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

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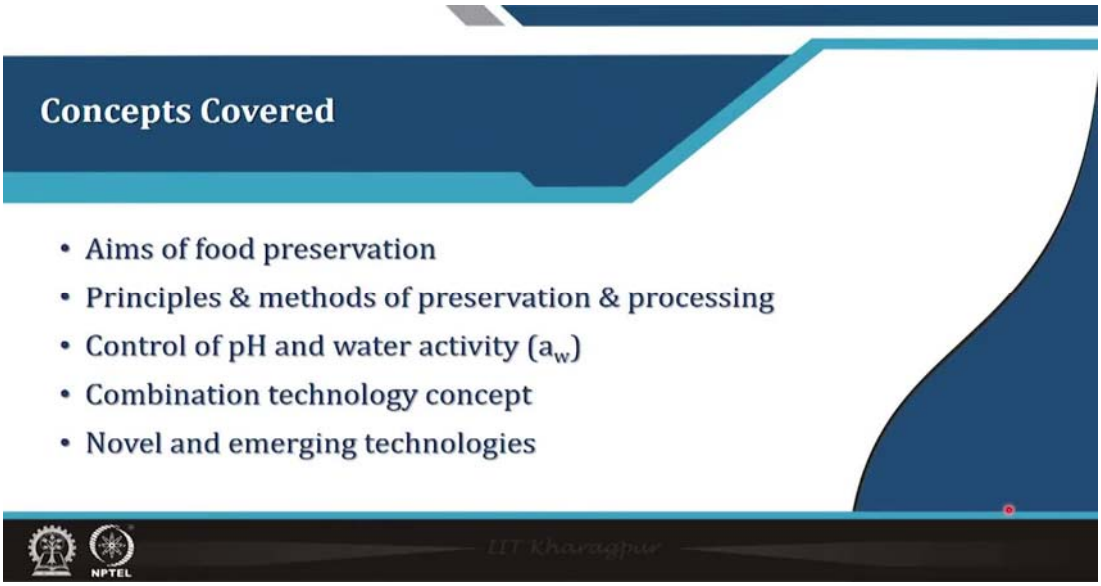
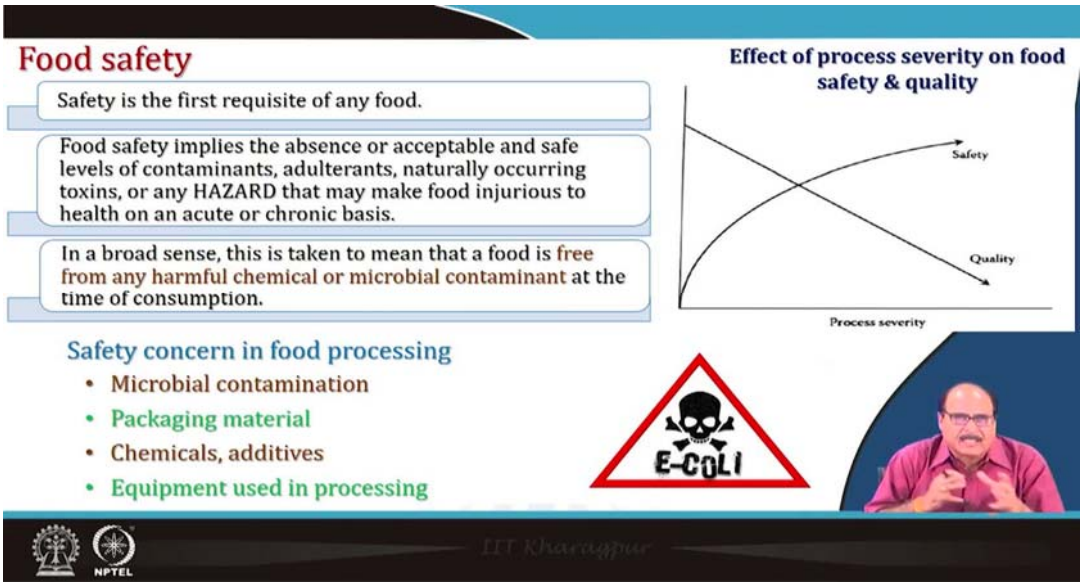
Lecture 11

Basics of Processing and Preservation

The processing and preservation principles will be discussed about the basics of processing and preservation.



The concepts include aims of food preservation, principles and methods of preservation and processing, control of pH and water activity, combination technology concept and an overview of the novel and emerging technology in the processing.



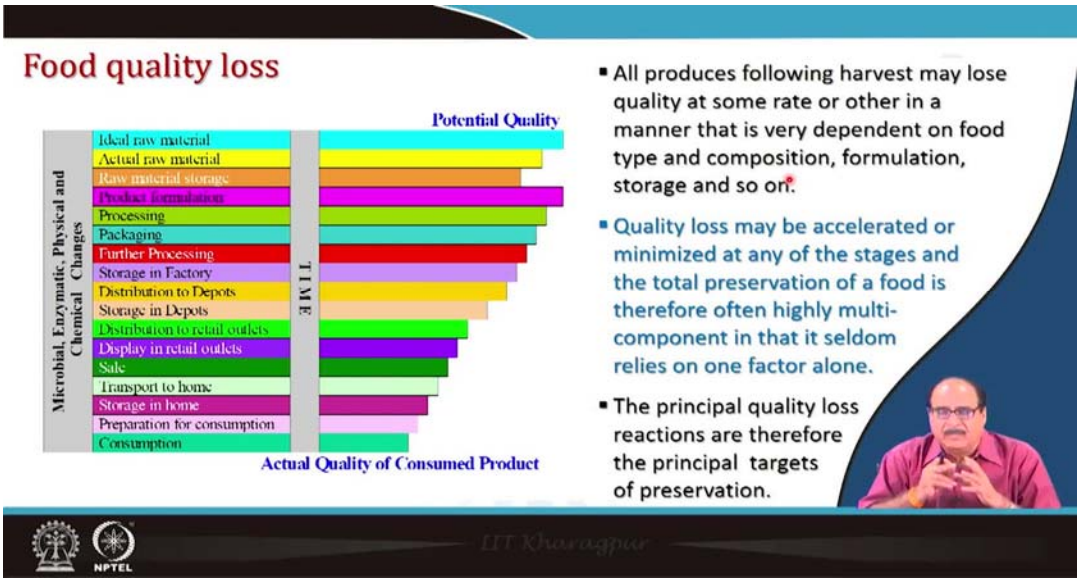
Food safety

In the last lecture, the various method to determine food quality attributes QA and QC were discussed. Safety is the first prerequisite of any food. Food safety implies the absence or acceptable and safe levels of contaminants, adulterants, naturally occurring toxins, or any hazard that may make food injurious to health on an acute or chronic basis.. So, the food at the time of its consumption should be free from any such hazards or undesirable toxin or chemical components. In a broad sense, this is taken to mean that the food is free from any harmful chemical or microbiological contaminant at the time of its consumption.

Safety concerns in the food processing include:

1. Microbiological contamination
2. Contamination arising out of packaging material
3. Contamination which may come from the chemicals or
4. Processing or equipment which are used in the processing i.e if they are not properly cleaned; they may also be a source of contaminants.

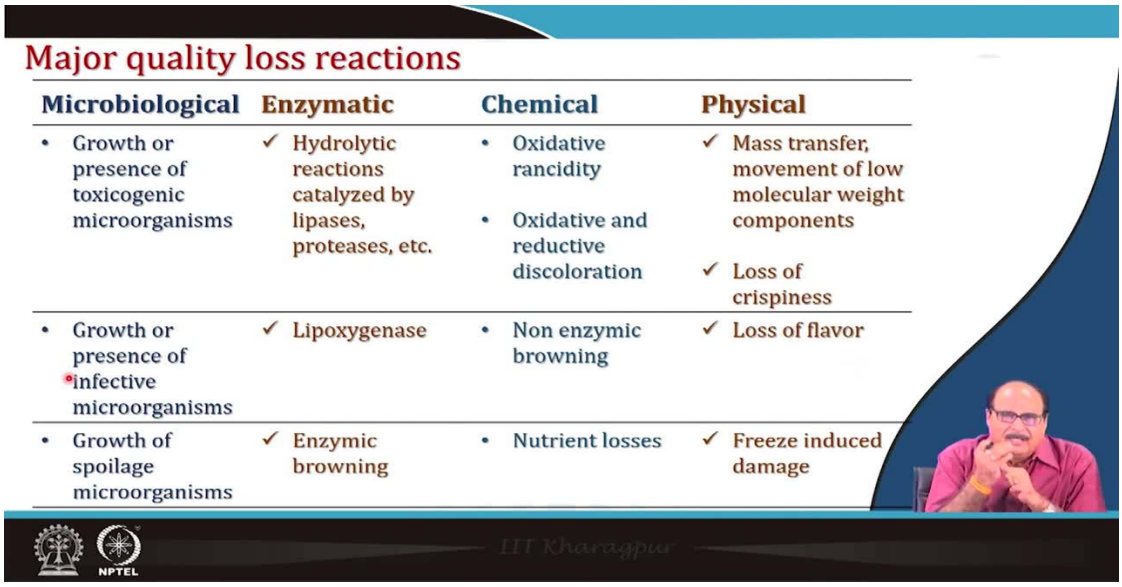
The effect of processing on safety and quality are both interrelated which means more severe processing will lead to a better safety of the product, but that it may also result in deterioration of the quality. So the particular severity level and combinations of the process parameters is critical to get a food which is of good quality as well as at the same time it is safe for consumption.



Food quality loss

All the products following harvest may lose quality at some rate or other in a manner that is highly dependent on the food type and composition formulation and storage. The figure represents that actually the value chain starting from the ideal raw material and passes through various stages till it reaches to the consumer's table.

Quality loss may be accelerated or minimized at any of the stages and the total preservation of a food is therefore often highly multi- component in that it seldom relies on one factor alone. The food material which is being handled here, it is a biological material and various agents like microbiological in geometric, physical, chemical agents are acting on it and they bring about various changes. So, the principal quality loss reactions are therefore, the principal targets of food preservation or food preservation technology.



Major quality loss reaction

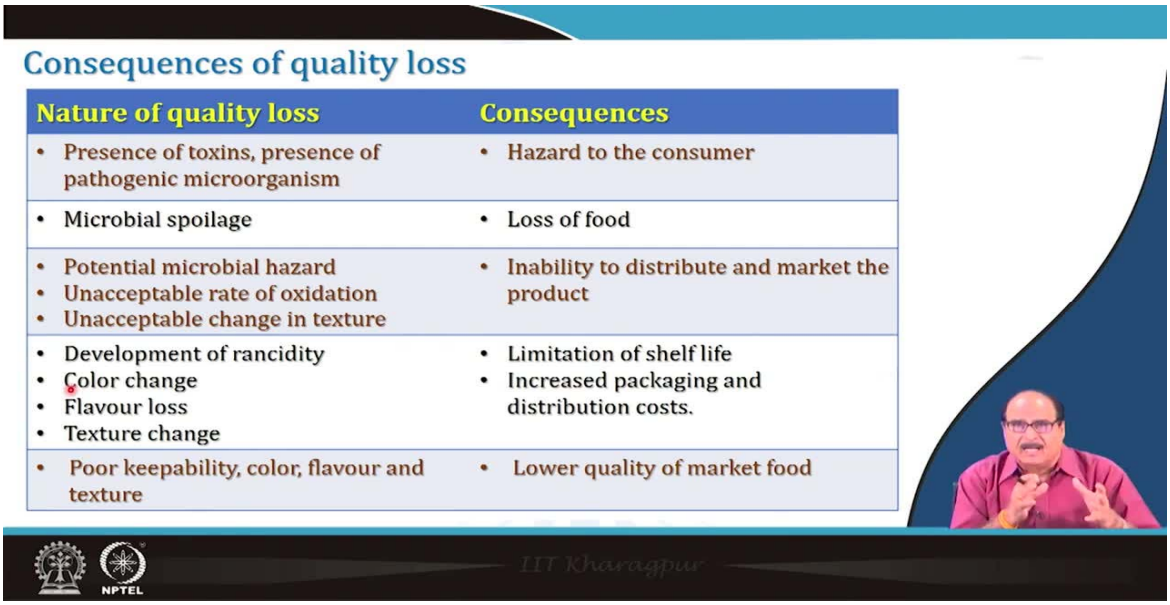
The major quality loss react include the following :

1. **Microbiological factors:** growth or presence of toxicogenic microorganism or there may be growth or presence of impact to microorganism or just growth of spoilage microorganism.

