Novel Technologies for Food Processing and Shelf Life Extension
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Lecture – 09
Traditional Food Preservation Technologies – Part 1

In the earlier lecture, the factors which influence spoilage of foods were discussed. Among the various agents, the growth and multiplication of microorganisms has been found to be the major reason for the spoilage of the food. In this lecture, the issues related to traditional food preservation technologies will be discussed.

The major techniques which are traditionally used for preservation of food are based upon those limited set of factors that influence microbial ecology of foods.

Most of these techniques act through either slowing down or in some instances, the complete inhibition of microbial growth. Few techniques act by direct inactivation or killing of the target bacteria, yeasts or molds. In addition to those main inhibiting and inactivating techniques, there are a few comparatively new procedures that restrict the access of microorganisms to food products.

Accordingly all the food processing technologies which are being used currently as well as from ancient time traditionally, they can be broadly classified into three major categories.

Category 1 is those set of technologies that work on the principle of slowing down or inhibiting the growth of microorganisms. Temperature is an important factor which influences the growth and multiplication of microorganisms in food. If the temperature is lowered, the growth rate of the microorganism is reduced. The lowering of the temperature is used as one factor for slowing down or inhibiting the growth of microorganism in food. Accordingly, cold or chilled storage, freezing and frozen storage are the two traditionally used food preservation technologies that work on the principle of lowering of temperature of the food.

The other factor is water activity or osmotic concentration; that is either lowering of water activity or raising the osmotic concentration of the food, influences the microbial growth and multiplication. Rather, when the water activity is lowered down, the microbial growth is reduced. The traditionally used preservation technologies which work on these principles include drying, freeze drying, curing and salting, conserving with added sugars, etc.

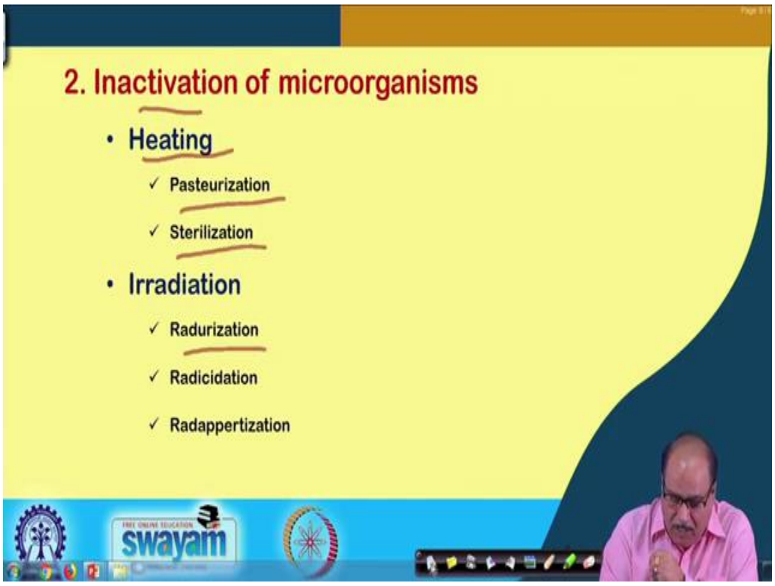
Another technology which is based on slowing down the microbial growth is to manipulate the nutrients present in food in such a manner that microorganism is not able to utilize or use that nutrient. This is done by compartmentalization of the aqueous phase in water in oil emulsions. A good example of this is butter, that is the milk fat. Fat is present in milk in the form of oil-in-water emulsion. In this form, it can be accessed easily by microbial enzymes and other factors and it can get spoiled. However, when this fat is separated from the milk in the form of cream, it becomes water-in-oil emulsion and the microorganisms find it difficult to break the emulsion and use the fat.

Similarly, decreased level of oxygen in the environment around the food or within the food is another way of slowing down or inhibiting the growth of microorganisms in food. The vacuum technology or nitrogen packaging is a common example which works on this basis. Similarly, controlling the gaseous composition like increasing the level of carbon dioxide or lowering the level of oxygen influence the respiration rate of the microorganisms. This lowering of the oxygen and increasing the carbon dioxide form the basis of two major processes, like controlled atmosphere storage or modified atmosphere packaging.

