Novel Technologies for Food Processing and Shelf Life Extension

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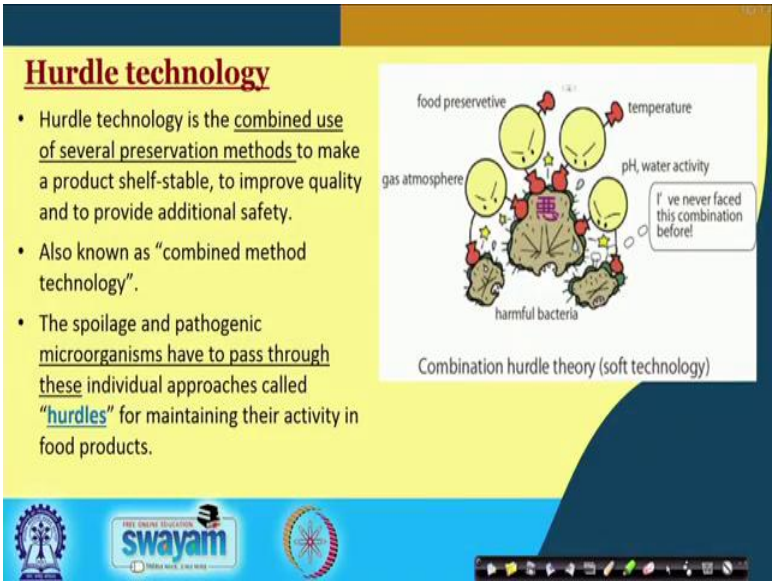
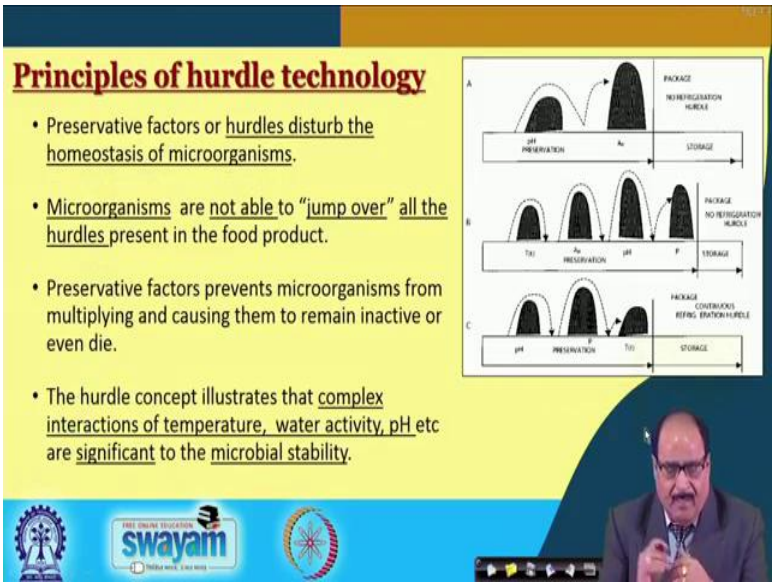
Lecture - 27
Hurdle Technology, High & Intermediate Moisture Foods

In this lecture, an important aspect of food processing, which is commonly known as 'hurdle technology' and its use in stabilization of high moisture or intermediate moisture foods is studied.



Hurdle technology is the combined use of several preservation methods to make a product shelf-stable, to improve its quality and to provide additional safety to the product. It is also known as "combined method technology". The spoilage and pathogenic microorganisms are not able to jump over the individual factors, which are applied to the food i.e. the combined factors are generally called hurdles.

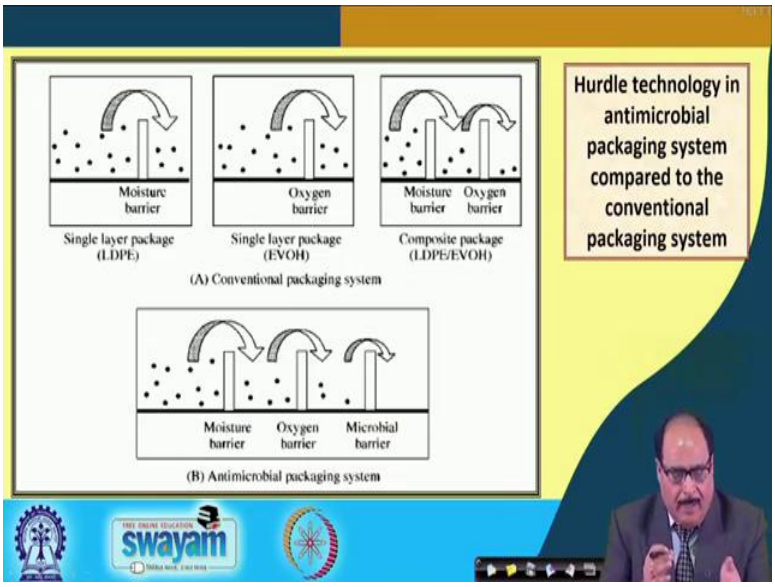
Some bacterial cells are shown in the picture. Different factors like temperature, pH, water activity, gaseous atmosphere, food preservatives, etc. are the hurdles. So, if these factors are applied individually then in order to get the desired sterility severe conditions of individual factors might be required. But, when they are applied together then many a times various synergist effect occurs by different factors. So, their severity can be reduced and even the microorganism find it difficult to jump over them to overcome the stress created by the different factors together.