2. **Enzymatic reactions**: these include hydrolytic reactions which are catalyzed by lipases and proteases etc. There are reactions catalyzed by lipoxygenase and enzymatic browning.

3. **Chemical reactions**: like oxidative rancidity, oxidative and reductive discolorationor nutrient losses.

4. **Physical reactions**: maybe mass transfer, movement of low molecular weight components from one place to other and there may be loss of crispiness, loss of flavor as well as freeze induced damages.

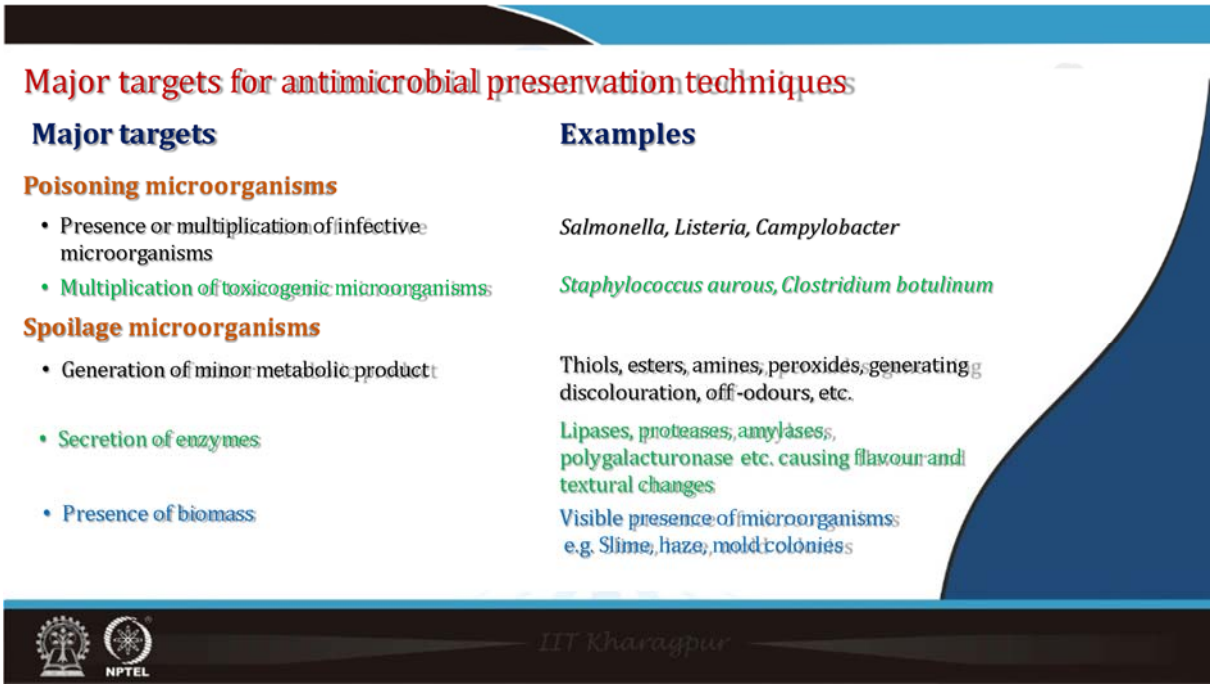


Consequences of quality loss

Processing and preservation steps are done to minimize these reactions undesirable reactions. So, if this quality loss is not properly controlled, the consequences may range broadly like poor keepability, changes in color, flavor and texture etc. leading to quality loss. The lower quality of the marketed food may reduce the marketability.

If there is a potential microbial hazard, unacceptable rate of oxidation, unacceptable change in texture, its consequences may be inability to distribute and market the product. But if there is presence of toxin and presence of a pathogenic microorganism in the food, it may be a hazard to the consumer.

The consequences of these quality loss reactions or the failure of the technology may lead to lower quality of the marketed food as well as hazard to the consumer. So, one has to be careful during processing and preservation



Major targets for antimicrobial preservation techniques

Poisoning microorganism

The major targets for antimicrobial preservation techniques may be either poisoning microorganism as most of the spoilage in the food is caused by the microbiological reactions and it also may be multiplication of toxicogenic microorganisms poisoning microorganism or spoilage microorganisms. The poisoning microorganism also include presence or multiplication of infective microorganism. Few examples of infective microorganism are *Salmonella, Listeria, Campylobacter* etc. Multiplication of toxicogenic microorganism bacteria include *Staphylococcus aurous or Clostridium botulinum*. When they grow in the food, they produce toxin. major targeted is that these should not be presented there as well as this will not be allowed to grow inside the food.

Spoilage microorganism

Spoilage microorganism grow and multiply and may cause generation of minor metabolic products like thiols, esters, amines, peroxides, generating, discoloration off–odors, etc. Lipases, proteases, amylases, polygalacturonase etc. causing flavour and textural changes. There maybe even presence of physical presence of the biomass like visible presence of the biomass like visible presence of the microorganisms for example slime, haze, mold to colonies etc.

Factors affecting microbial growth

- Intrinsic factors
- Processing factors
- Extrinsic factors
- Implicit factors
- Net effects

Chemical and physical factors within the food from which a contaminating microorganism is therefore inextricable in contact.

Factors affecting microbial growth

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- Processing factors
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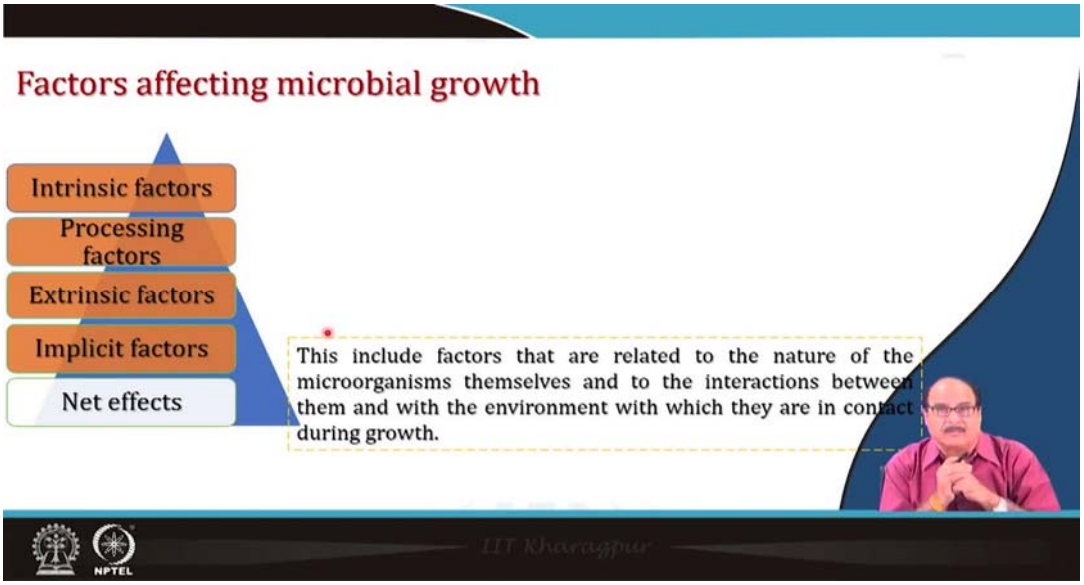
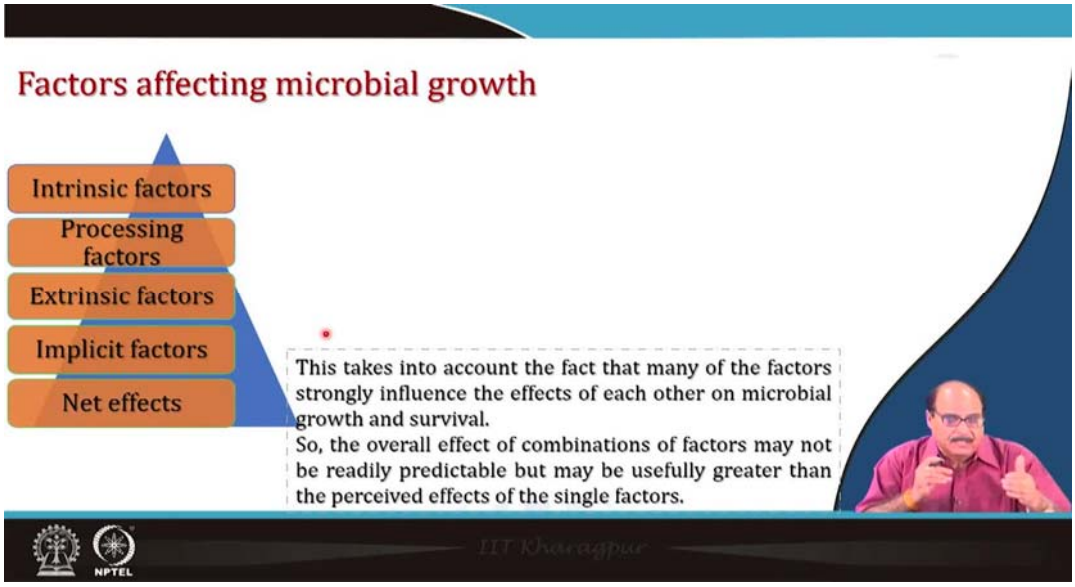
Factors applied to food during processing for improved preservation.

Factors affecting microbial growth

- Intrinsic factors
- Processing factors
- Extrinsic factors
- Implicit factors
- Net effects

Factors that influence microorganisms in food but which are applied from outside the food and act during storage.





Factors affecting microbial growth

There are various favorable conditions that influence and favor the growth and multiplication of microorganism in the food.

