Novel Technologies for Food Processing and Shelf Life Extension

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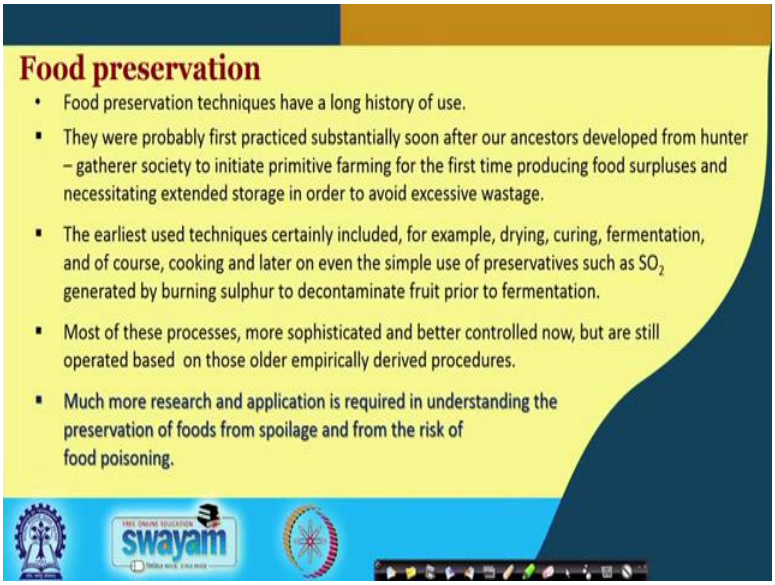
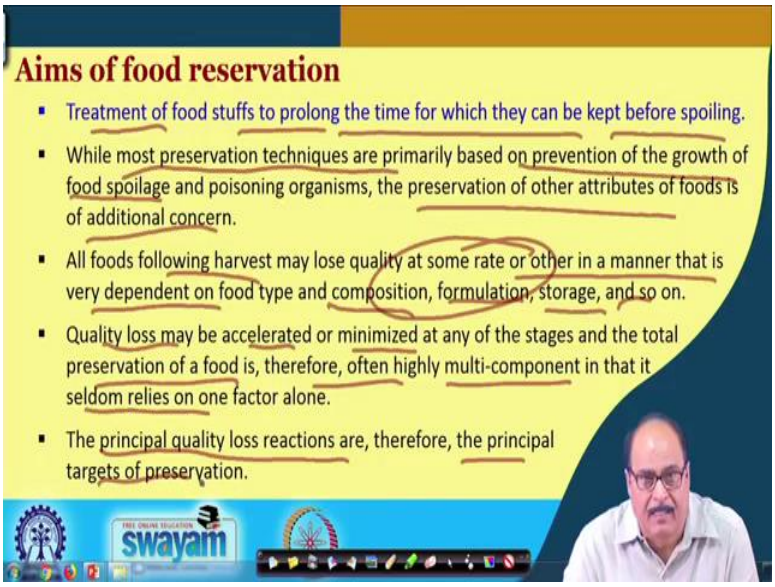
Lecture - 08
Principles of Food Preservation

In this lecture, the Principles of Food Preservation and Processing are briefly discussed.



Food preservation techniques have a long history of its use. It was probably first practiced soon after our ancestors developed from hunter gatherer society to initiate primitive farming producing food surpluses and then necessitating extended storage in order to avoid wastage. The earliest used technologies certainly included, for example, drying, curing, fermentation and cooking. Later even simple chemical preservatives, such as burning of sulphur to generate sulphur dioxide to decontaminate fruits prior to its fermentation, were used. Though these processes are more sophisticated and better controlled, they are still being operated based on those empirically derived old procedures.

There is a need to find out the required application oriented effects so as to understand the preservation of the food from spoilage as well as from the risk of the food poisoning. If the different factors that govern the spoilage of the food, that pose a risk to the food safety around food consumption is properly understood, then the process of food preservation gets simplified.



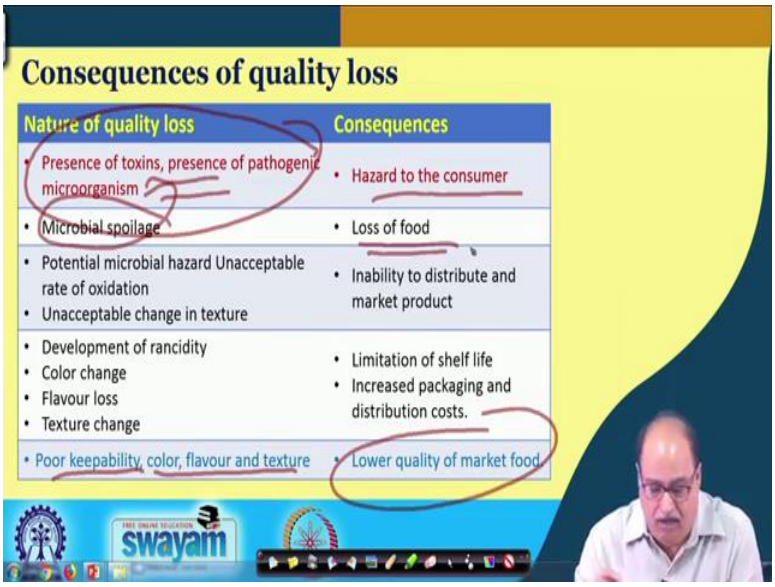
The aim for any food preservation process is to extend the time for which the food can be kept before spoiling. The preservation therefore, may be defined as the treatment of food, to prolong the time for which it can be kept before spoiling. While most of the food preservation techniques are primarily based upon the prevention of growth of food spoilage and food poisoning microorganisms, the preservation of other attributes of the food like quality attributes and the sensory characteristics become of additional concern.