Increasing the acid content of the food either by addition of acids or in situ formation of certain acid like lactic acid or acetic acid by bacterial fermentations or other such reactions is another process to prevent microbial growth. Spoilage microorganisms are unable to survive under a higher alcoholic concentration. So, another set of technology which is used for slowing down or inhibiting the growth of microorganism is by increasing the content of alcohol in food material or in beverages. Vinification or brewing is the conversion of malt into beer. Then by fortification using appropriate fortification technologies one can increase the alcohol content.

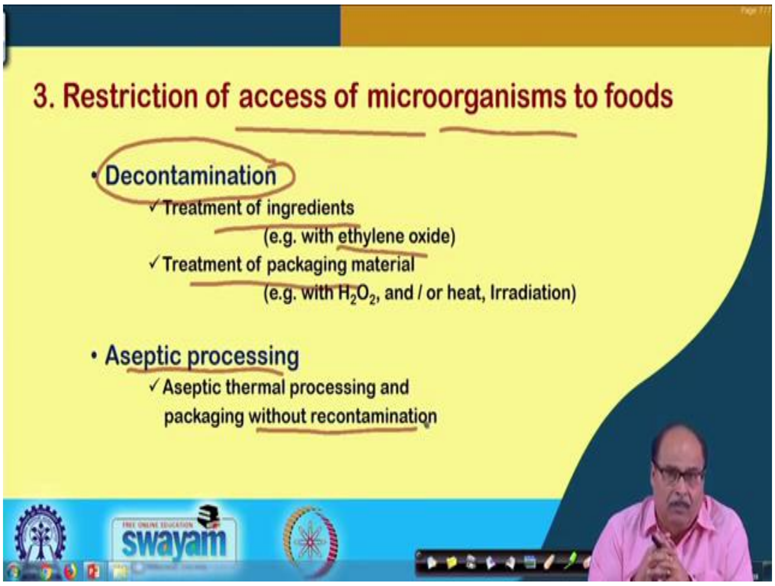
Another important method is by changing the acidity or alkalinity of the food material, mostly the acidity. In this case, there are certain chemical preservatives which can be used. This preservatives may be inorganic compounds, like sulphites, nitrites, organic compounds; such as propionate, sorbate, benzoate, paraben etc., or antibiotics like nisin, pimaricin might influence the growth or complete inhibition of the microorganism. So, accordingly these are one set of technologies which are used traditionally for preservation of food.

Controlling all these factors does not result in the killing or inactivation of the micro organism. By controlling all these factors, the microorganism is forced to go under the stationary phase or the rate of exponential phase is lowered down. When these factors are removed, if the microorganism finds a favorable condition, it will grow and multiply.

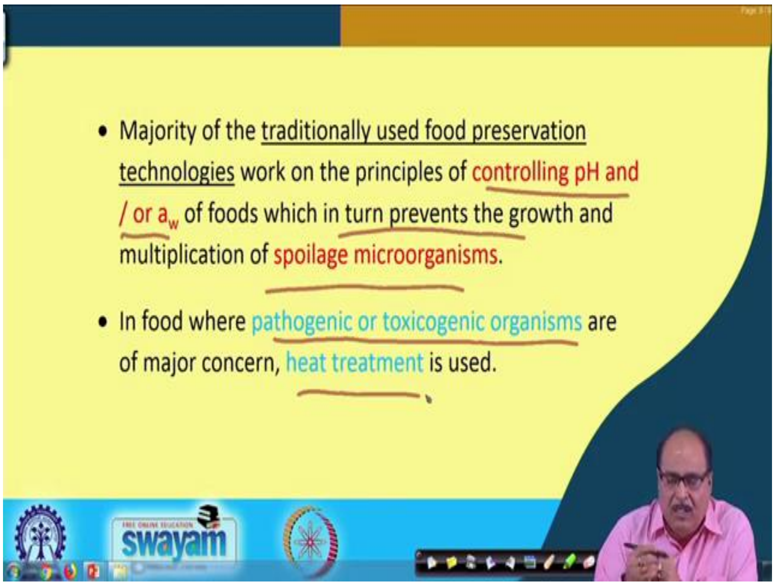


Toxicogenic or pathogenic microorganisms are of prime concern. It is essential to ensure that these toxicogenic bacteria or other organisms are completely inactivated or killed from the system. It can be achieved by providing some sort of energy for the killing of these microorganisms. Traditionally heating has been used to inactivate the microorganism.