Principles of hurdle technology

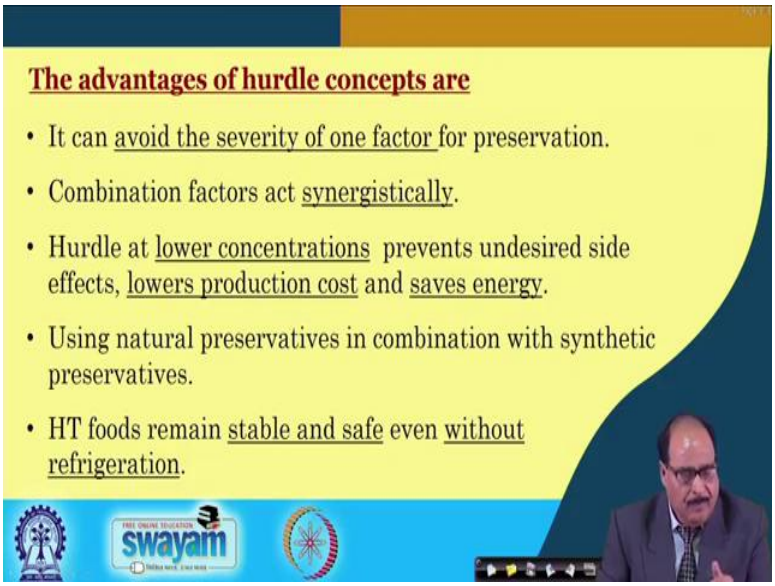
- Preservative factors or hurdles disturb the homeostasis of microorganisms.
- Microorganisms are not able to "jump over" all the hurdles present in the food product.
- Preservative factors prevents microorganisms from multiplying and causing them to remain inactive or even die.
- The hurdle concept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

The overall concept of the hurdle technology has been shown in picture. If there is only one factor, it becomes easy for the microorganism to crossover but when there are 2 or more factors, it may be that microorganism has jumped one but cannot cross others. Finally, it dies and the food gets stabilized. So, the complex interactions of the various factors like temperature, water activity, pH, etc. are utilized in positive sense to get a better product with longer shelf life and better value.



Hurdle technology in the antimicrobial packaging system compared to the conventional packaging system

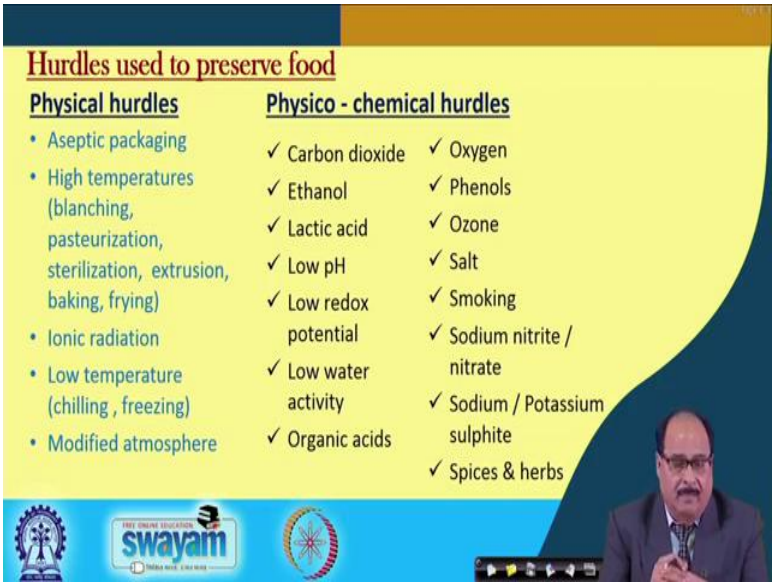
In the top portion of the figure, when any packaging material is applied, the laminates may provide oxygen barrier and are impermeable to moisture. Antimicrobial compounds can also be mixed with the packaging material. Ultimately the products have better quality and long shelf life.



Advantages of hurdle concepts

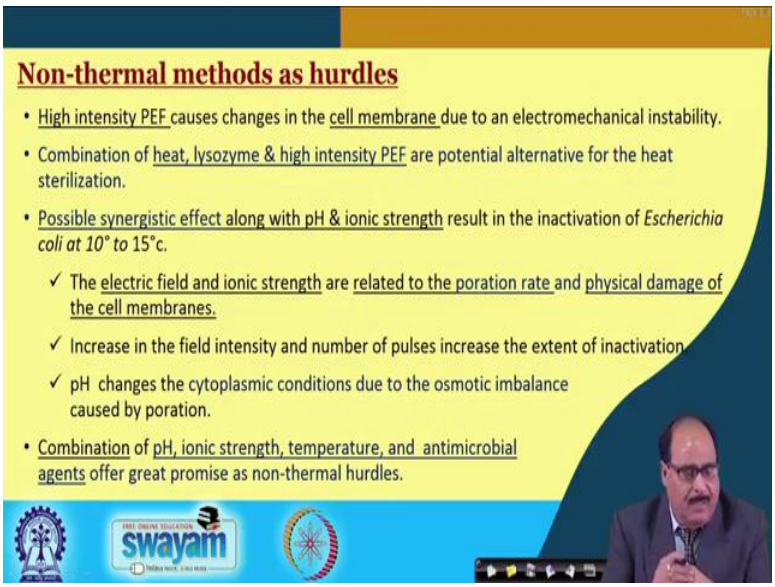
- It can avoid the severity of one factor for preservation.
- Combination factors act synergistically.