All foods, following harvest, may lose quality at some rate or the other in a manner which are very dependent on the type of the food, its composition, formulation, storage and so on. This quality loss may be accelerated or may be minimized at any stage. Total preservation of a food, therefore, is highly multi component that it seldom relies on only one factor. There are different factors which influence the growth and multiplication of microorganisms. In the earlier lectures, it was discussed how different reactions of the food can change its characteristics, resulting into generation of new compounds which may influence the sensory characteristics of the food.

The two different quality loss reactions become a principal target of food preservation technology. One is the microbial quality loss reaction and other is the general quality loss reactions. Whatever techniques are applied it should not result in the quality reductions of food.

This slide gives an overview of different types of quality loss reactions that may occur in food. It may be microbiological, enzymatic, chemical or physical in nature. The microbiological quality loss reactions may be because of the growth or presence of toxin producing microorganisms or bacteria in food or the growth or presence of infective microorganisms or growth of spoilage microorganisms.

The enzymatic processes which influence the quality of the food may be hydrolytic reactions catalysed by enzymes like lipases, proteases, etc. It may be lipoxygenase initiated reactions or enzymatic browning. In earlier lecture on browning reactions, the activity of phenolase enzyme causing the browning of the fruits and vegetable has been discussed. Chemical reactions like oxidative rancidity, oxidative and reductive discoloration, non-enzymatic browning or even nutrient losses due to leaching or other losses may influence the quality of the food. Mass transfer, movement of low molecular weight components, loss of crispiness, loss of flavor, freeze induced damages etc. can be included in the physical factors or physical reasons for the quality reduction in food materials.



The quality loss due to one or the other reasons mentioned earlier can result in different consequences. It could be just simple loss of the marketability of the food. For example, due to one or the other change in its attributes like color, flavor, texture, etc. which is not appealing might result in economic loss or lower marketing ability of the food.

On the other hand, if the spoilage of food or quality loss is due to the microbiological processes, and if the food is contaminated with toxic or pathogenic microorganism and proper preservation technology is not adopted to remove the contamination then it may cause health hazard to the consumers. Similarly in other case, where the food is spoiled by the spoilage organism it will be deemed that the food is unfit for consumption but may not cause any potential health hazard to the consumer.

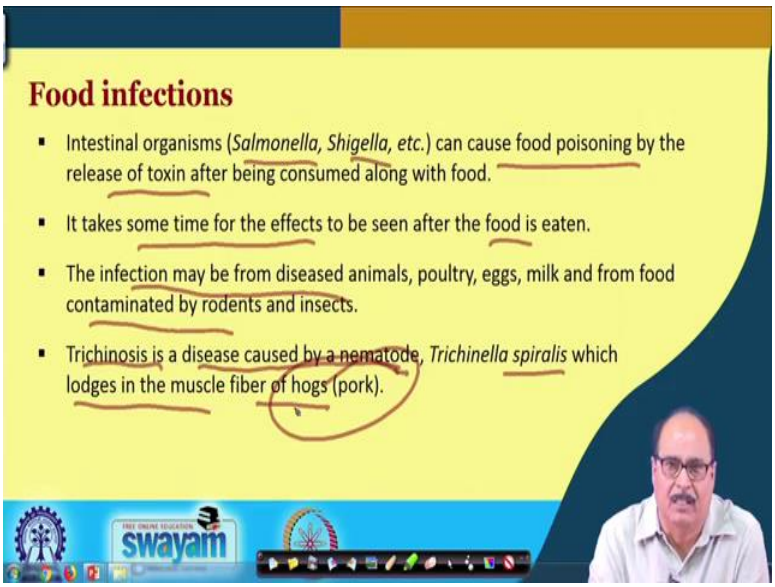
It is important to identify the causative agent in the food, the type and nature of the microorganism and/ or the changes it is likely to bring in the food materials. This will enable one to decide appropriate processing technology for food preservation.

What is food spoilage? Spoilage is the process in which food deteriorates to the point at which it is not fit for consumption. It becomes inferior in its quality and its edibility becomes reduced. There are different factors responsible for the spoilage of the food. The spoilage of food due to the growth and multiplication of bacteria is one of the major concerns to the food processers and even the consumers.

There are different types of microorganisms that cause spoilage of food. Some microorganisms while growing in food, consume the nutrient because incidentally the microorganisms also require similar types of chemicals or nutrients for its survival. Microorganisms consume food for their survival. It grows on food, multiplies and in the process, certain secondary metabolites are produced by them which may cause the change in sensory and textural characteristics of the food. These changes do not render the food toxic and it is not a safety risk. This spoilage of food by such microorganism are called food spoilage microorganisms.