There are processes like pasteurization where only mesophilic group of microorganism or spoilage microorganisms are eliminated. In the sterilization process, all forms of microorganisms are removed or killed. Other way of killing the microorganism is providing radiation energy and the processes which are used for food irradiation include radurization, radicidation, radappertization, etc.

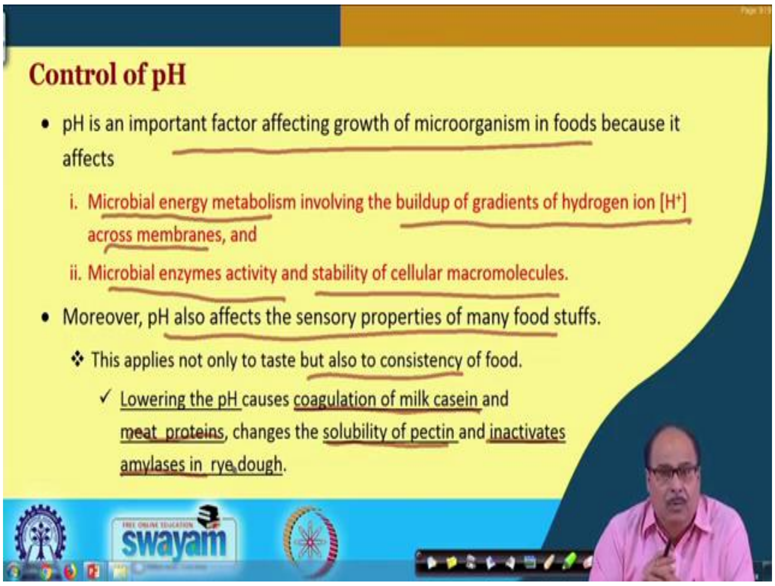


Third group of technology which is rather comparatively a new addition in traditional food preservation technologies list is restricting the access of microorganisms to the food. For example: either by treatment of the ingredients with ethylene oxide or by treatment of the packaging material with hydrogen peroxide or heat or irradiation can fully decontaminate the food material. Decontaminating the ingredient and the packaging material and then aseptic processing is called aseptic thermal processing and packaging to make sure that there is no recontamination. By these processes, the load of the microorganisms from the food are reduced and made sure that its shelf life is increased.



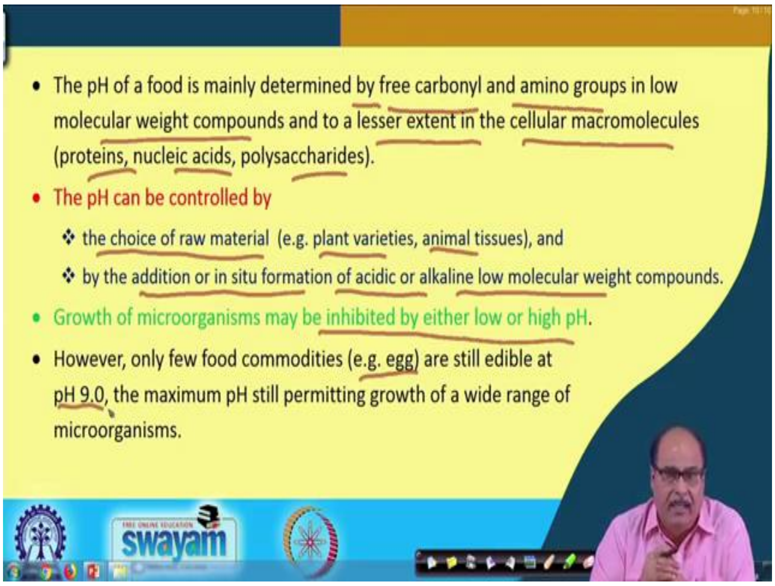
It can be said that majority of the traditionally used food preservation technologies work on the principles of controlling the pH and water activity of the food and which in turn prevents the growth and multiplication of spoilage microorganisms. In other instances where pathogenic toxicogenic microorganisms are of concern, heat treatment is used.