- Hurdle at lower concentrations prevents undesired side effects, lowers production cost and saves energy.
- Using natural preservatives in combination with synthetic preservatives.
- Hurdle technology foods remain stable and safe even without refrigeration.



Hurdles used to preserve food

Physical hurdles which can be used may include aseptic packaging, high temperature (blanching, pasteurization, sterilization, extrusion, baking, frying), ionic radiation, low temperature (chilling, freezing), modified atmosphere, etc. Physico-chemical hurdles are carbon dioxide, ethanol, lactic acid, low pH, etc. as listed in the slide.



Non-thermal methods as hurdles

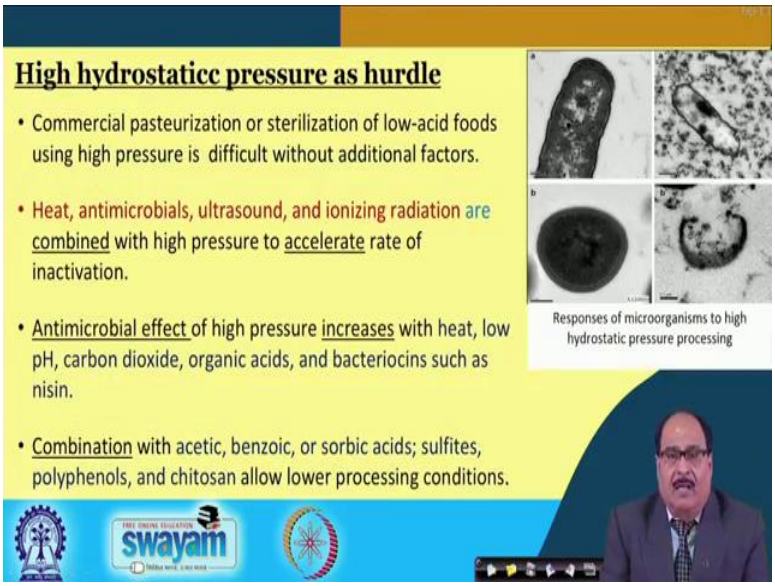
- High intensity PEF has a good potential to be used together with pH, water activity, etc. It causes changes in the cell membrane due to an electromechanical instability.
- Combination of heat, lysozyme & high intensity PEF are potential alternative for the heat sterilization.
- Possible synergistic 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.

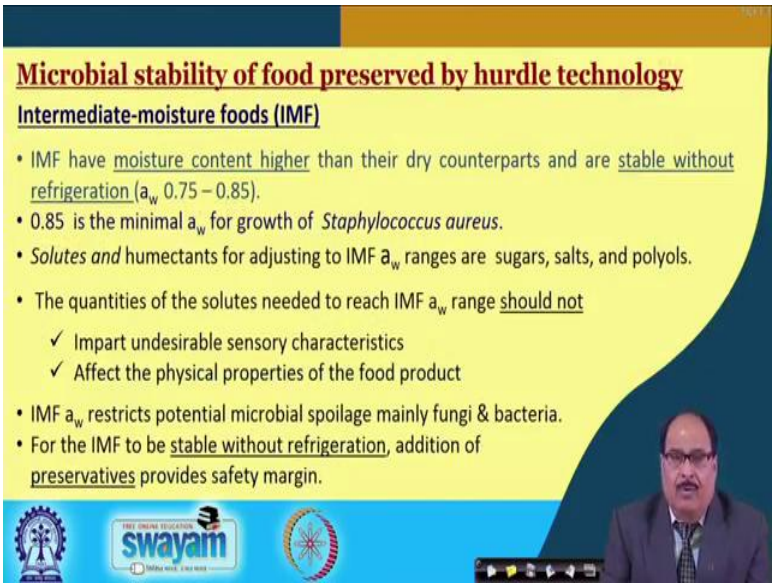


High hydrostatic pressure as hurdle

- Commercial pasteurization or sterilization of low-acid foods using high pressure is difficult without additional factors. Enzymes or microorganisms provide very

high resistance to pressure under low acid conditions. If the pressure is combined with temperature or water activity, it might have a much better effect.

- 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 and better beneficial effects.