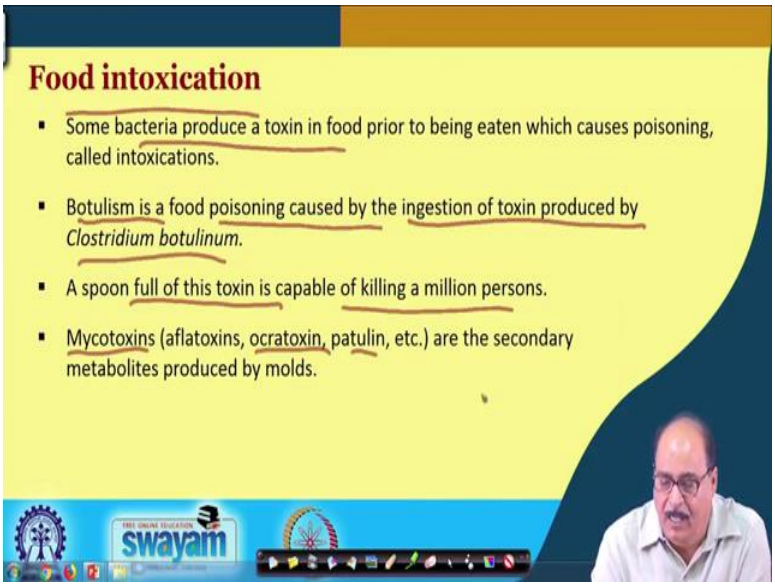
On the other hand, there are certain microorganism, which when grow into the food produce certain metabolites that might be toxic and therefore, they are poisonous and such foods can cause potential damage to the health of an individual. These types of microorganisms are called food intoxicating microorganisms. Third type is the infectious microorganisms where they do not grow or multiply on the food or water, but rather they simply use food or water as their carrier source. Consumption of such type of contaminated food will enable these microorganisms to enter into our system and grows

and multiplies in small intestine or large intestine wherever environment is favorable, and produce toxin. These are called infectious microorganisms.



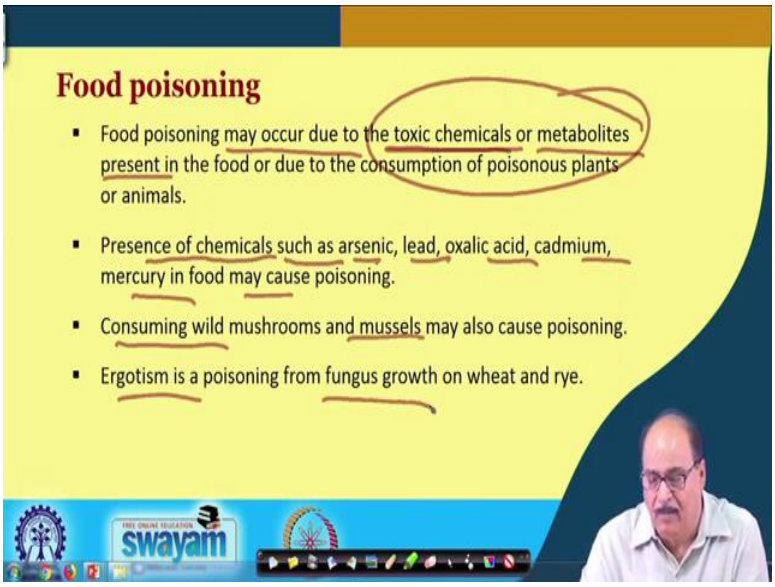
Salmonella, *Shigella*, etc. are some common bacteria, which may cause food poisoning by releasing toxins after the food is consumed. It needs to be known that these infectious bacteria, even if it is present in food may not be a problem prior to consumption. After consumption, these organisms do not grow on food rather it grows and releases the toxin in our system. So, it takes time for the symptoms to appear after consumption of food with such poisoning organisms.

The infection may be from the diseased animal, poultry, eggs, milk or from the food contaminated by rodents, insects, etc. Even some environmental pollutants can cause contamination. Trichinosis is a common disease caused by certain nematodes that is *Trichinella spiralis* which lodges in the muscle fiber of the hogs or pork muscles. It is of less concern as long as the organism is present in the pork. But when humans consume, this bacteria along with the muscle goes into the system, it grows and multiplies and creates problem.