The various factors which are affecting the microbial growth are as follows:

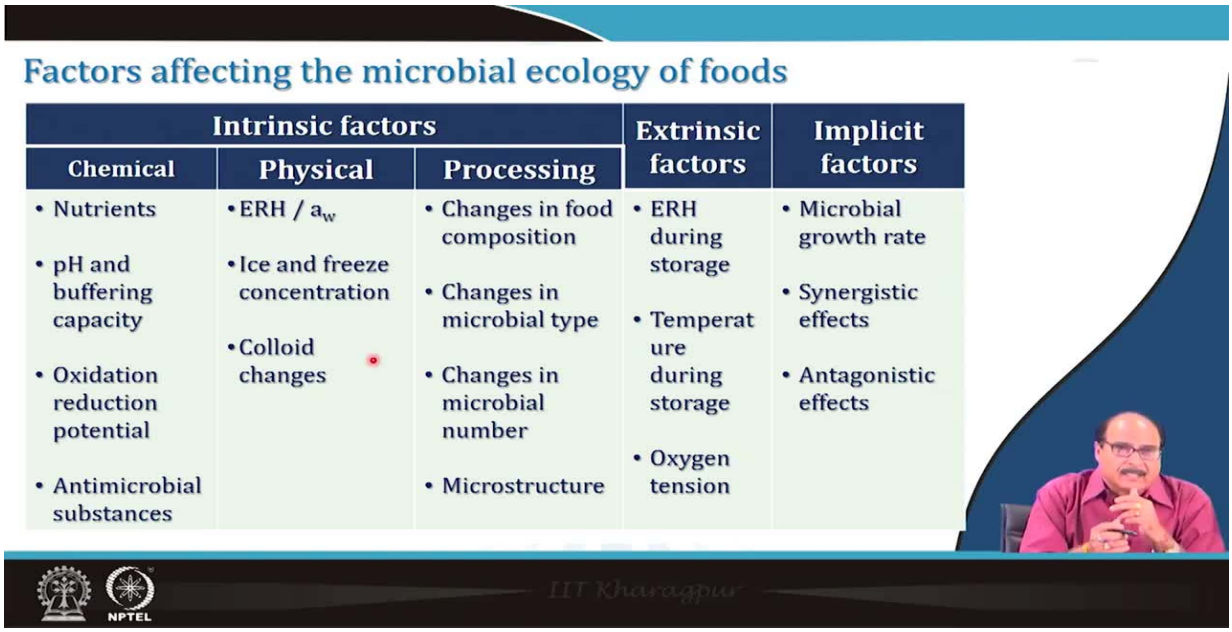
1. **Intrinsic factors** like the chemical and physical factors within the food from which a contaminating microorganism is inextricable in contact.

2. **Processing factors** are the factors which are applied to food during processing for improved preservation. These factors also may influence the growth.

3. **Extrinsic factors** are those factors that influence microorganism in food, but, these are applied from outside the food and they act during storage like temperature of a storage environment, relativity humidity of the storage environment etc

4. **Implicit factors** include factors that are related to the nature of the microorganisms themselves and to the interactions between them and with the interactions between the microorganism and the environment, which is they are in contact during growth.

5. Overall in this there is a **net effect**, this takes into account the fact that many of the factors strongly influence the effects of each other on microbial growth and survival. So, the overall effect of combinations of factors may not be readily predictable but may be usefully greater than the perceived effects of the single factors.

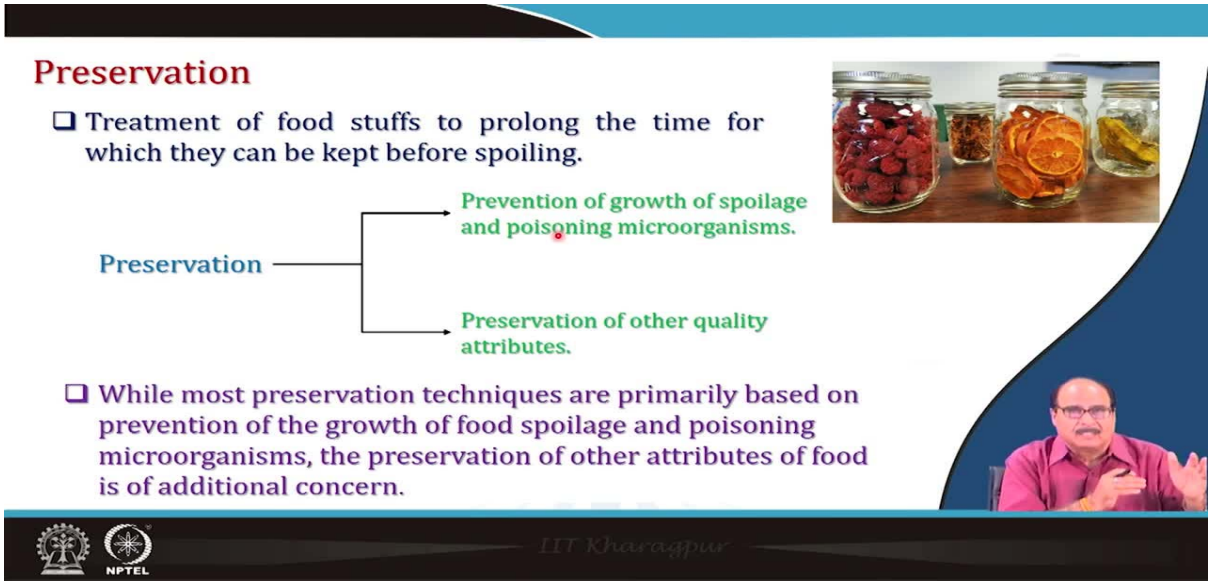


Factors affecting the microbial ecology of foods

The factors in this table I have summarize that all these physical factors, the intrinsic factors like chemical, nutrient, pH and buffering capacity, oxidation, reduction, potential antimicrobial substances. Physical that is ERH and water activity, ice and freeze concentration, colloidal changes are processing factor that changes in the food composition during processing, changes in the microbial type, changes in the microbial number or changes in the microstructure of the food etc.

Extrinsic factors is the equilibrium relative humidity during storage, temperature during storage, oxygen tension etc. And implicit factors like microbial growth rate that is the synergic

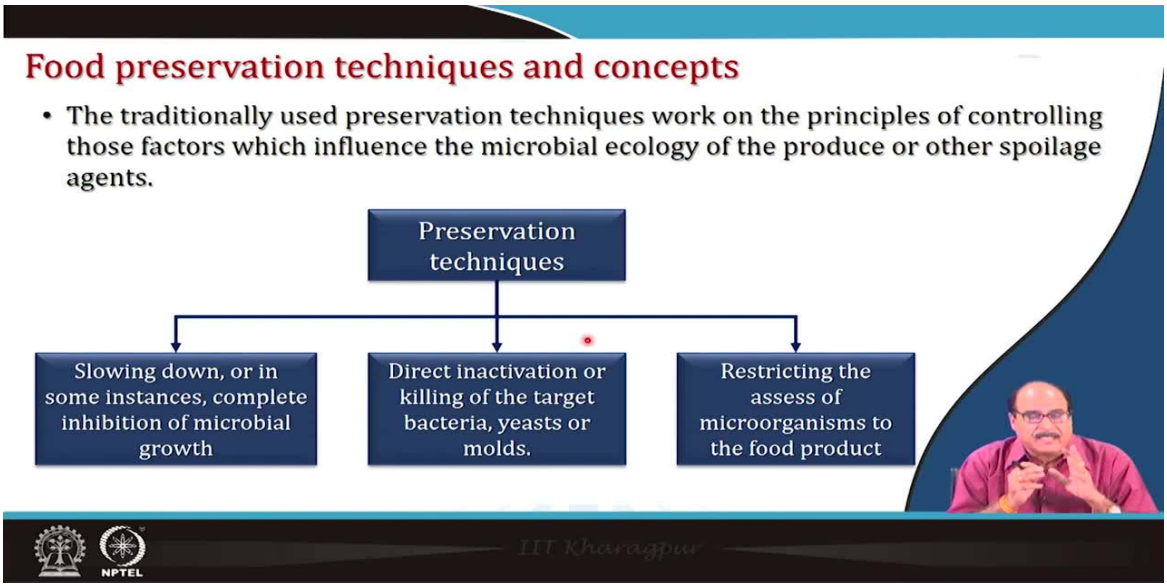
effects i.e the microorganism growth leads to the favorable environment for the growth of the other microorganism or there may be vice versa that the antagonistic effect. So, all these things affect and these are the factors which affect the microbial ecology of a food in general of fruits and vegetable in particular.



Preservation

The preservation is the treatment of food to prolong the time for which, they can be kept before spoiling.

While most preservation techniques are primarily based on the prevention of growth of the food spoilage and poisoning microorganism, the preservation of other quality attributes is also of major concern. A proper compromise that the both quality and safety is properly maintained.



Food preservation techniques and concepts

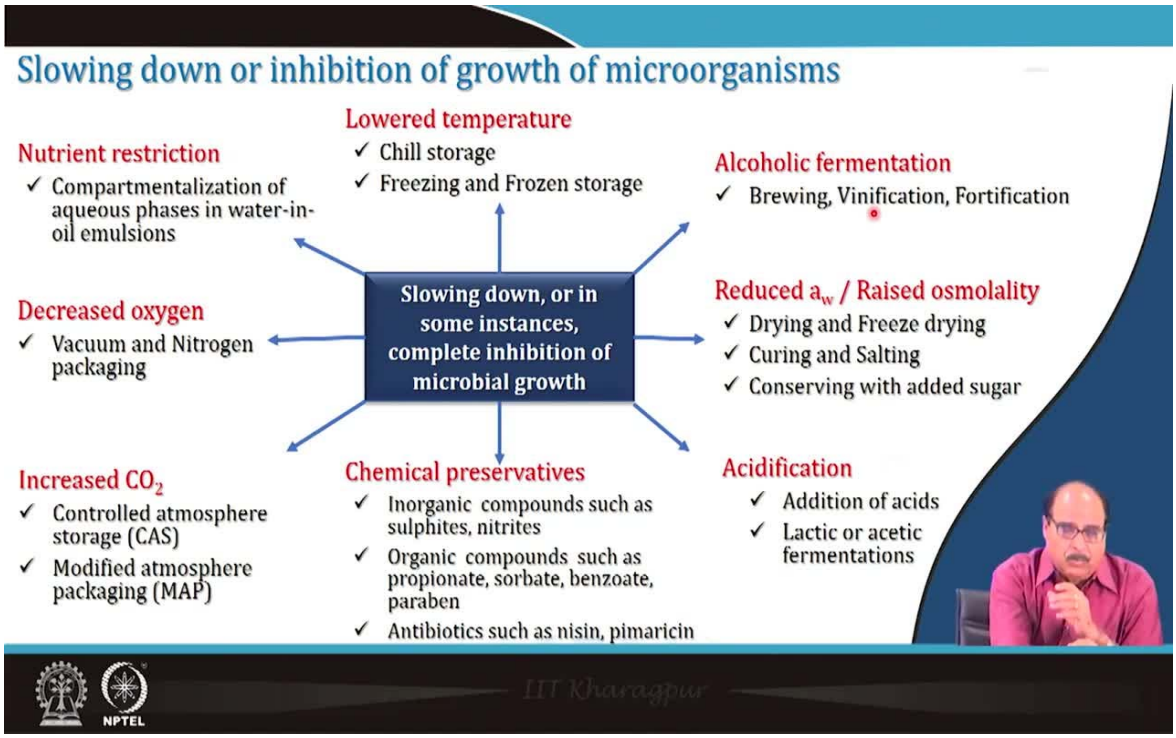
The traditionally used preservation techniques work on the principles of controlling those factors which influence the microbial ecology of the produce or other spoilage agents.

There are three set of preservation techniques

1. The slowing down that is one set of factors, which slows down or in some instances, complete inhibition of the microbial growth.