Microbial stability of food preserved by hurdle technology

Intermediate-moisture foods (IMF)

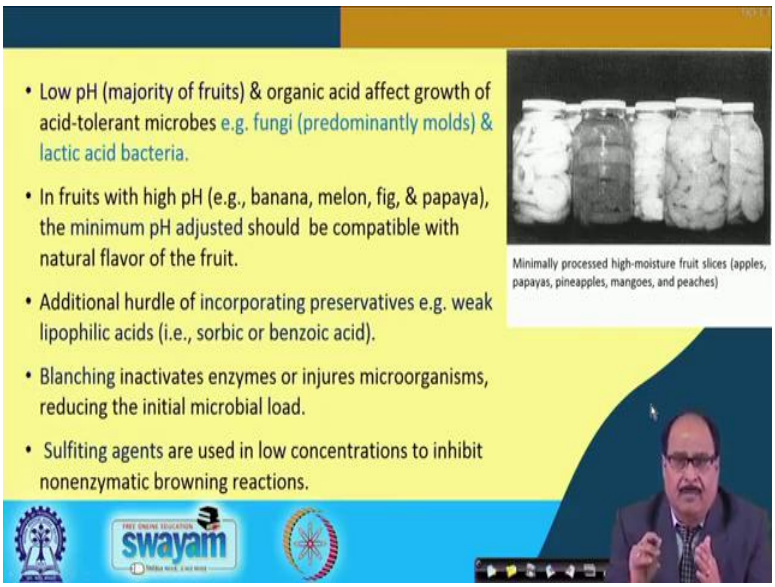
- IMF have moisture content higher than their dry counterparts and are stable without refrigeration (a_w 0.75 – 0.85).
- 0.85 is the minimal a_w for growth of spoilage producing organisms like *Staphylococcus aureus*.
- Solutes and humectants for adjusting to IMF a_w ranges are sugars, salts, and polyols.
- The quantities of the solutes needed to reach IMF a_w range should not
  - ✓ Impart undesirable sensory characteristics
  - ✓ Affect the physical properties of the food product
- IMF a_w restricts potential microbial spoilage mainly fungi & bacteria.
- For the IMF to be stable without refrigeration, addition of preservatives provides safety margin.

Adding more amount of solutes or removing more amount of water from the foods, may adversely affect the sensory and textual characteristics. So, a combination of both i.e. partly remove the water and partly add the humectants would work better in stabilizing the food.

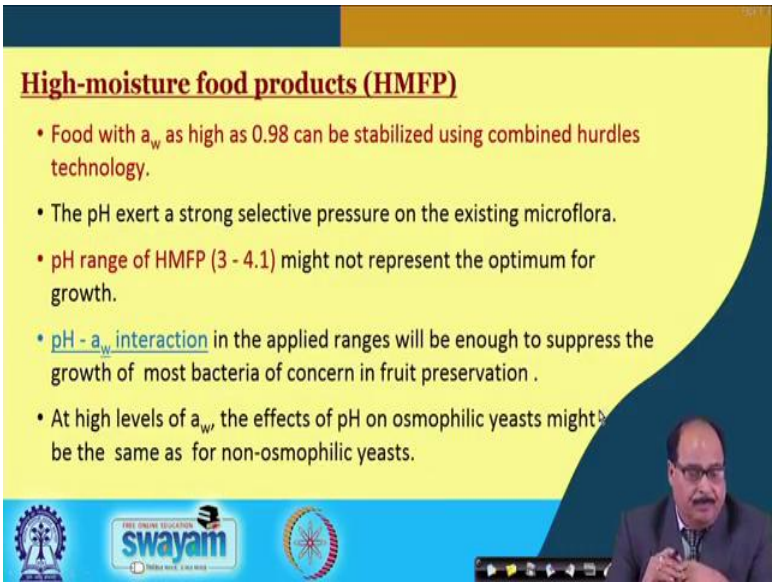
So, various factors which provide stability to the intermediate moisture foods, include water activity, redox potential, pH, addition of preservatives as well as thermal treatments. So, these should be properly optimized to get the room temperature stabilized intermediate moisture foods.

Fruits as IMF

- Fruits can tolerate pH reduction without affecting flavour significantly.
- Minimum addition of humectants for a_w reduction to maintain freshness and converting them into suitable grade IMF.
- To compensate stability, for the high moisture of the product, a blanching treatment can be applied.
- pH reductions that will not result in flavour impairment can be employed.
- Permitted preservatives can be used to reduce the risk of spoilage.
- Combination of these factors for hurdle technology principles applied to fruits, results in alternative to traditional IMF fruits is a better strategy to prepare stable and good quality hurdle technology foods.