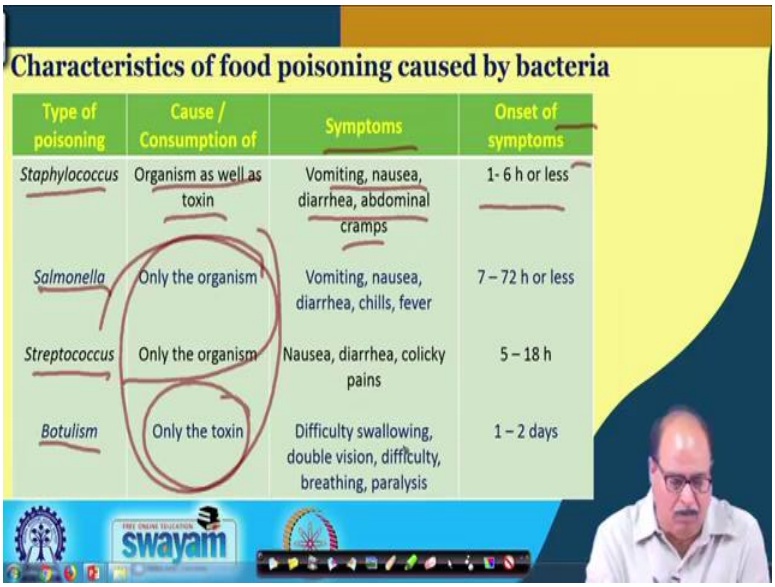
The other type of food poisoning is the food intoxication. This type of bacteria grows in the food and produces toxin. The toxin produced may be of two types i.e. endotoxin or exotoxin. Exotoxin producing bacteria grow in the food and release the toxin there. Endotoxin may remain inside the bacterial cell while the bacteria continue to grow in the food. So, the food may not become toxic, but it may contain the toxic bacteria. Common example is the botulism; it is a type of food poisoning which is caused by ingestion of toxin that is produced by the *Clostridium botulinum*. The *Clostridium botulinum* is an anaerobic toxin producing bacteria and is capable of forming spores. It is a common problem in the low acid foods and it produces such a potent toxin, that a spoonful of this toxin is capable of killing a million of persons.

Food materials which are likely to be contaminated by *Clostridium botulinum* should be made sure that this contamination is totally eliminated from the food. Another type of toxins are the mycotoxins, like aflatoxins, ocratoxins, patulin etc. which are the secondary metabolites produced by certain varieties of molds like *Aspergillus niger* and they grow into the food and release this toxin which becomes fatal upon consumption.



The food poisoning is of different types, i.e. the poison may be naturally present in the food or it might be released by the microorganisms as it was referred to in exotoxin. These toxins exist in food in a very low concentration and do not alter any sensory property of food but consumption leads to deleterious effects.

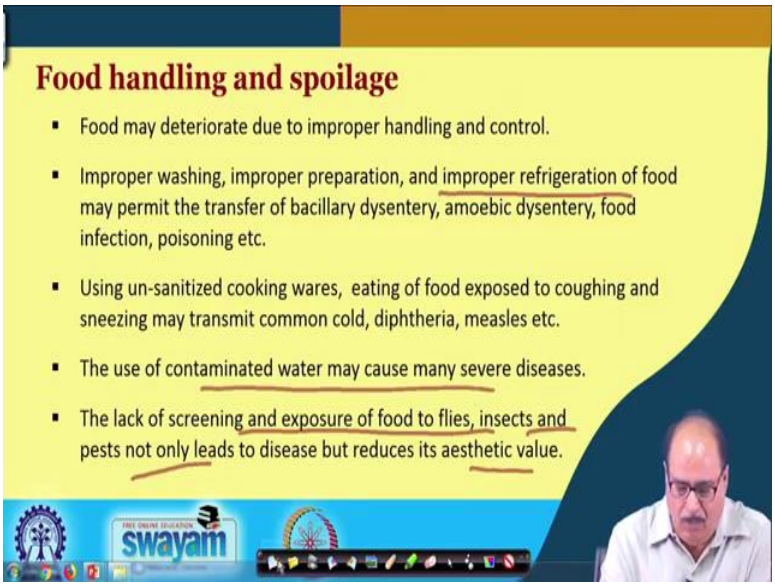
A few examples of the natural food poisoning agents are the arsenic, lead, oxalic acid, cadmium, mercury etc. which might be present in the food materials due to contact with heavy water, from the environment or from the other sources. Ergotism is a type of poisoning which develops from the growth of the fungus on wheat or rye.



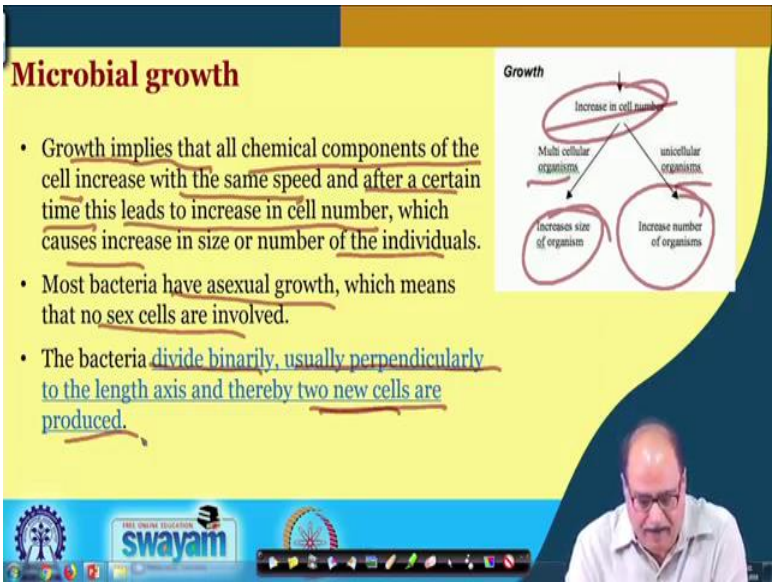
Staphylococcus food poisoning is a case where the organism as well as the toxin both can make the food toxic. The symptoms of *Staphylococcus* food poising include vomiting,

nausea, diarrhoea, abdominal cramps, etc. and it takes around 1 to 6 hours or less time for the onset of the symptoms.