2. There is other particularly that direct inactivation or killing of the targeted bacteria yeast or mold, particularly if the bacteria of concern is a toxicogenic bacteria or pathogenic bacteria. An adaptive method is applied which kills and inactivate these microorganism

3. there are also one set of technologies, preservation technologies which restrict the access of microorganism to the food products.

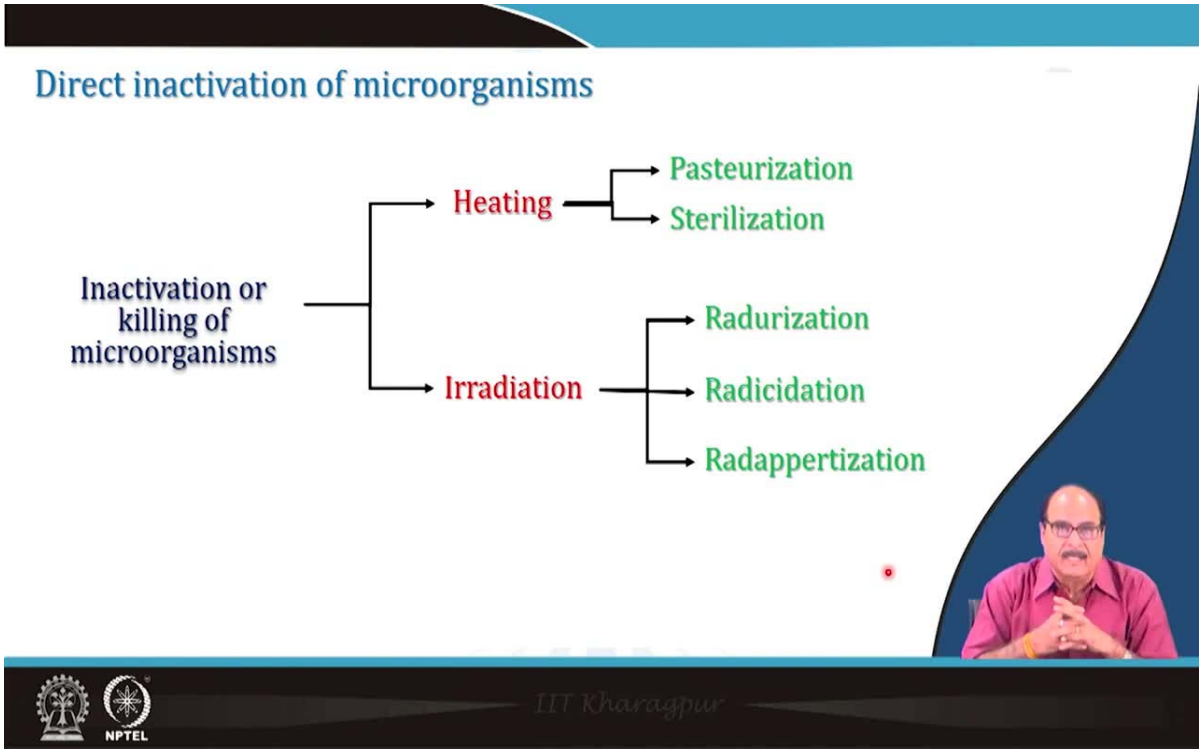


Slowing down or inhibition of growth of microorganisms

1. **Lowered temperature**: The technology which work on the principle of slowing down or inhibiting the growth of microorganism in food include lowering of the temperature, because temperature is one factor which influences the rate of microbial growth rate. So, the lowering of the temperature like chill storage, or freezing and frozen storage.

2. **Nutrient restriction**: where there is a compartmentalization of aqueous phases into water in oil emulsions and the nutrients which are present in the food material, can be compartmentalized in such a manner that the microorganism is not able to utilize that particular nutrient.
3. **Decreased oxygen:** like vacuum and nitrogen packaging because oxygen is another factor which influences the growth.
4. **Increased carbon dioxide:** this include Control Atmospheric Storage (CAS) or Modified Atmosphere Packaging (MAS).
5. **Chemical preservatives**: these are inorganic compounds such as sulphites, nitrites etc. The organic compounds such as propionate, sorbate, benzoates, paraben etc or antibiotics such as nisin, pimaricin.
6. **alcoholic fermentation:** could be activated by brewing, vinification or fortification. Apple juice and grape juice is preserved by converting it into wine to alcoholic fermentation.
7. **reduced water activity or raised osmolality:** like drying and freeze drying, curing and salting, conserving with added sugar is where the water is removed from the food materials this is water activities lower down.
8. **Acidification:** method like addition of acids, lactic or acetic fermentation like this pH management or even pickling et cetera is the process for the fruits and vegetables which work on this principle.

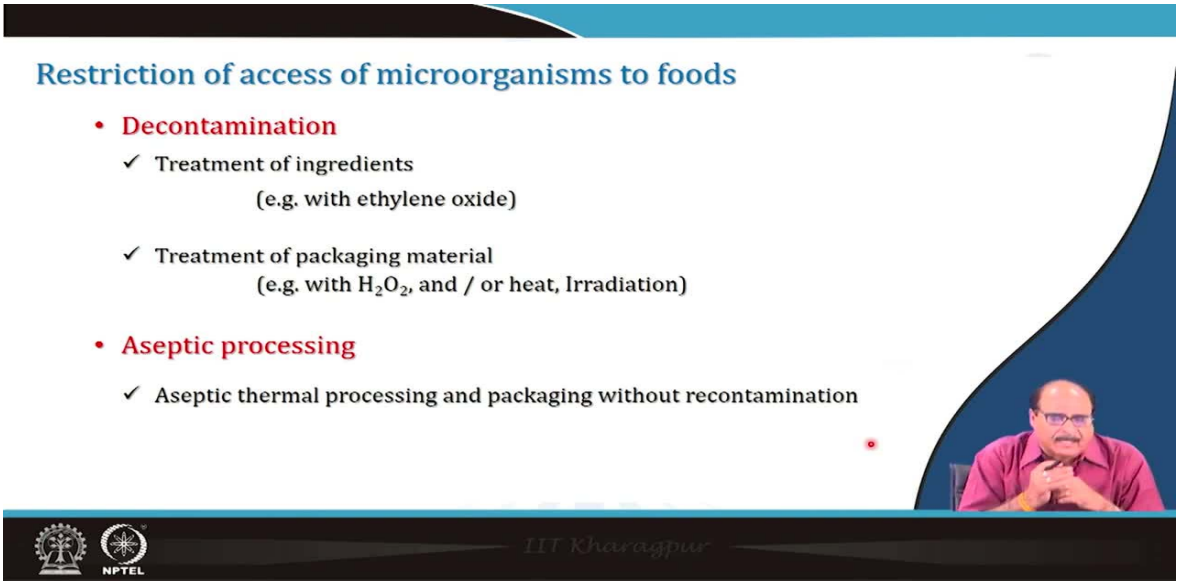
All these methods are based on that the bacteria or microorganism of the concern will not be killed, it just slows down or goes into the dormant state, it goes in the stationary phase. But when these factors are removed the product losses its shelf life. for example, you have kept a food material in a chili storage; as long as it is in the cold storage, the microorganism will not grow, but as soon as it is taken out from there or that stress factor is removed, the microorganism will again find a favorable environment, it will grow and multiply.



Direct inactivation of microorganisms

The direct inactivation of microorganism is based on killing the microorganisms. Some sort of energy is applied, ut could be either heat energy or radioactive energy for killing the microorganism. Regarding heating it may be pasteurization and sterilization and irradiation include radurization, radicidation and radappertization.

So, these are the some of the technology where the energy is put into the food and in the microbial cell and the transfer of energy kills the microorganism. This may result into the denaturation of the body enzyme system or physiological processes are adversely affected and microorganism particularly enzyme is inactivated resulting in microorganism get destroyed.

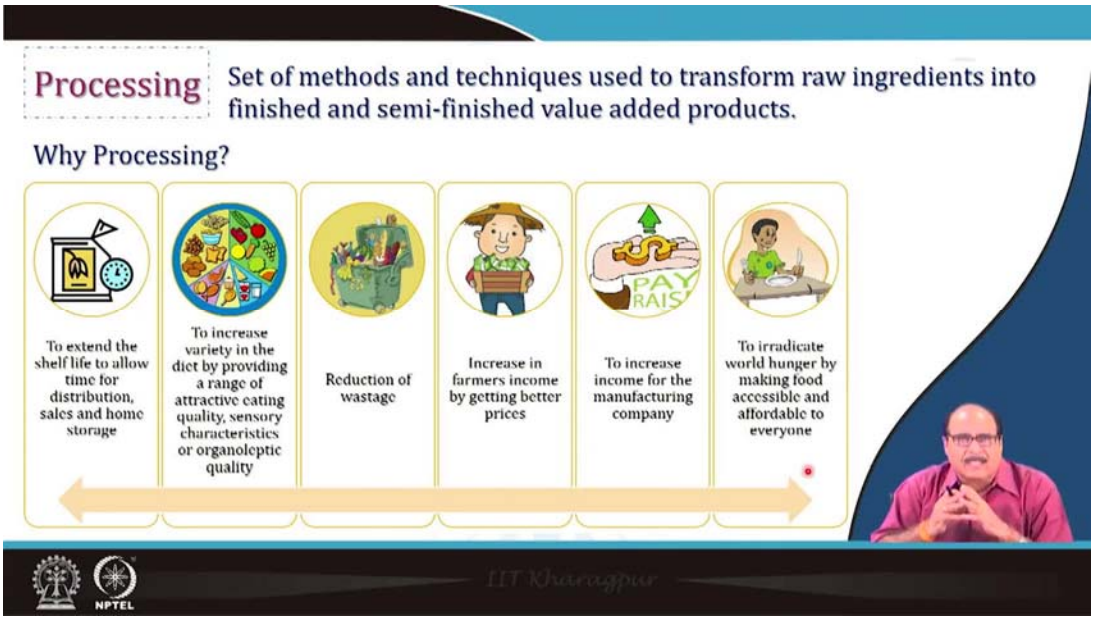


Restriction of access of microorganisms to foods

There are techniques which restrict or access of microorganisms in food.

Decontamination is lowering the level of contaminants of the packaging material or of the food like treatment of the ingredients with by for example with ethylene oxide or treatment of the packaging material with H_2O_2 and or heat, irradiation etc.

And then finally, aseptic thermal processing and packaging without recontamination makes decontaminate the components and then packet in an aseptic environment and this is the principle of **aseptic processing** and packaging.

