the supernatant is taken off and the biomass is added with buffer of pH 7.0 and thoroughly mixed. The cell suspension is put into the manosonication chamber, where liquid nitrogen gas is purgerd into it with the application of pressure. After centrifugation, the cell debris are removed.



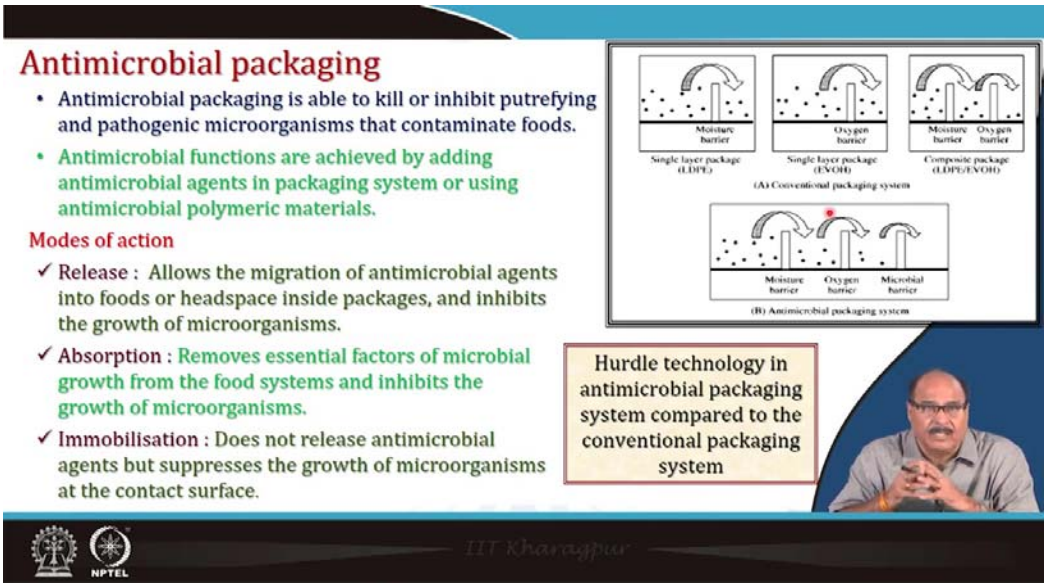
Mano-thermo-sonication

Combination of low pressure (0.3 MPa), mild heat treatment, and ultrasonic wave treatment, for inactivation of microorganisms. Inactivation of peroxidase, lipoxygenase, and polyphenol oxidase by mano-thermo-sonication is reported. Synergistic effect, reduce enzyme resistance & heat treatment required for inactivation. Processing of juices and other drinks to solve problems caused by thermostable enzymes. More research is needed to clarify the mechanisms responsible for the observed enzyme inactivation under this new technique.



Osmodehydrofreezing

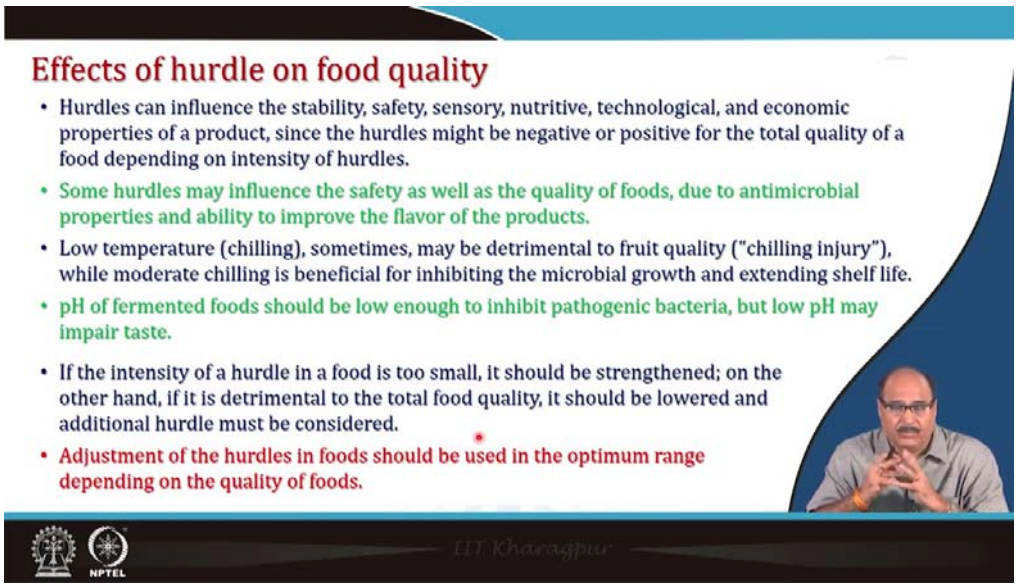
Combined process in which osmotic dehydration is followed by air dehydration and freezing. Fresh like reduced-moisture vegetable ingredients free of preservatives. Osmotic concentration followed by air drying using the hurdle technology as an alternative to traditional drying Advantage of the porous microstructure and increasing water transfer rate.