In *Streptococcus* and *Salmonella* type of food poisoning, only the microorganism is involved that is if the microorganism is consumed, it gets established in our system and produces toxin. In the case of *botulinum*, it releases toxin into the food we consume. Vomiting, nausea, diarrhea, difficulty in swallowing, double vision, etc. are some of the symptoms for these types of toxicities.

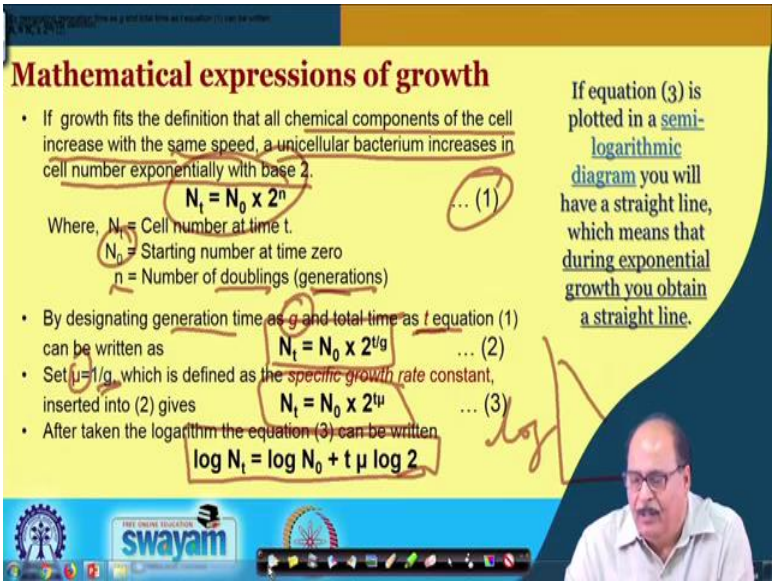


Various conditions may result to the contamination of the food and its spoilage. Handling of food, environmental pollution or contamination from the handling equipment, processing machines, improper washing, improper preparation, improper refrigeration, etc. may result into spoilage of food. The use of contaminated water, lack of screening and exposure of food to flies, insects, pests, etc., not only lead to diseases, but also reduce the aesthetic value of the food. One should take proper care to eliminate these sources of contamination from the food materials.



It is necessary to understand the microbial growth and its kinetics. The growth normally refers to the increase in cell number or increase in size of the organism depending upon whether it is a multicellular or unicellular organism.

In the unicellular organism, the growth is measured by increase in number of the organism. In multi cellular, growth is measured by the increase in size of the organism. So, growth is defined as the increase of all the chemical components of the cell, this leads to increase in cell number which causes increase in size or number of the cell of the individual. Most of the bacteria reproduce asexually, which means that no sex cells are involved in these cases. Bacteria reproduce by binary fission, i.e. divide perpendicularly to the length axis and there by two new cells are produced from each bacterial cell.



There are different models to express the growth of bacterial cell in the form of mathematical equations. If growth fits the definition that all chemical components of the cell increase with the same speed, a unicellular bacterium increases in cell number exponentially with base 2.

$$N_t = N_0 \times 2^n \qquad \ldots (1)$$

Where, N_t = Cell number at time t.

N_0 = Starting number at time zero

n = Number of doublings (generations)

By designating generation time as g and total time as t equation (1) can be written as

$$N_t = N_0 \times 2^{t/g} \qquad \ldots (2)$$

Set $\mu=1/g$, which is defined as the specific growth rate constant, inserted into (2) gives

$$N_t = N_0 \times 2^{t\mu} \qquad \ldots (3)$$

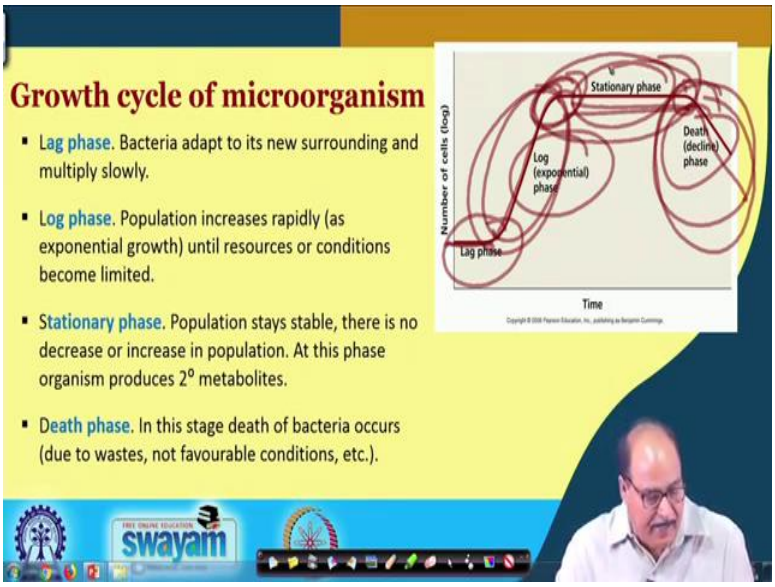
After taken the logarithm, the equation (3) can be written as

$$\log N_t = \log N_0 + t\,\mu \log 2$$

Another phenomenon that is very important is the period of balanced and unbalanced growth seen in the microbial culture. Growth of bacteria is related to the composition of the medium. If all the essential components are available, the growth is balanced

throughout. Balanced growth means all the components are increasing in same proportion; cell number, cell size, cell components, etc.