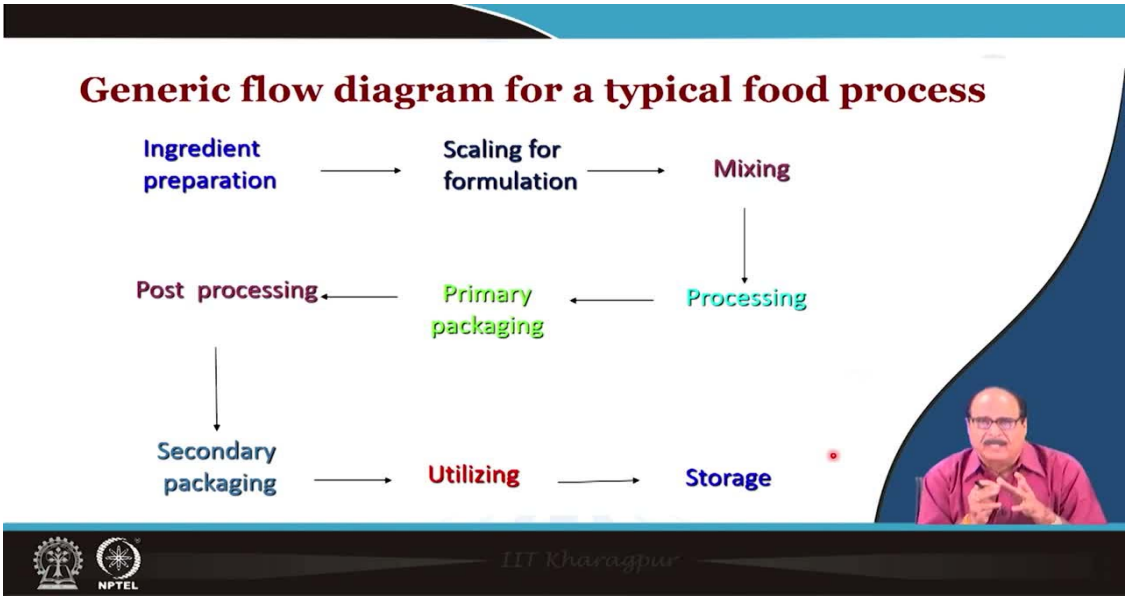


Processing

There is processing is the setup methods and techniques, which are used to transform raw ingredients into finished and semi-finished value-added products.

Why do we need processing?

- To extend the shelf life and allow time for distribution, scale and home storage.
- To increase variety in the diet by providing a range of attractive eating quality, sensory characteristics or organoleptic quality
- Reduction of wastage
- Increase in farmers income by getting better prices
- To increase income for of the manufacturing company
- To eradicate hunger by making food accessible with affordable to everyone so, these are the objectives of processing.

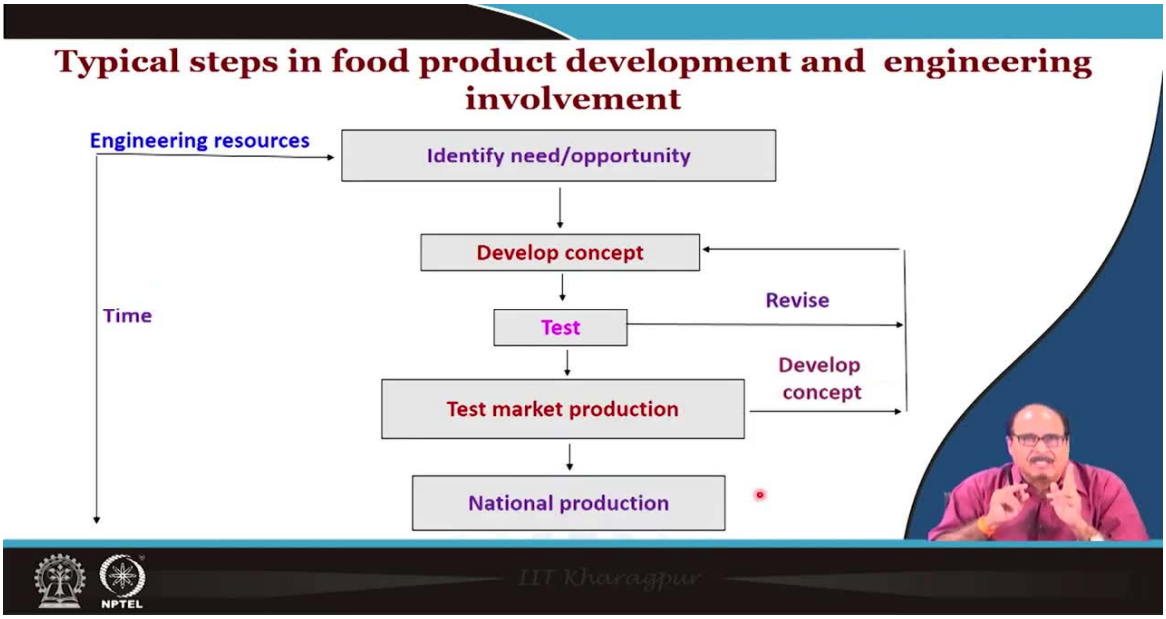


Generic flow diagram for a typical food process

This is a generic flow diagram for a typical food process for ingredient preparation i.e., primary processing like sorting, grading and converting into fine powder or paste and usage accordingly. This the ingredient preparation and these prepared ingredients then go for scaling for formulation either by automatic metering units or by individual or manual metering where the ingredients are taken as per the formula.

Invariably in all food process, there is a mixing operation either mixing up of solid to solid, solid to liquid, liquid to solid, liquid to gas, gas to gas so on. So, appropriate equipment and machinery are used for mixing as per the formulation. And then after the mixed formulation is

sent to the processing or the primary packaging sometime or even after after primary packaging, they are again sent for secondary processing and further secondary packaging and utilizing and finally storage. So, this is the generic flow diagram process flowchart for any food process in general.



Typical steps in food product development and engineering involvement

These are typical steps in Food Product Development and Engineering Involvement that depends upon engineering resources availability or financial availability to identify the need an opportunity i.e., what is the need and where is the opportunity, then developing the concept. Testing the concept; if the concept upon testing in the laboratory is approved and can go for the market production. If the concept fails in the laboratories, the concept is revised to be tested again.

Sometimes the concept is tested in the laboratory, but when it goes for large or national scale production or market production; the technology fails. Then in that case, it can be concluded that there is a anomaly. Again, a new concept is developed and proceed for larger scale, but this timeline should be as short as possible. Otherwise, the competitors may bring similar product into the market.

SWOT of food processing

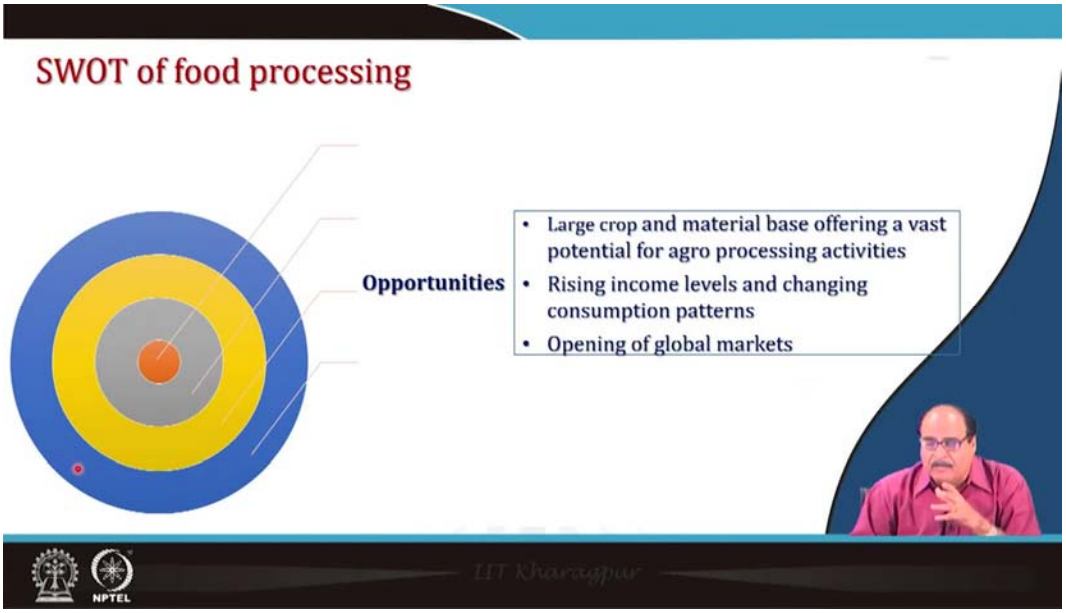
Strength

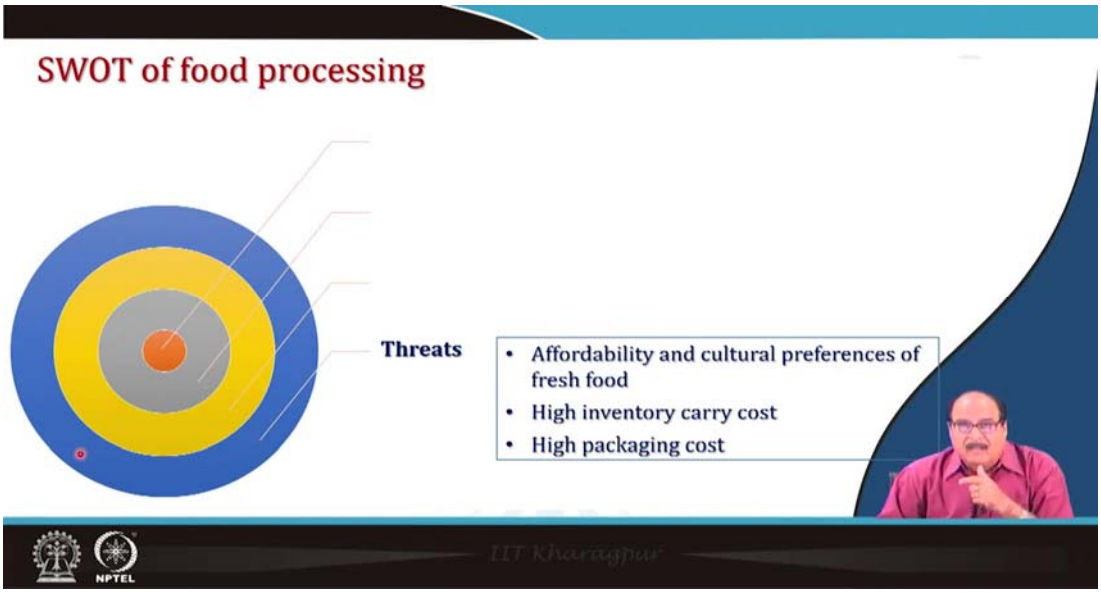
- Abundant availability of raw material
- Priority sector status for agro-processing by the central government
- Vast domestic market

SWOT of food processing

Weakness

- Low availability of adequate infrastructural facilities
- Lack of adequate quality control and testing methods as per international standards
- Inefficient supply chain due to a large number of intermediaries
- High requirement of working capital
- Inadequately developed linkages between R&D labs and industry
- Seasonality of raw material





SWOT of food processing

The SWOT analysis of the food processing include the following:

1. **Strength:** Abundant availability of raw material.

- Priority sector is status for agro processing by the central government.
- There is a vast domestic market of the processed food.