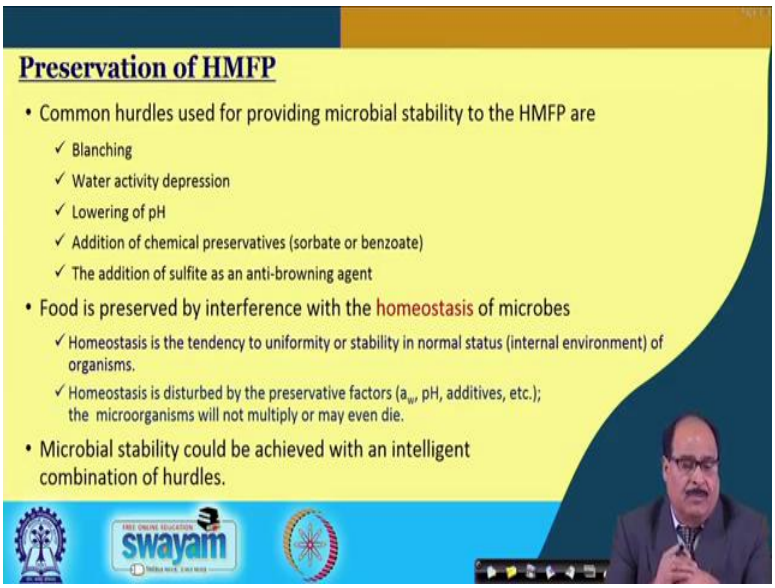


- Low pH (majority of fruits) & organic acid affect growth of acid-tolerant microbes e.g. fungi (predominantly molds) & lactic acid bacteria.
- In fruits with high pH (e.g., banana, melon, fig, & papaya), the minimum pH adjusted should be compatible with natural flavor of the fruit.
- Additional hurdle of incorporating preservatives e.g. weak lipophilic acids (i.e., sorbic or benzoic acid).
- Blanching inactivates enzymes or injures microorganisms, reducing the initial microbial load.
- Sulfiting agents are used in low concentrations to inhibit nonenzymatic browning reactions.



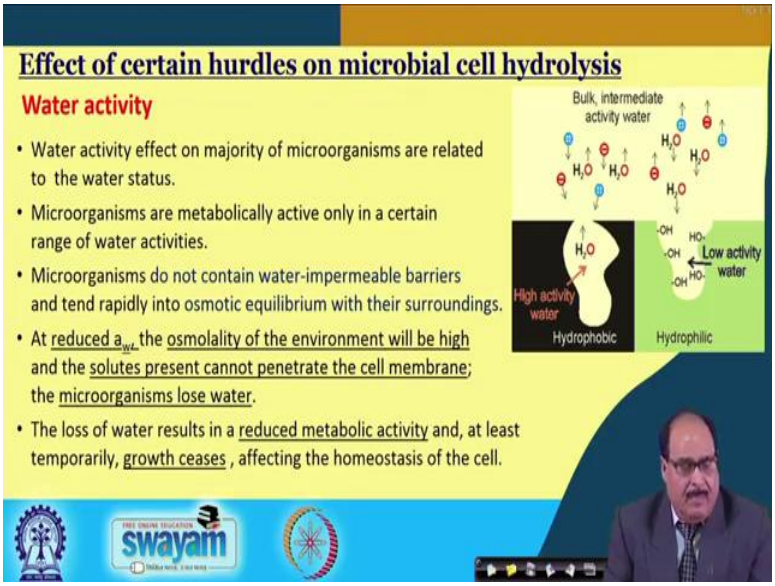
High-moisture food products (HMFP)

- Food with a_w as high as 0.98 can be stabilized using combined hurdles technology.
- The pH exert a strong selective pressure on the existing microflora.
- pH range of HMFP (3-4.1) might not represent the optimum for growth and the microorganism may not be able to grow under this pH.
- pH - a_w interaction in the applied ranges will be enough to suppress the growth of most bacteria of concern in fruit preservation .
- At high levels of a_w, the effects of pH on osmophilic yeasts might be the same as for non-osmophilic yeasts.



Preservation of HMFP

- Common hurdles used for providing microbial stability to the HMFP are
    - ✓ Blanching
    - ✓ Water activity depression
    - ✓ Lowering of pH
    - ✓ Addition of chemical preservatives (sorbate or benzoate)
    - ✓ The addition of sulfite as an anti-browning agent
- Food is preserved by interference with the homeostasis of microbes
    - ✓ Homeostasis is the tendency to uniformity or stability in normal status (internal environment) of organisms.
    - ✓ Homeostasis is disturbed by the preservative factors (a_w, pH, additives, etc.); the microorganisms will not multiply or may even die.
- Microbial stability could be achieved with an intelligent combination of hurdles.

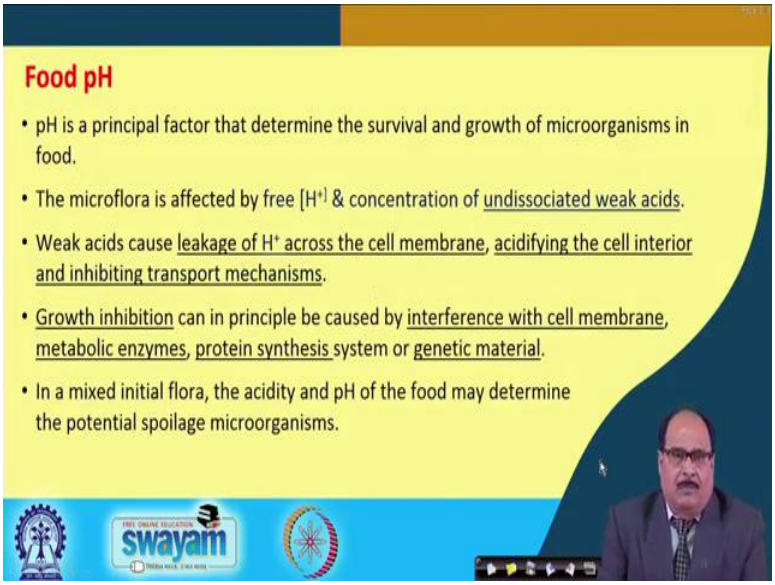


Effect of certain hurdles on microbial cell hydrolysis

Water activity

- Water activity effect on majority of microorganisms are related to the water status. It is not only the water quantity, but in the form in which water represent i.e. water activity.