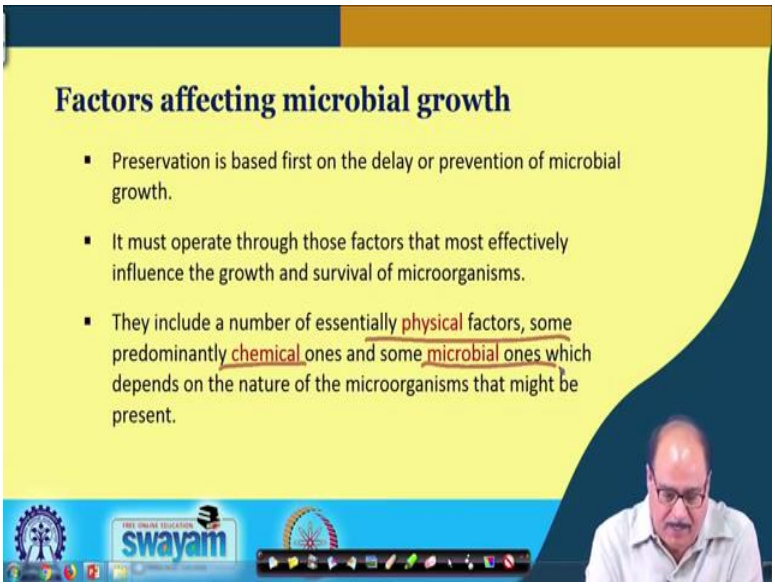
If, however, one or several essential components are missing, the growth is terminated due to unbalanced growth, which often leads to the death of the culture. If two different energy sources are available in the growth medium, the growth curve normally shows two exponentially distinct phases.



The growth curve of bacteria is expressed in four phases; lag phase, log phase, stationary phase and death phase. After being inoculated into the system, bacterial cell takes some time for adjustment and the growth is very minimal or there is no growth, it is called lag phase. Lag phase is followed by exponential phase or log phase where the bacteria grow exponentially. Then finally, either due to depletion of one or the other constituent or because of the secondary toxic metabolites, there is some period of unbalanced growth and is followed by a stationary phase. In this condition, the bacteria remains alive under dormant condition without growth. During stationary phase, there may be accumulation of the toxic metabolites or there may be depletion of the food reserves resulting in death of the bacteria. The death phase is similar to log phase; here the bacteria die exponentially.

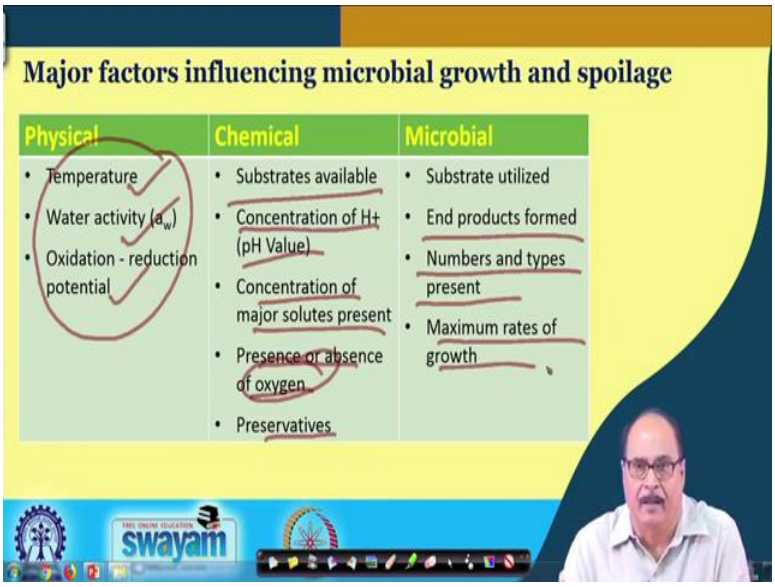
There are many incidents or processes where it is necessary to grow the bacteria under certain conditions and where the bacteria need to be killed. There is also certain situation where the bacteria are not killed but necessary to keep it under dormant condition.

Understanding the growth and death kinetics of microorganism will enable one to determine the food process operations, even processing technology that is necessary to be adopted as per the requirement.



What are the various factors, which influence the growth of bacteria or microorganism in food? If the factors governing the growth are properly understood, it becomes simpler as to select which process to be applied to encourage the growth or to cause the death of the microorganism.