2. **Weakness:** There is a low availability of adequate infrastructural facility

- Lack of adequate quality control and testing methods as per international standards.
- There are inefficient supply chain due to a large number of intermediaries is involved in the value chain
- High requirements of working capital for most of the food processing industry

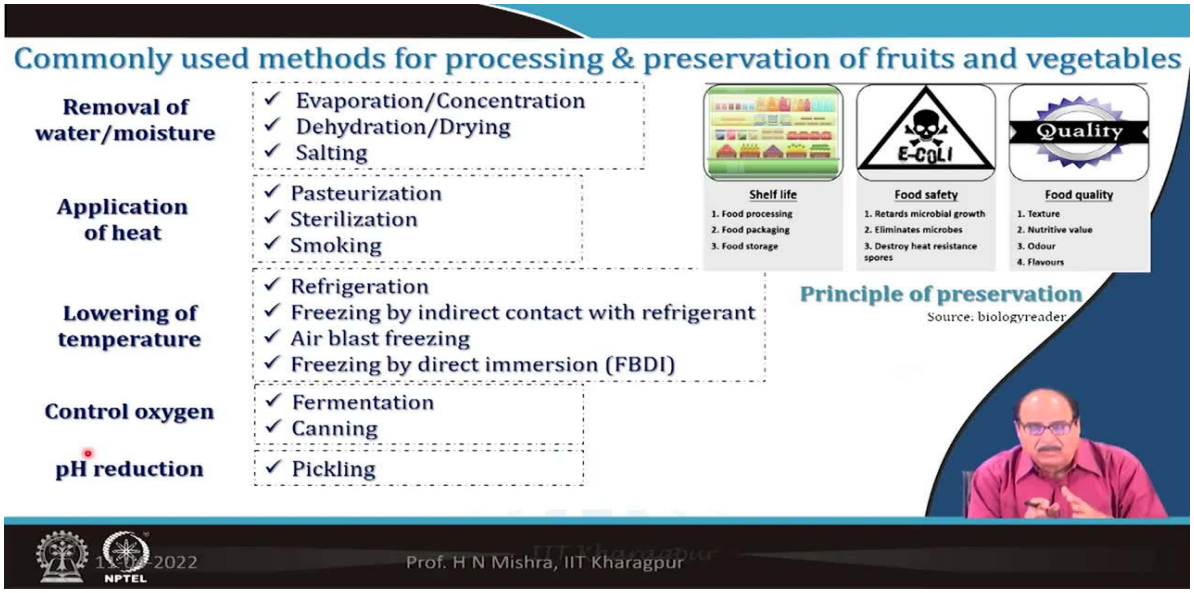
- Inadequate develop linkage between r&d labs and the industry
- Season availability of the raw material. So, these are some of the weaknesses.

3. **Opportunity:** like large crop and market material base offering a vast potential of agro processing activities.

- rising income levels and changing consumption patterns.
- opening up global markets.

4. **Threats:** Affordability and cultural preferences of fresh food

- High inventory carry cost.
- High packaging cost.

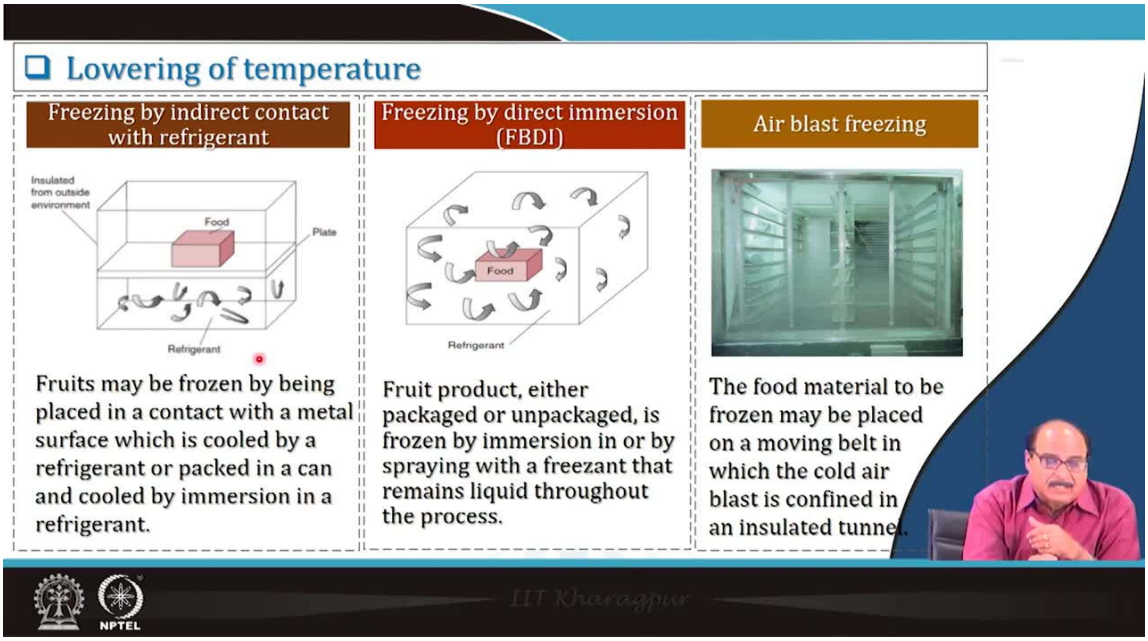


commonly used methods for processing of preservation of fruits and vegetables

commonly used methods for processing of preservation of fruits and vegetables involves the principle of preservation i.e. enhancing the shelf life by food processing, packaging and storage, achieving the food safety by retarding microbial growth, eliminating microbes and destroying heat resistant spores and finally by improving food quality by improving the texture, nutritive value, odor and flavors of food.

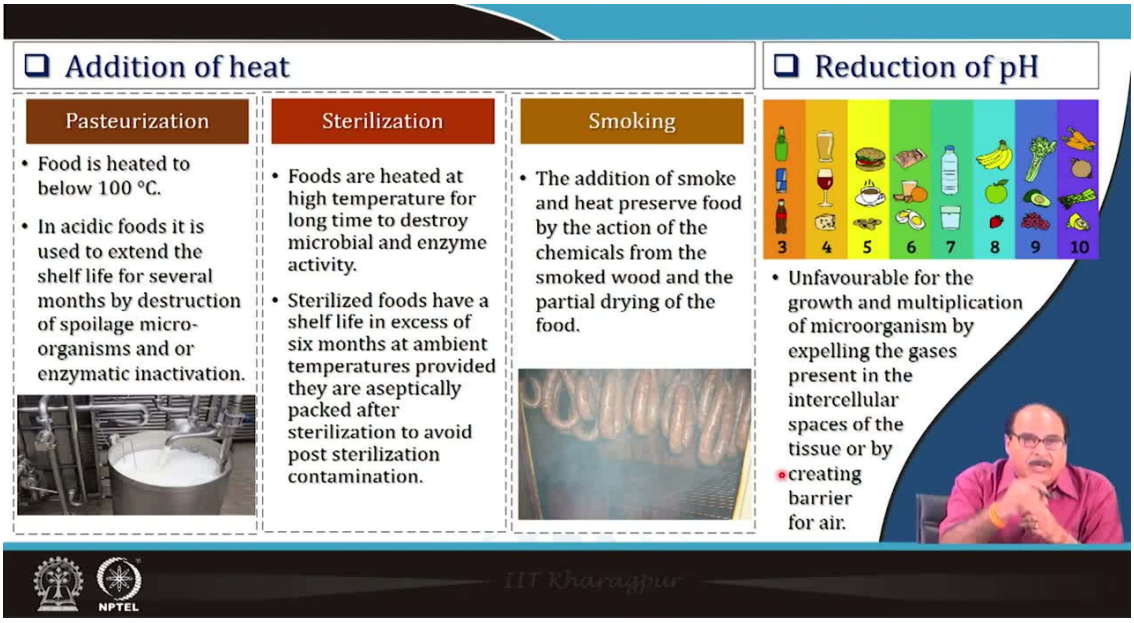
1. Removal of water or moisture like evaporation concentration, dehydration and drying salting.
2. Application of heat like pasteurization, sterilization, smoking.
3. Lowering of temperature like refrigeration, freezing by indirect contact with the refrigerant, air blast freezing, freezing by direct immersion.

4. Control of oxygen like fermentation and canning.
5. Ph reduction like pickling of fruits and vegetables. Et cetera. And all these methods we will take up details of their methodology concept and the even equipment et cetera in the next classes.



Lowering the temperature

1. **Freezing by direct immersion**: Fruit may be frozen by being placed in contact with a metal surface which is cooled by a refrigerant or packed in a can and is cooled by immersion in a refrigerant.
2. **Freezing by direct immersion:** Food product either package or unpackaged is frozen by immersion in or by spraying with freezant that remains liquid throughout the process.
3. **Air blast freezing**: The food material is to be frozen may be placed on a moving belt in which the cold air is confined in an insulated tunnel.

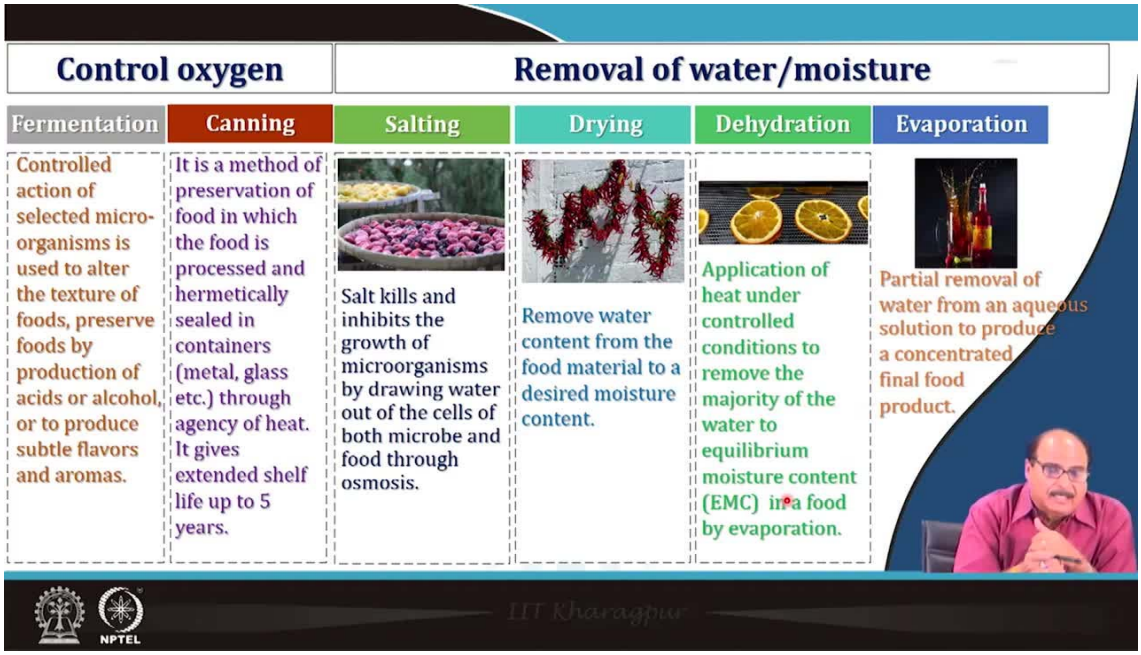


Addition of heat

1. **Pasteurization** where the food is heated below 100°C. in acidic food it is used to extend the shelf life for several months by destruction of the spoilage microorganism and or enzymatic inactivation.
2. **Sterilization** the food is heated to high temperature for a long time to destroy microbial and enzymatic activity. Sterilized foods have a shelf life in excess of six months at ambient temperatures provided they are aseptically packed after sterilization to avoid post sterilization contamination.
3. **Smoking** The addition of smoke and heat preserve food by the action of the chemicals from the smoked wood and the partial drying of the food.

reduction of pH

Unfavorable for the growth and multiplication of microorganism. Then ph is unfavorable that is the both extreme this side. This is done by expelling the gases present in the intracellular spaces of the tissue or by creating barrier.