How the control of the pH and water activity influences the growth and multiplication of the food? What is the mechanism by which the change of pH resuls in reduction of microbial growth?



Control of pH: The pH is an important factor affecting the growth of microorganism in food. It affects the microbial energy metabolism involving the buildup of gradient of hydrogen ion across the microbial cell membrane. It also affects the microbial enzyme activity and stability of the cellular macromolecules. Also, pH affects the sensory properties of many foods. For example, if you increase or decrease the pH below a certain level the food may be more acidic, its taste may be sour, it may be more alkaline. And therefore, it may become sensoririly unacceptable.

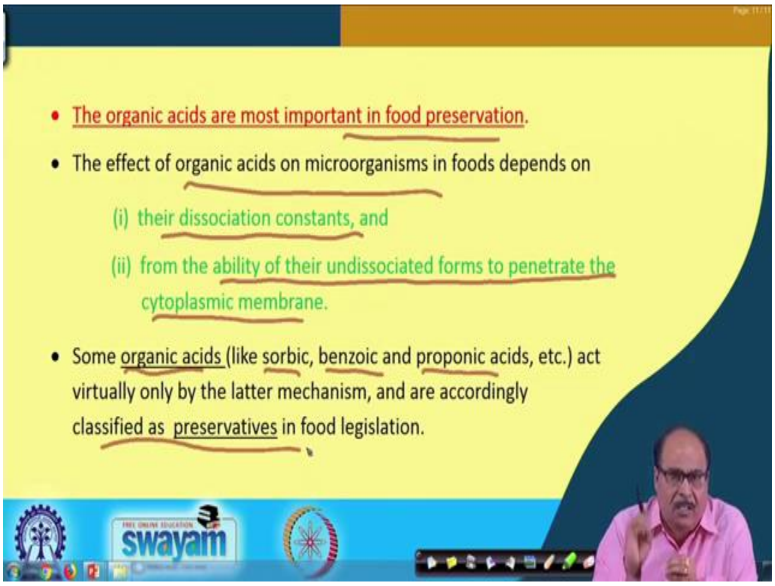
Changes in the pH, apart from affecting the sensory properties they also influence the consistency of food. For example, the lowering of the pH can cause coagulation of milk casein and milk proteins, and it may change even the physical state of the milk. It may change the solubility of the pectin which may cause softening of the fruits or changes in the fruit texture. It may result in inactivation of the enzymes like amylases in rye dough. So, all these changes in the constituents of the food which take place due to lowering of the pH may cause significant change in the consistency or textural characteristics of the food material.



Also, the pH of the food is determined by free carbonyl and amino group in low molecular weight compounds and to a lesser extent in the cellular macromolecules like proteins, nucleic acid, polysaccharides, etc. There are different methods of controlling pH in food. It depends upon proper selection of the raw material, whether it is of plant source or animal tissues. So, by proper selection of ingredient or certain additive, the pH of that food can be manipulated and the microorganism growth can be prevented.

The pH can be controlled by the addition of certain acid or by allowing the in situ formation of acidic or alkaline low molecular weight compounds. The growth and multiplication of the microorganisms may be influenced by both either low or high pH.

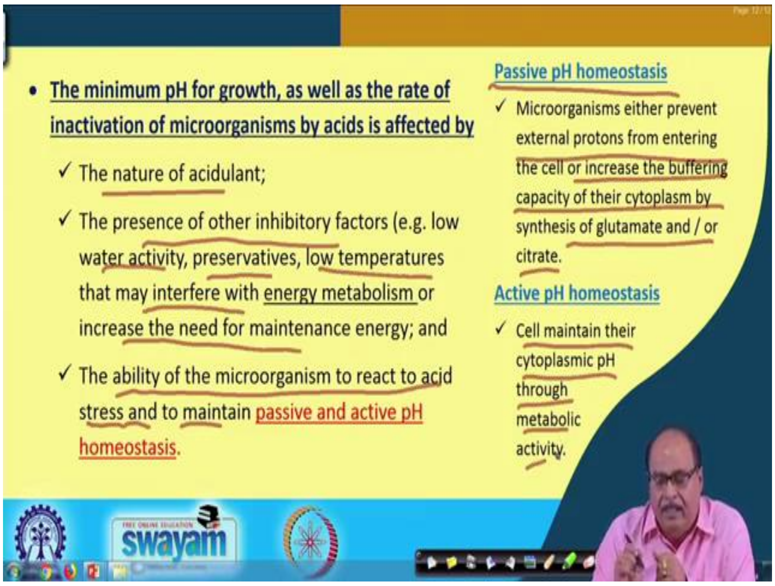
Most of the foods that we eat are either low acid food or acid food. So, majority of the microorganism can easily grow into the low acid food, a few of them can also grow into the acid food. But, there are few foods for example, egg which we consume is a highly alkaline food material or in fact it has a pH about 9; so it is an alkaline food. Egg even at pH 9, it favors the growth and multiplication of microorganism.