- 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 because of the gradient in the osmotic inside as well as outside the cell, in order to maintain the equilibrium; 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

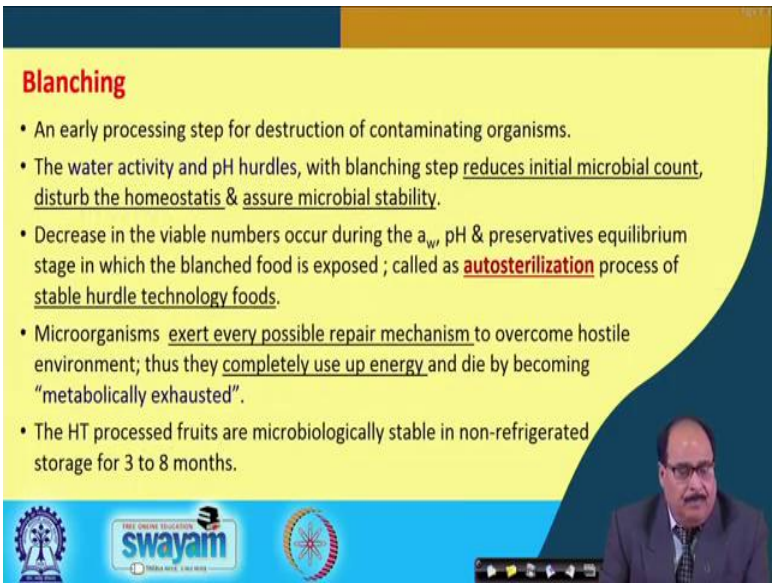
- Acidity slows down the growth of spoilage organisms and pathogens.
- Pathogens won't grow and spores won't germinate at pH < 4.5 (e.g. fruit juices & sauerkrat).

Preservatives

- Inhibit bacteria, yeasts and molds
- Used at low levels (mg /kg) for specific applications.

Example,

Benzoate in soft drinks, propionates in baked goods, nitrites in meat, sulfites in wines), ascorbates in juices, etc.



Blanching

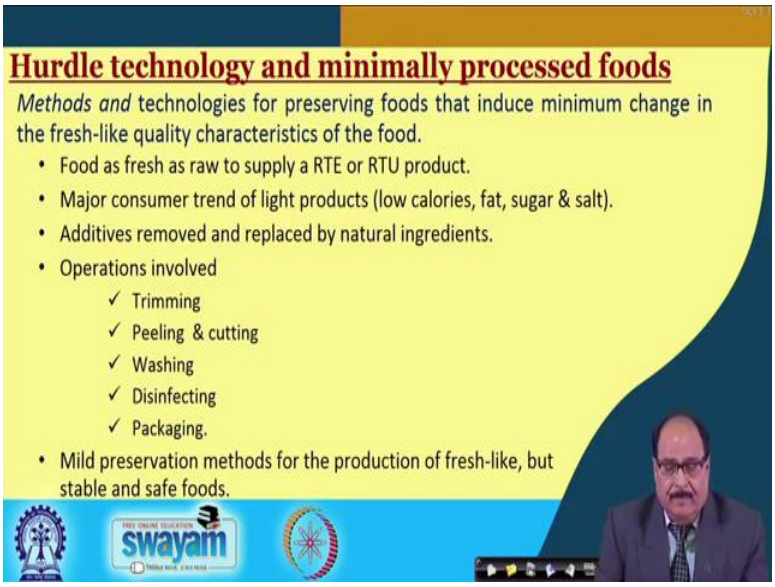
- An early processing step for destruction of contaminating organisms.
- Blanching is a comparatively less severe heat treatment applied to fruits or vegetable tissues, as a preprocessing step. The main aim here is to inactivate enzymes or sometime it also results in bacterial destructions.
- The water 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. And, once after the once the equilibrium is set then after few time slowly and slowly the microorganisms die, there is a decrease seen in the viable numbers count during this stage. This is called as **autosterilization** 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".
- There are several reports in the regard that the HT processed fruits are microbiologically stable in non-refrigerated storage for 3 to 8 months.

Hurdles technology in quality control and hazard analysis

- Sanitation is an essential prerequisite for production, and contamination can always be minimized by employing proper sanitary and handling techniques.
- Proper HACCP program should be designed to assure safety of HT foods.
- Overall quality of HMFP is necessary; GMP should be adopted.
- It should not represent significant risks of pathogenic hazards.
- Inhibition of food-spoilage and pathogenic microorganisms should be ensured.
- Food quality attributes should also be preserved.
- HT foods must have a consistent texture, fresh appearance, and acceptable colour.