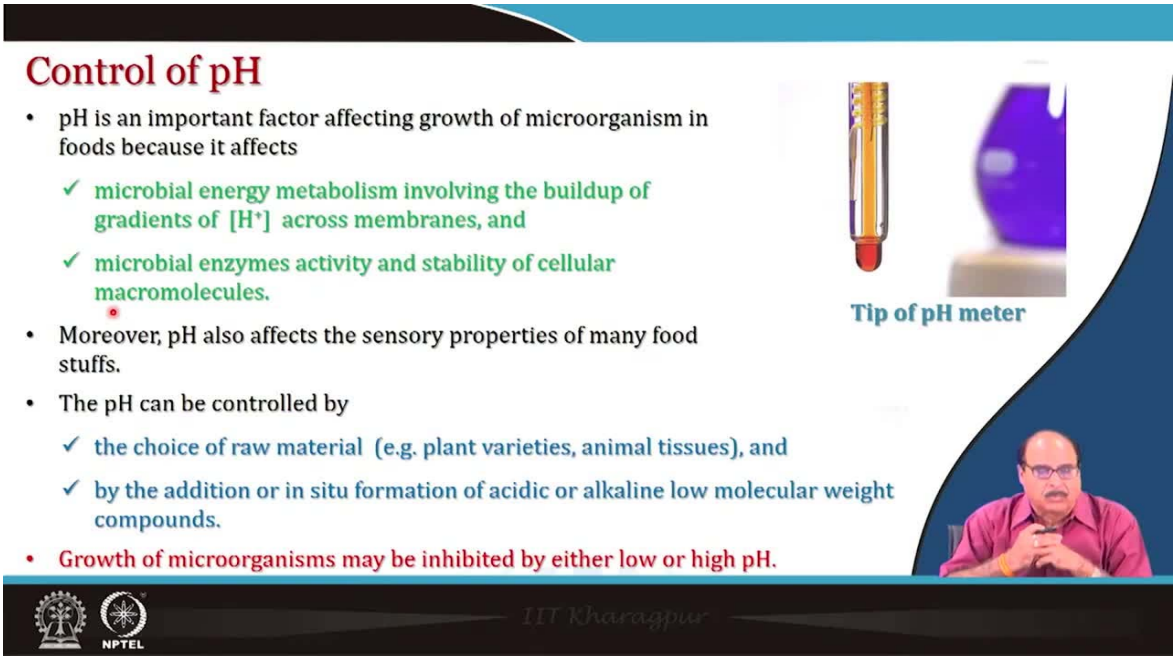
Control of oxygen

1. **Fermentation**: Controlled action of selected micro-organisms is used to alter the texture of foods, preserve foods by production of acids or alcohol, or to produce subtle flavors and aromas
2. **Canning**: It is a method of preservation of food in which the food is processed and hermetically sealed in containers (metal, glass etc.) through agency of heat. It gives extended shelf life up to 5 years.

Removal of water/moisture

Preservation of water or removal of water or moisture, thus trying to the control the water activity.

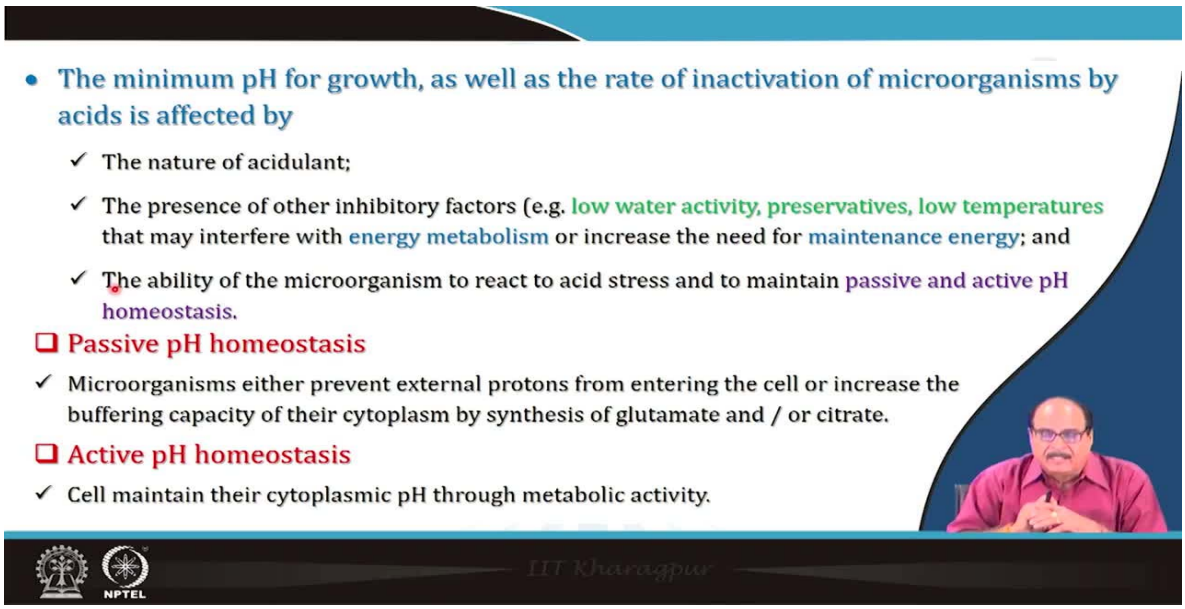
1. **Salting**: Salt kills and inhibits the growth of microorganisms by drawing water out of the cells of both microbe and food through osmosis.
2. **Drying:** Removal of water content from the food material to a desired level of moisture content.
3. **Dehydration:** Application of heat under control conditions to remove the majority of the water to equilibrium moisture content (EMC) in a typical food evaporation.
4. **Evaporation**: It is the partial removal of water from an aqueous solution to produce a concentrated final food product.



Control of pH

pH is an important factor affecting growth of microorganism in the food because it effects microbial energy metabolism involving the buildup of gradient hydrogen ion (H+) concentration across membranes and the microbial enzymes activity and the stability of cellular microorganism.

Moreover, pH also affects the sensory properties of many foods. So, pH can be controlled by the choice of raw material and by the addition or in situ institute fermentation of acidic or alkaline low molecular weight compounds. So, growth of microorganism may be inhibited by either low or high pH.



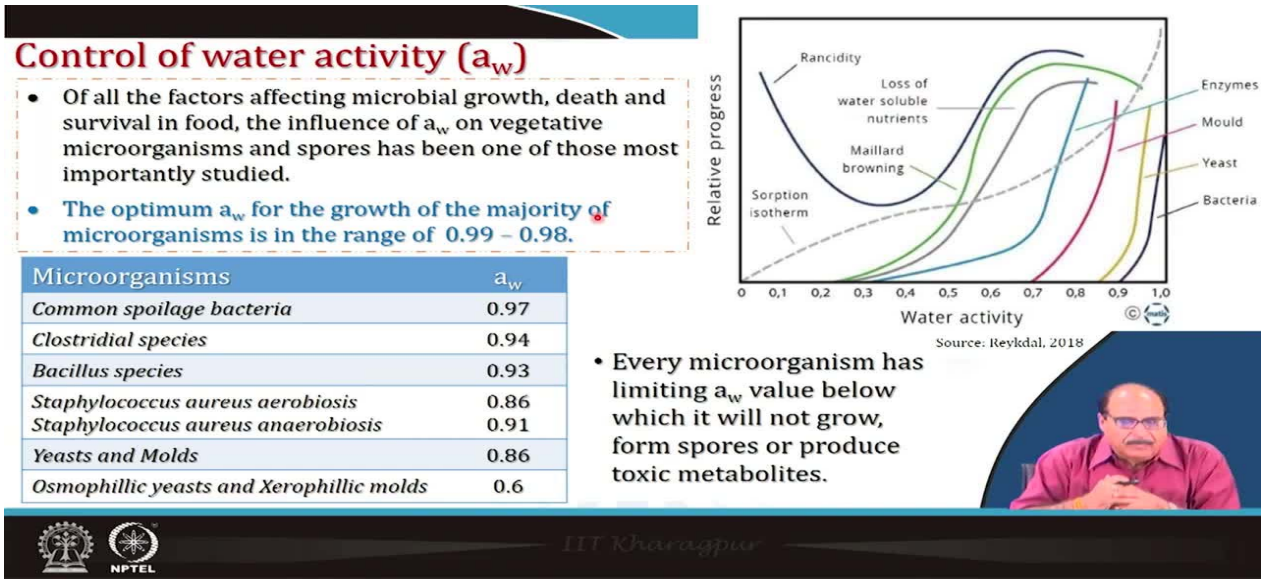
The minimum pH for the growth of microorganism as well as the rate of inactivation of microorganism by acid is affected by:

- The nature of acidulant.
- The presence of other inhibitory factors like no water activity, preservative low temperature, that may interfere with the energy metabolism or increase the need of maintenance energy.
- The ability of microorganism to react to acid is stressed to maintain passive or active pH homeostasis.

Passive pH homeostasis means microorganism either prevent external protons from entering the cell or increases the buffering capacity of their cytoplasm by synthesis of the glutamate and or citrate.

Active pH homeostasis cell maintains their cytoplasm pH through metabolic activity.

Till the pH homeostasis is maintained inside the cell the microbe will survive and at once homeostasis is disturbed, the microbes get disturbed. So, microorganism will try to maintain either active, passive or active pH homeostasis. Microbes try to manage and try to fight with the stress etc. and in this way they exhaust all their energy.



Control of water activity

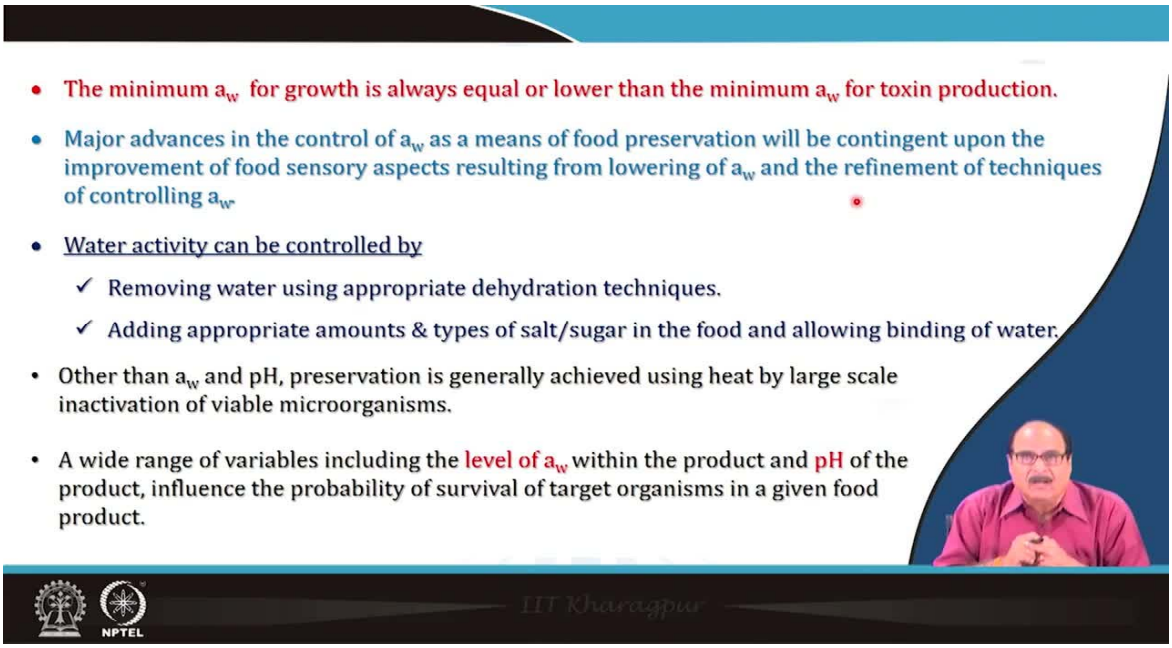
Of all the factors affecting microbial growth, death and survival in a food, the influence of water activity (a_w) on vegetative microorganism and spores has been one of the most important studies. The optimum water activity for growth of the majority of microorganism in the range

of 0.99 to 0.98 and some important common microorganism spoilage microorganism it is so near to this range.