For the control of the pH, one important factor is the use of organic acid. It becomes an important agent or important additive for food preservation. The effect of organic acid on microorganism in food depends on two major factors viz., (1) The dissociation constant. How the acid get dissociated when it comes in contact with food, and (2) The ability of the undissociated form to penetrate the cytoplasmic membrane.

Certain acids do not dissociate rather their un-dissociated form penetrate into the cytoplasmic membrane and goes into the cell and causes a disturbance in the pH homeostasis. There is a buildup of hydrogen ion gradient across the membrane, inside and outside and that actually affects the normal physiological process of the cell and microorganism's growth is inhibited or lowered down.

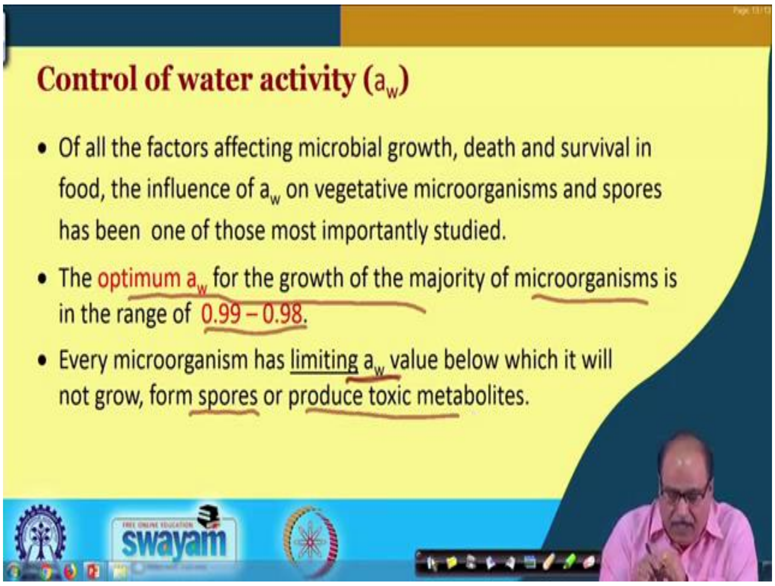
Some of the organic acids like sorbic acid, benzoic acid, propionic acid, etc. act virtually by the second way. Its un-dissociated form penetrates into the cytoplasmic membrane and does the job. These organic acids are classified as preservatives in food legislation. So, the organic acids or other acid which have the ability to penetrate into the microbial cell in undissociated form, and to create gradient of this disturbed homeostasis inside the cell, they actually are designated as preservatives.



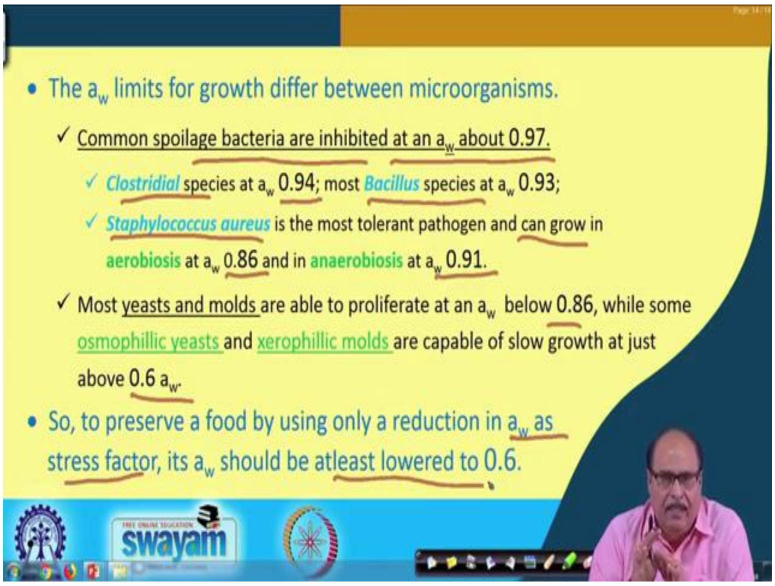
The minimum pH for growth as well as the rate of inactivation of microorganism by acid is affected by certain factors:

(1) Nature of the acid and its ability to penetrate into the cytoplasm membrane in its undissociated form. Also the presence of other inhibitory factors, like low water activity, certain other preservatives, low temperature; all these may interfere with the energy metabolism or which can increase the need of maintenance energy for the cell of the microorganisms.

(2) The ability of the microorganism to react to the acid stress and to maintain passive or active homeostasis and how the cell or microorganism is able to react to the acid stress, and how it is able to maintain the pH homeostasis either by active means or by passive means. Passive pH homeostasis means that the microorganisms either prevent external protons from entering the cell or increase the buffering capacity of its cytoplasm by synthesis of glutamate or citrates. Active pH homeostasis, means that cell maintain its cytoplasmic pH through metabolic activities.



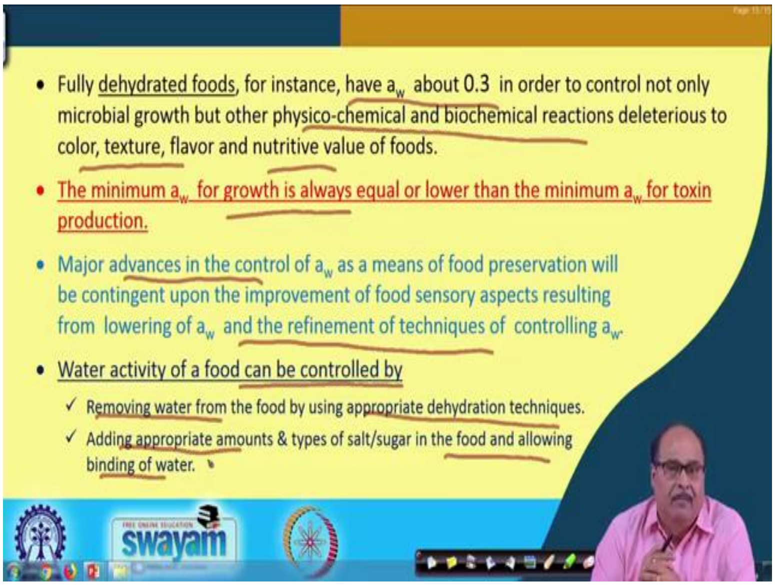
The other factor is the control of water activity. Water activity is one of the major factors which influences the growth and multiplication of microorganisms in food. In fact, optimum water activity for the growth of the majority of the microorganisms is in the range of 0.99 to 0.98. Every microorganism has a limiting a_w value below which it will not be able to grow, to form spores or to produce toxin. This is taken care of while creating condition for minimizing the microbial growth.



The a_w requirement for the growth of different group of microorganisms varies. For example, the common spoilage bacteria are inhibited at an a_w of about 0.97 i.e. if the water activity of the food material is brought below 0.97, most of the food spoilage bacteria will not be able to grow and multiply.

The pathogenic or toxicogenic bacteria are comparatively little more tolerant. For example, that *Clostridial* species of bacteria can grow at a water activity level of 0.94, *Bacillus* species 0.93, *Staphylococcus aureus* is considered to be the most tolerant pathogen which can tolerate a_w to the maximum level and can grow at a_w as low as 0.86 under aerobic conditions, as well as 0.91 a_w under anaerobic conditions. Majority of the yeast and molds are able to proliferate at an a_w below 0.86, while some osmophillic yeasts and xerophillic molds are capable of slow growth at just above 0.6 a_w.

So, it becomes clear that to preserve a food by using reduction of a_w as a stress factor, its a_w should be lower to 0.6 i.e. if the a_w of a food is brought down below 0.6, it will not support any growth of microorganism in it.