Antimicrobial packaging

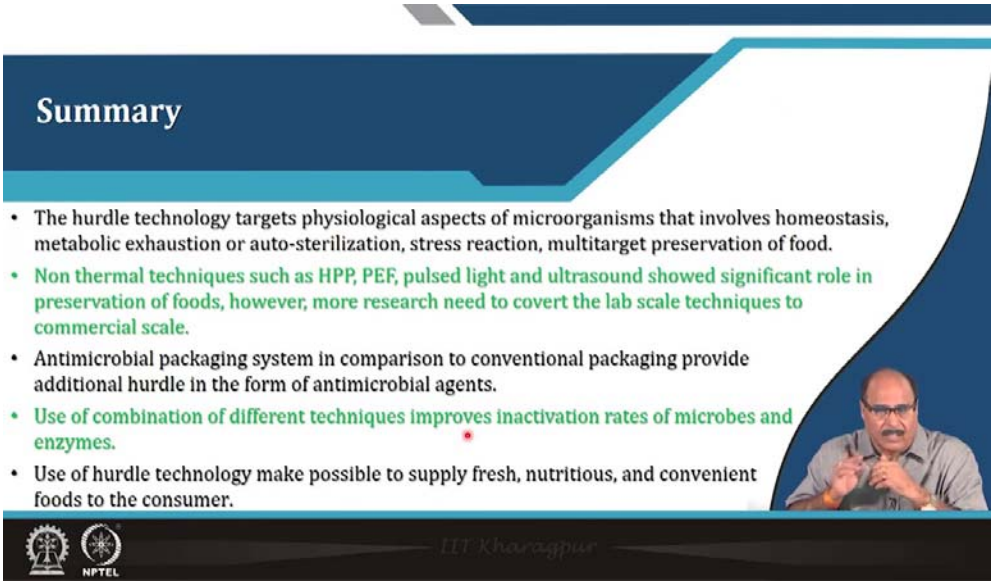
Antimicrobial packaging is able to kill or inhibit putrefying and pathogenic microorganisms that contaminate foods. Antimicrobial functions are achieved by adding antimicrobial agents in packaging system or using antimicrobial polymeric materials. It allows the migration of antimicrobial agents into foods or headspace inside packages, and inhibits the growth of microorganisms, removes essential factors of microbial growth from the food systems and inhibits the growth of microorganisms, and does not release antimicrobial agents but suppresses the growth of microorganisms at the contact surface.

In this table, some studies showing the use of hurdle technology in preservation of plant foods are discussed. For example, heating for 70 $^{\circ}$C for 10 minutes with the addition of 200 ppm potassium metabisulfite can extend the shelf life of juices blend made from radish and sugarcane by three months under refrigeration conditions.

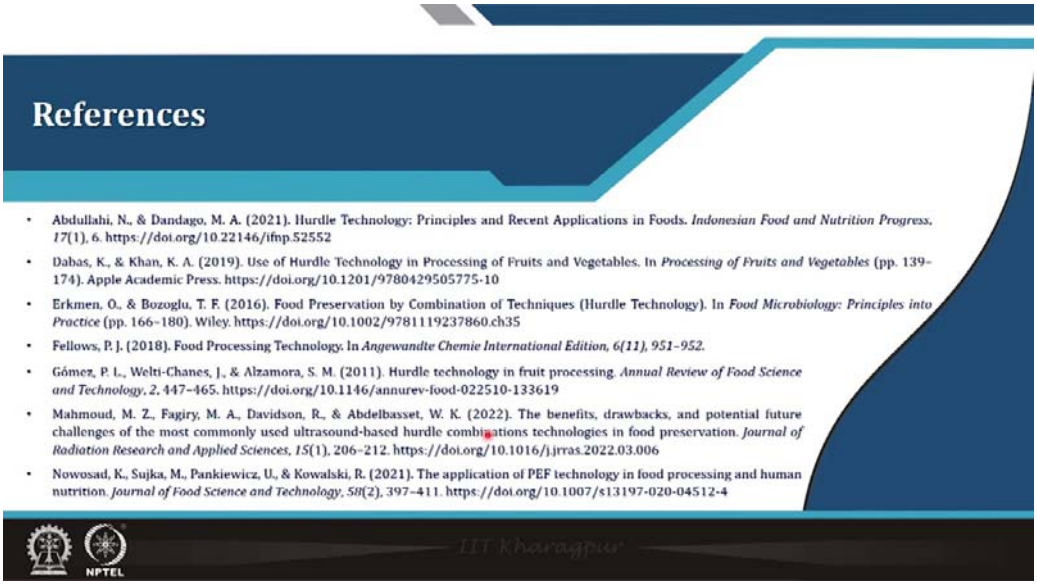


Effects of hurdle on food quality

Hurdles can influence the stability, safety, sensory, nutritive, technological, and economic properties of a product, since the hurdles might be negative or positive for the total quality of a food depending on intensity of hurdles. Some hurdles may influence the safety as well as the quality of foods, due to antimicrobial properties and ability to improve the flavor of the products. Low temperature (chilling), sometimes, may be detrimental to fruit quality ("chilling injury"), while moderate chilling is beneficial for inhibiting the microbial growth and extending shelf life. pH of fermented foods should be low enough to inhibit pathogenic bacteria, but low pH may impair taste. If the intensity of a hurdle in a food is too small, it should be strengthened; on the other hand, if it is detrimental to the total food quality, it should be lowered and additional hurdle must be considered. Adjustment of the hurdles in foods should be used in the optimum range depending on the quality of foods.



In summary, the hurdle technology targets physiological aspects of microorganisms that involves homeostasis, metabolic exhaustion or auto-sterilization, stress reaction, multi target preservation of food. Non thermal techniques such as HPP, PEF, pulsed light and ultrasound showed significant role in preservation of foods, however, more research need to covert the lab scale techniques to commercial scale. Antimicrobial packaging system in comparison to conventional packaging provide additional hurdle in the form of antimicrobial agents. Use of combination of different techniques improves inactivation rates of microbes and enzymes. Use of hurdle technology make possible to supply fresh, nutritious, and convenient foods to the consumer.



These are the references for further study. Thank you.