So, every microorganism has limiting water activity below which it will not grow and it will not form a spore or it will not produce toxic metabolites.

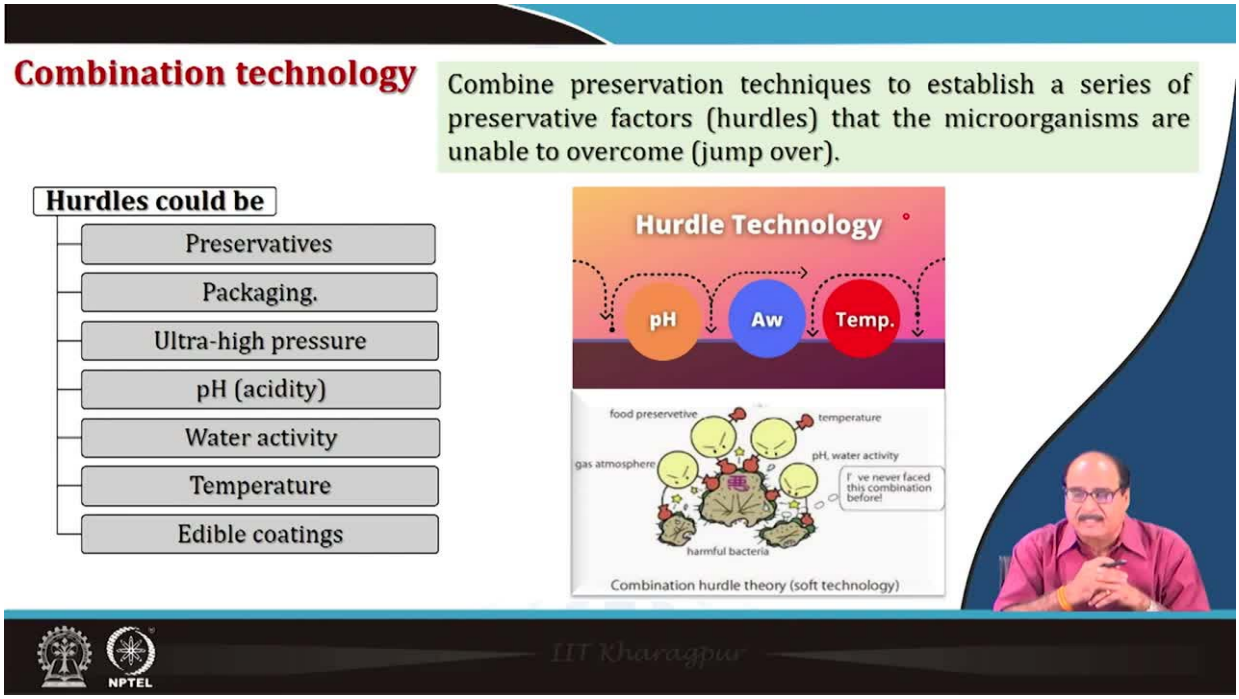
The figure shows the relationship between water activity and the progress of spoilage. The most important points are as follows:

- Growth of most spoilage bacteria is inhibited at about a_w 0.9.
- Growth of most spoilage yeast is inhibited at about a_w 0.88.
- Growth of most spoilage moulds is inhibited at a_w 0.7-0.8.



So, the minimum a_w for growth is always equal or lower than the minimum water activity for toxin production. Major advances in the control of water activity as a means for food preservation will be the contingent upon the improvement of food sensory aspects resulting from lowering of water activity and refinement of techniques for controlling the water activity. Because lowering the water activity adversely affect the sensory characteristics of the food.

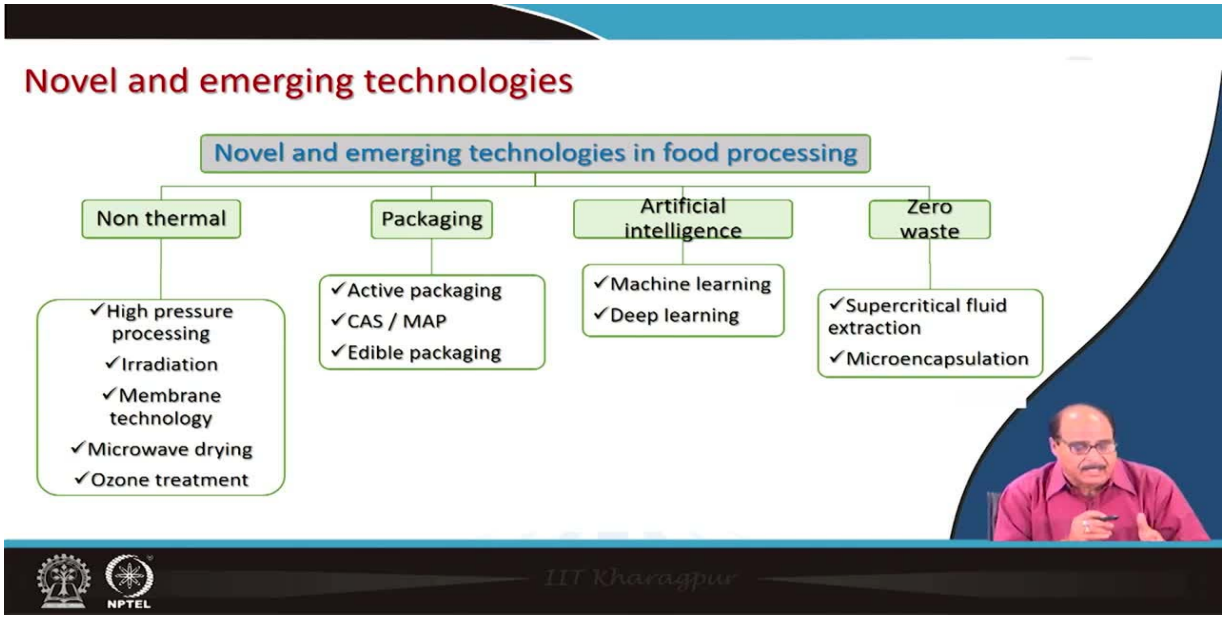
Water activity can be controlled by either removing water using appropriate dehydration techniques or by adding appropriate amounts and types of salt or sugar in the food and allowing the binding of water. Other than the water activity and pH preservation is generally achieved using heat by large scale inactivation of viable microorganism. A wide range of variables including the level of water activity within the product and the pH of the product influenced the probability of the survival of the target organism in a given food products.



Combination technology

Combination technology preservation techniques is to establish a series of preservative factors or hurdles i.e. the preservative factors that the microorganism are unable to overcome.

To prevent the spoilage instead of using a severe parameter of a single process, one can use different types of more than 2 - 3 processes together and therefore severity of the whole process can be reduced. This results in a better quality of the end product. So, various hurdle like preservatives, packaging, ultra-high pressure, pH, water activity temperature and edible coatings all these in the combination can be used.



Novel and emerging technologies

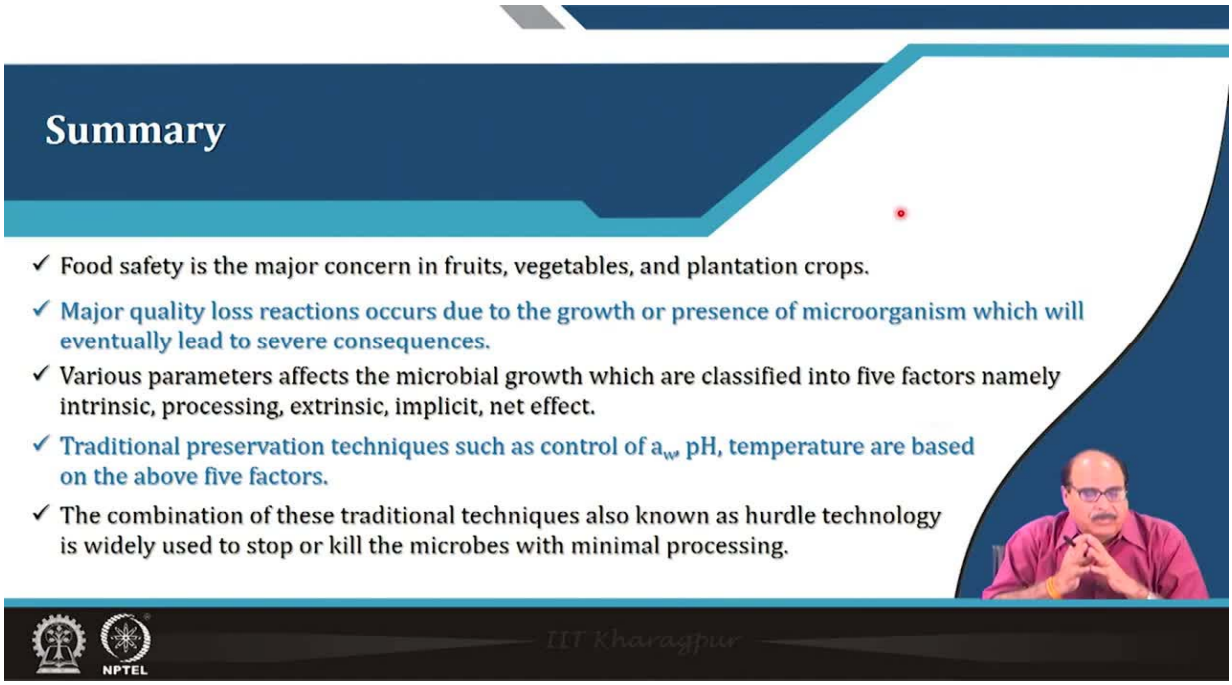
The novel and emerging technologies in the food processing include:

Non-thermal technology like high pressure processing, irradiation, membrane technologies, microwave drying, ozone treatment etc.

Packaging like active packaging, controlled atmosphere storage (CAS) and modified atmosphere packaging (MAP), edible packaging or edible coating.

Artificial intelligence which include machine learning and deep learning.

Zero waste technologies include supercritical fluid extractor or micro encapsulation.



Summary

The food safety the important or major concern in fruits vegetables and plantation crops. The major quality loss reaction occurred due to the growth or presence of microorganism which will eventually lead to the severe consequences and various parameters affect the microbial growth, which are classified into 5 factors namely intensive, processing, extensive, implicit and the net effect. All traditional preservation techniques such as control of water activity, pH temperature is based on all these such factor. These are used for food preservation, they work on the basis of the principle of controlling these microbial or their activity.

The combination of the traditional techniques also known as hurdle technology is widely used to stop or kill the microorganism with minimal processing. A minimal processing strategy which gives a better quality products.