Fully dehydrated foods have lower water activity like in the range of 0.3 or so. In dehydrated foods, this lowered water activity does not support any growth of chemical, biochemical or other processes which are deleterious to food texture, flavor, and nutritive value.

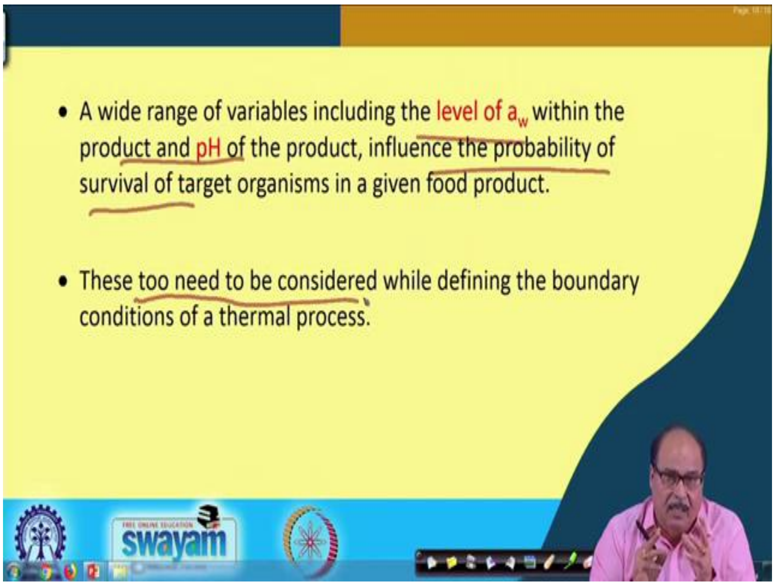
The minimum water activity for growth is always equal or lower than the minimum water activity for toxin production. So, major advances in the control of water activity as a means of food preservation will therefore are contingent upon the improvement of the food sensory aspects. It is like the same case as it was observed with pH. Secondly, what is the method of controlling a_w, whether it is drying, whether it is freeze drying, whether it is concentration, evaporation or which techniques are adopted to control the water activity.

Water activity in a food can be controlled either by removing the water from the food by using appropriate dehydration techniques. Or, it can also be controlled by adding appropriate amounts and types of salt or sugar in the food and allowing the binding of the water with these salts or sugars.

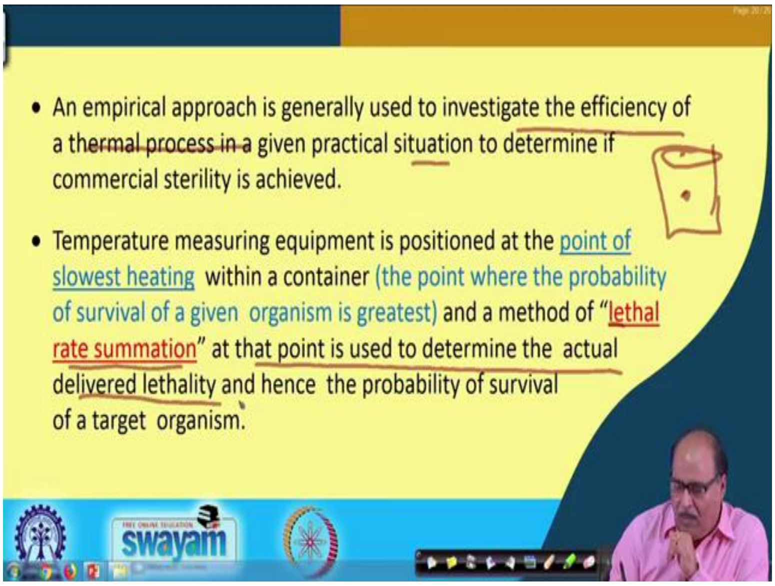
Having seen the influence of pH and water activity and means of controlling and how the control influences the characteristics of the food material, characteristics of the microbial growth, and thereby increasing its shelf life, it is important to focus on another aspect that is the conventional heat treatment. Particularly when toxicogenic microorganisms are of concern, heat treatment is used.