Sensory characteristics of hurdle technology foods

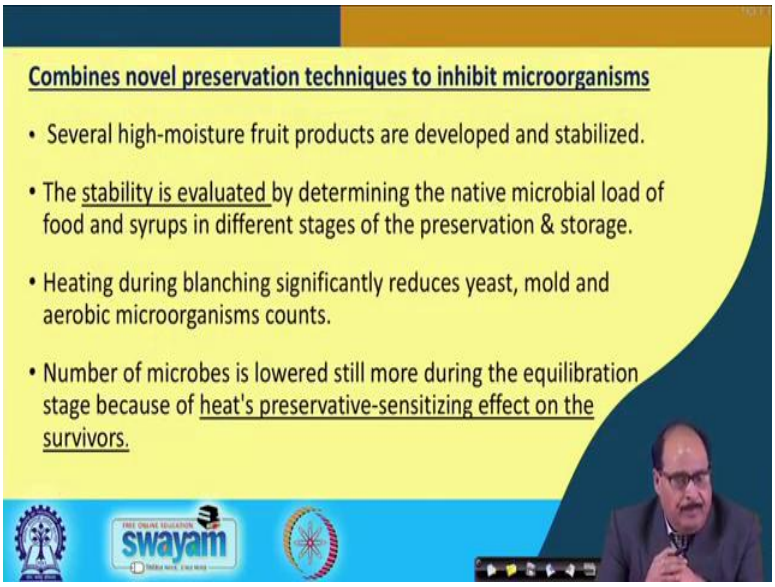
- Hurdle technology results in products with good sensory characteristics.
- The combined-methods technology applied by placing blanched food into a solution of sucrose, acids, and additives in such concentrations that after the stabilization time, the desired water activity, pH, and additive concentrations are obtained.
- The major changes are the result of an osmotic concentration process during stabilization process.



Hurdle technology and minimally processed foods

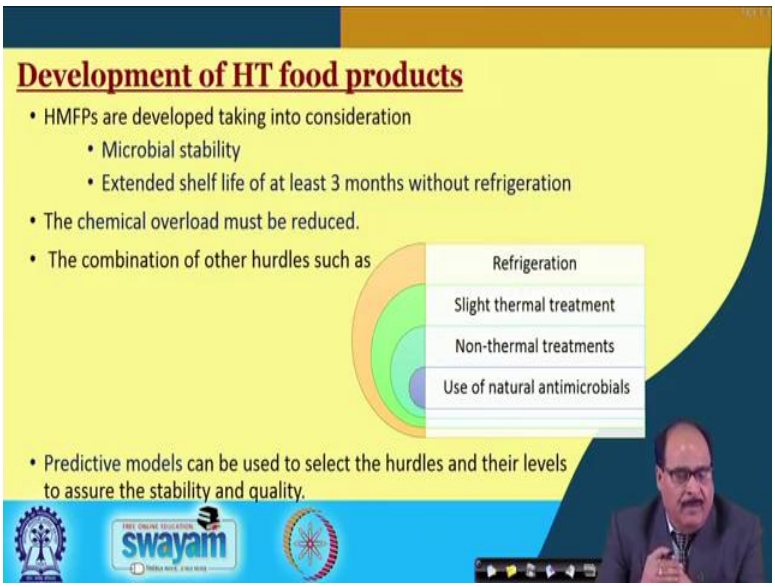
Methods and technologies for preserving foods that induce minimum change in the fresh-like quality characteristics of the food. There minimally processed foods are those which are exposed to least possible severe treatments or minimum possible processing.

- Food as fresh as raw to supply a RTE or RTU product.
- Major consumer trend of light products (low calories, fat, sugar & salt).
- Additives removed and replaced by natural ingredients.
- Operations involved
    - ✓ Trimming
    - ✓ Peeling & cutting
    - ✓ Washing
    - ✓ Disinfecting
    - ✓ Packaging.
- Mild preservation methods for the production of fresh-like, but stable and safe foods.



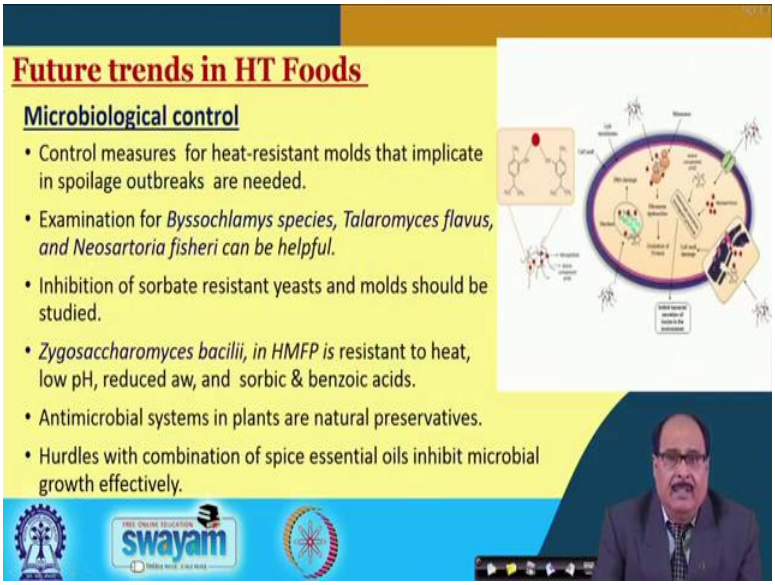
Combines novel preservation techniques to inhibit microorganisms