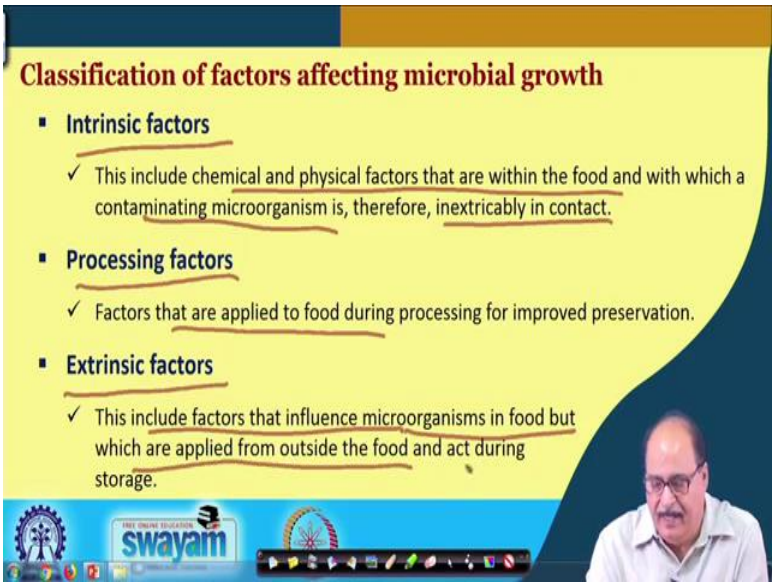
So, these factors therefore, which influence the growth and multiplication of microorganism in food, can be grouped into different classes like physical, chemical and microbiological factors. And there are certain factors which relate to the nature of the microorganisms as such.



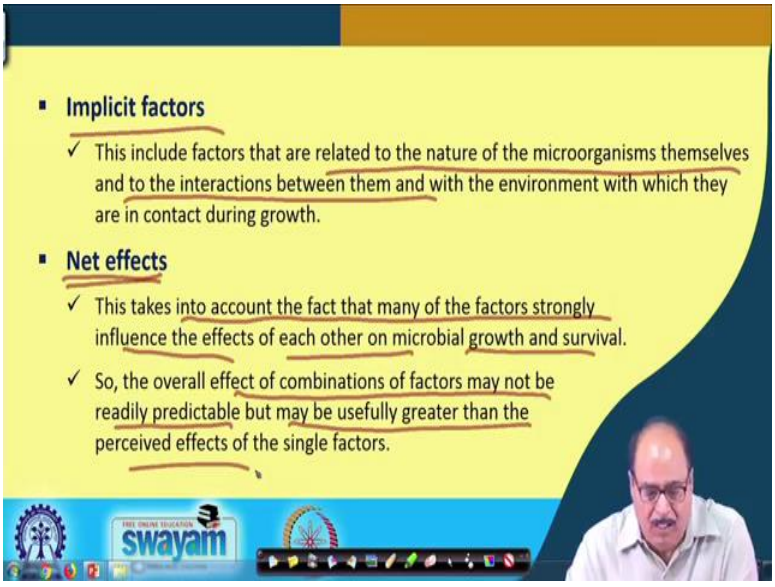
In physical factors, temperature, water activity and oxidation reduction potential become important factors. In general, the microorganisms need optimum temperature for growth. At lower temperatures, the growth ceases and at higher temperatures, the microorganism dies.

Similarly water activity, oxidation and reduction potential, etc., are important variables. Among the chemicals that is the substrate available in the food material for the growth of the microorganisms, concentration of hydrogen ions like pH of the food, concentration of the major solutes present in the food or even presence or absence of oxygen, air or preservatives, also influences the microbial growth kinetics. Even the microbial characteristics like how the microorganism is able to utilize the substrate influences its growth behavior. For example, bacteria cannot use starch as its food, but if starch is hydrated and is converted into glucose, then they find it easy to consume.

Even the number and type of the microorganism present and the growth rate at which one microorganism will be able to consume a particular nutrient are some of the factors, which might influence the characteristics of the growth of microorganism in food material.



Factors affecting microbial growth can be classified into different ways that is the intrinsic factors which include those chemical and physical factors that are within the food and with which inextricably in contact throughout the period. The other factors might be the processing factors that are deliberately applied to the food during processing for improved preservation. Some of those factors can be categorized as extrinsic / extensive factors, which include those factors that influence microorganism in food, but they are applied from outside, generally they act during storage.

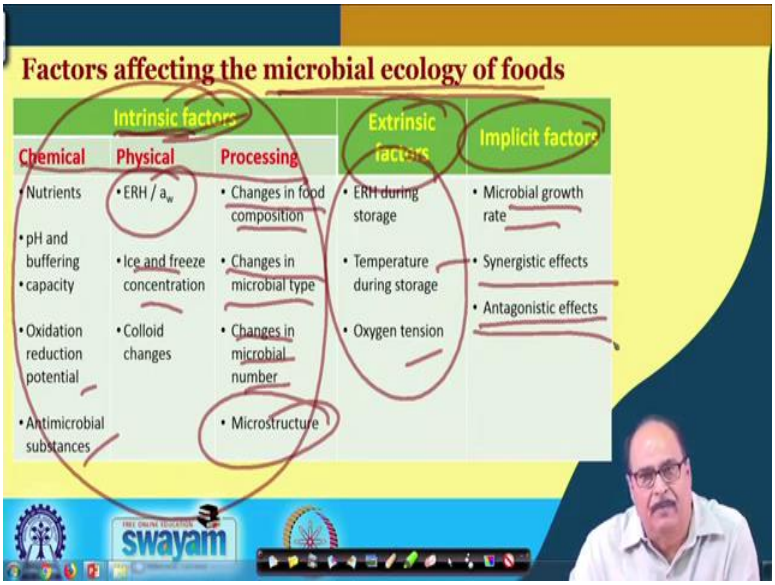


The other two important factors are the implicit factors and net effects. The implicit factors include those factors that are related to the nature of the microorganism, the interactions which microorganism have among themselves, and the interactions which

these microorganisms have with the environment or with other food materials with which it comes into contact during storage.