The preservation of food by application of heat is achieved by large scale inactivation of viable microorganisms. *Clostridium botulinum* is generally considered to be the most heat resistant spores forming bacteria which cause trouble in food processing industries as it can grow in low acid foods. The surviving spores of this organism can germinate in the container because inside the container anaerobic environment is maintained and *Clostridium botulinum* is anaerobic bacteria. So, these spores, if it survives the heat process, it can grow and can germinate in the food and produce toxin. The toxin which is produced by *Clostridium botulinum* is a highly poisonous toxin; micromicrogram of this toxin is sufficient to kill a healthy person.

The severity of the thermal process which is selected to deliver sufficient lethality to ensure that the processed food stuffs achieve commercial sterility, the required shelf life, and it does not pose a risk to the public health is a function of the probability of the survival of the target organism. How much the heat treated food has attained commercial sterility is a function of how the heat treatment is able to kill the target microorganism; for example, *Clostridium boltulinum* in the case of low acid food.



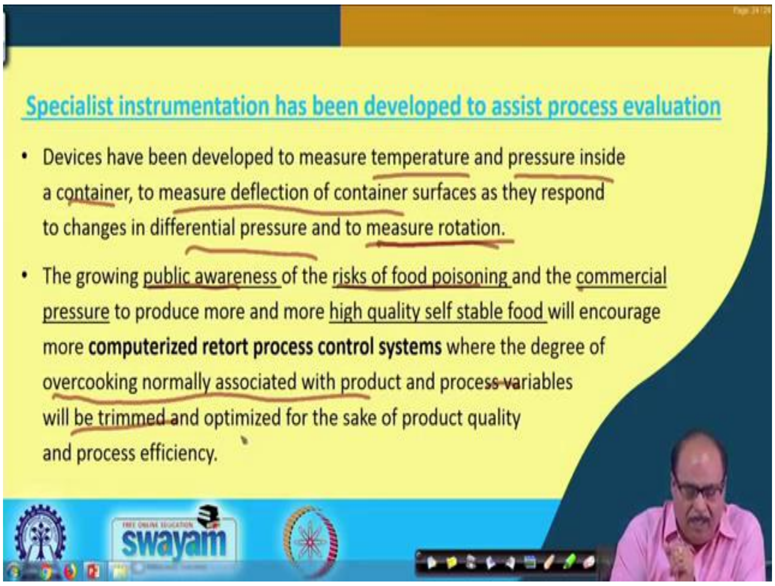
A wide range of variables influence the probability of the survival of the microorganisms in the product under a given condition. Therefore, there is a need that these factors that that influence the killing, or inactivation of microorganism should be considered while defining the boundary conditions of a thermal process.



An empirical approach is generally used to investigate the efficiency of a thermal process in a given practical situation to determine whether the commercial sterility has been achieved or not. For this purpose there are certain temperature measuring instruments. These temperature measuring instruments like thermocouple are positioned at the point of slowest heating within a container. The point where the probability of survival of a given organism is greatest is normally the geometrical centre of the container.

The process should be sufficient enough to give the desired sterility at its slowest heating point. The slowest heating point and at several other points the temperature is measured and this method of lethal rate summation at that point is used to determine the actual delivered lethality, and hence the probability of the survival of a target microorganism.

This approach is used to develop thermal process designs, to suit new product, packages as well as process systems. This approach is also used to establish and quantify new production scenarios ahead of commercial use, and is used to validate all processes at regular and frequent intervals.



Special instruments have been developed to assist process evaluation, to measure temperature, and pressure inside a container, even to measure deflection of container surfaces as a response to changes in differential pressure, as well as even to measure the rotation of the container which is normally performed in order to improve the heat transfer efficiency.

The growing public awareness of the risk of food poisoning and the commercial pressure to produce more and more high quality safe stable foods will encourage more computerized retort process control system, where the degree of overcooking thermally associated with products and process variables will be trimmed, and optimized for the sake of product quality and process efficiency.

Another way of improving the process is combining heat treatment, as well as control of water activity and pH to preserve the food. It is possible that new forms of preservation may be combined with conventional retorting to further optimize the delivered lethality and maximize product quality, whilst reducing manufacturing costs. Synergies are practically interesting, because the combination of processes like hurdle technology is a promising means of enhancing safety while retaining the quality of the food.