- Several high-moisture fruit products are developed and stabilized.
- The stability is evaluated by determining the native microbial load of food and syrups in different stages of the preservation & storage.
- Heating during blanching significantly reduces yeast, mold and aerobic microorganisms counts.
- Number of microbes is lowered still more during the equilibration stage because of heat's preservative-sensitizing effect on the survivors.



Development of HT food products

- HMFPs are developed taking into consideration
    - Microbial stability
    - Extended shelf life of at least 3 months without refrigeration
- The chemical overload must be reduced.
- The different combinations or hurdles which can be used may be refrigeration, slight thermal treatment, non-thermal treatment, use of natural antimicrobial, etc.
- Predictive models can be used to select the hurdles and their levels to assure stability and safety of the products.

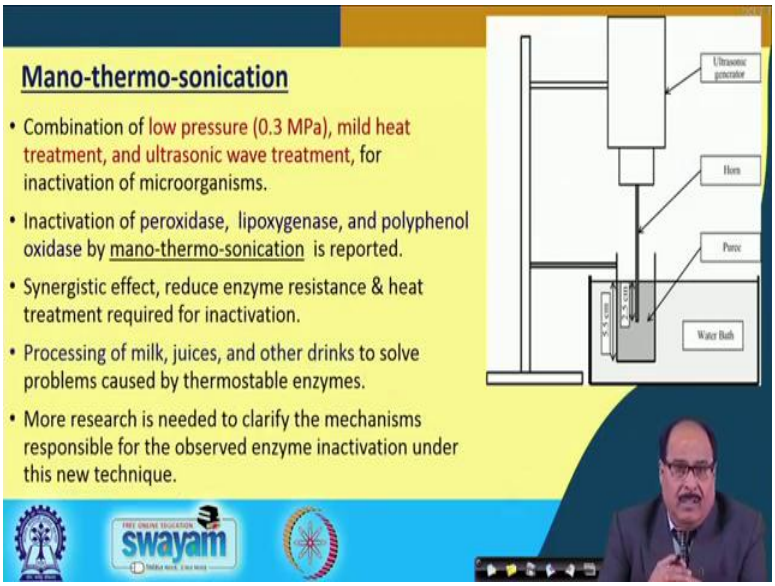


Future trends in HT Foods

Microbiological control

- Control measures for heat-resistant molds that implicate in spoilage outbreaks are needed. How the different heat resistant micro-organisms can be controlled by using less severe processes are to be evaluated.
- Examination for *Byssochlamys species, Talaromyces flavus,* and *Neosartoria fisheri* can be helpful.
- Inhibition of sorbate resistant yeasts and molds should be studied.
- *Zygosaccharomyces bacilii,* in HMFP is resistant to heat, low pH, reduced aw, and sorbic & benzoic acids.

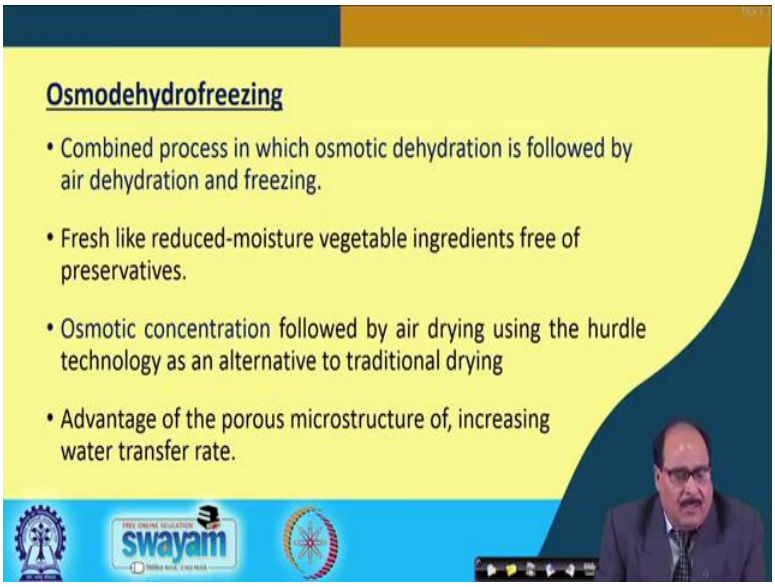
- Antimicrobial systems in plants are natural preservatives.
- Hurdles with combination of spice essential oils inhibit microbial growth effectively.



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 milk, 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.

So, to understand the mechanism, how the synergistic effect actually results, the way of better utilization of the technology should be taken up to successful commercialization of the process.



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 of the osmodehydro frozen products, as well as increasing water transfer rate, reduced drying or freezing time and better reconstitution characteristics.