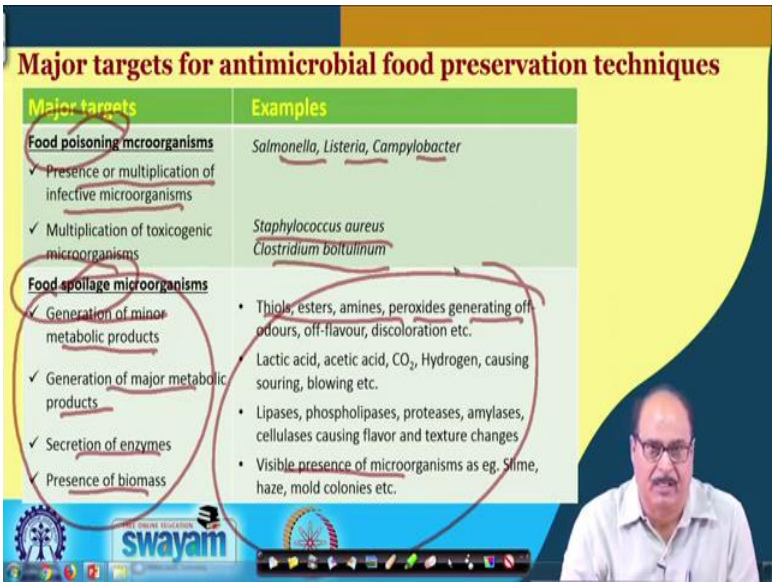
Ultimately, the net effects become very important; when we analyze any processing situation, many individual factors indicate a particular effect individually, but food processing like hurdle technology concepts, when multiple factors are involved then overall effect of these multiple factors might be much more than what would have been expected by the individual factors alone.

So, the net effects take into account the fact that many of the factors strongly influence the effect of each other upon microbial growth and survival. So, the overall effect of combination of factors may not be although rapidly predictable, but may be useful in a greater way than the perceived effect of the single factor.



Further, intrinsic factors can be of three types; chemical factor, physical factor, and processing factor. The chemical factors may be nutrient, pH and buffering capacity, oxidation reduction potential or antimicrobial substances. Physical factor may be equilibrium relative humidity or water activity, ice and freeze concentration or certain colloidal changes. The processing conditions may change the food composition, may make the constituent or substrate easily available to the microorganism or otherwise. There may be changes in the microbial type, changes in the microbial number and even changes in the microstructure of the food, making the food easy or difficult to be utilized by microorganisms. These are the intrinsic factors present in the food.

The extensive factors are equilibrium relative humidity during storage, temperature of the storage environment, oxygen tension of the storage environment, etc. These are the factors which operate from outside. Milk is a very good example. There are several bacteria present in milk. Once lactic acid bacteria grow, it produces certain acidity into the milk which makes the milk favorable for the growth of acid tolerant lactic acid bacteria. So, there might be synergistic effect or antagonistic effect. Antagonistic effect means that certain microorganisms once they grow bring out changes in the acidity and might release alcohol which becomes detrimental to other microorganisms.



So, once having understood these different factors which influence the ecology of microorganism, their growth and development, or inactivation kinetics, it becomes easy to decide what type of food process one should go for, depending upon the type of microorganism involved and so on. Most of the antimicrobial food preservation techniques are for two types of microorganism. One type is for the food poisoning microorganisms and the others are for the food spoilage microorganisms. So, if it is infective type like *salmonella*, *listeria*, *campylobacter*, etc., it is necessary to manipulate the factors during processing, handling and storage in such a way that these are eliminated from the food.

Similarly, presence of the toxicogenic bacteria like *Clostridium botulinum*, *Staphylococcus aureus* might not be a problem. If they have contaminated the food, the condition around the food should be manipulated in such a way that they are not able to

grow and multiply, as these microbes can create problem only when they grow into the food and produce toxin.

So, these two types become, in fact, the target for the antimicrobial food preservation technologies, where the toxicogenic or toxin producing or poisoning types of microorganisms are involved. Other food spoilage microorganisms, when grow into the food, produce minor metabolic products like thiols, esters, amines, peroxide, which ultimately influence color and flavour of the material.

It may result into the generation of major metabolic products, secretion of enzymes, even presence of biomass itself, which results into the visual presence of microorganisms such as slime, haze, and mold colonies. The spoilage group of microorganisms grows and produces certain secondary metabolites which cause the sensory and other characteristics changed and it becomes unfit for consumption. So, in this case not only the presence, but its growth becomes important factor.