FOOD SCIENCE AND TECHNOLOGY

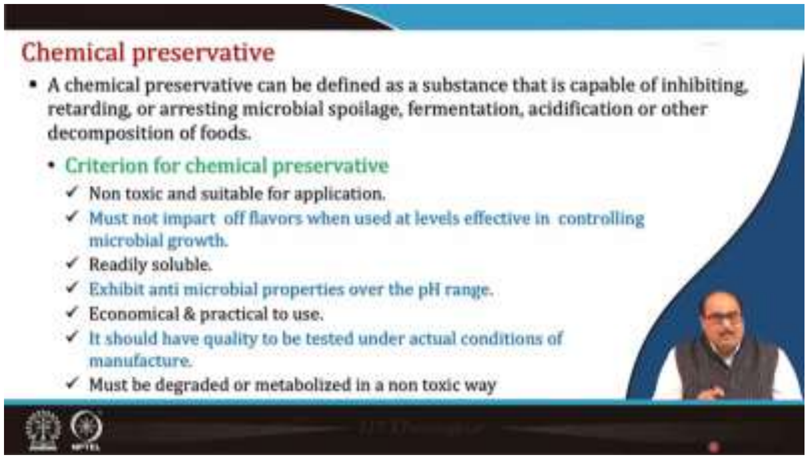
Lecture42

Lecture 42: Chemical & Bio Preservation of Foods

Hello everyone, Namaskar.

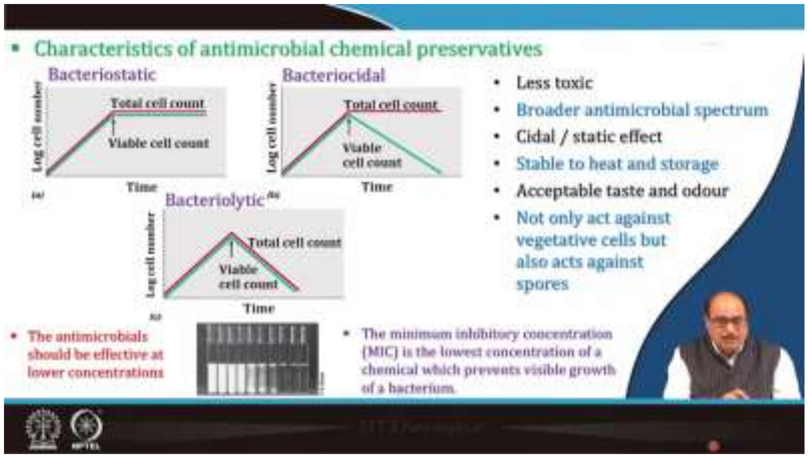
Now, in this lecture today, which is lecture 42, we will talk about the chemical and bio-preservation of foods.

We will discuss chemicals as food preservatives, what the various approved lists are, and then the mechanism of antimicrobial action of chemical preservatives. Limitations of using chemical preservatives, like the various factors that affect a chemical preservative's antimicrobial activity. And then finally, we will talk about biological preservation, where the use of microorganisms and bacteriocins to preserve food will be discussed.



So, what are chemical preservatives? In an earlier class, when we discussed food additives, we discussed functional food additive applications, and these chemicals can be added to food to improve certain functional characteristics. At the same time, certain chemicals extend the shelf life of food. So, those chemicals are used for food preservation, and accordingly, the method where chemicals are used to inhibit, retard, or arrest microbial growth, fermentation processes, acidification processes, or some other decomposition of food is known as chemical preservation of the food. Criteria for a chemical to be used in food as a preservative means that it should be non-toxic. The chemical should be non-toxic and suitable for application in food. Also, the chemical must not impart off-flavour when used at low levels, which is effective in controlling microbial growth. The chemical obviously should be readily soluble, exhibit antimicrobial properties over the pH range of the food, be economical and practical to use, have the quality to be tested under actual conditions of manufacture, and, more importantly, it must be degraded. degraded or metabolized in a non-toxic way. This means that while providing its preservative action, it should not lead to the development of any toxic metabolites.

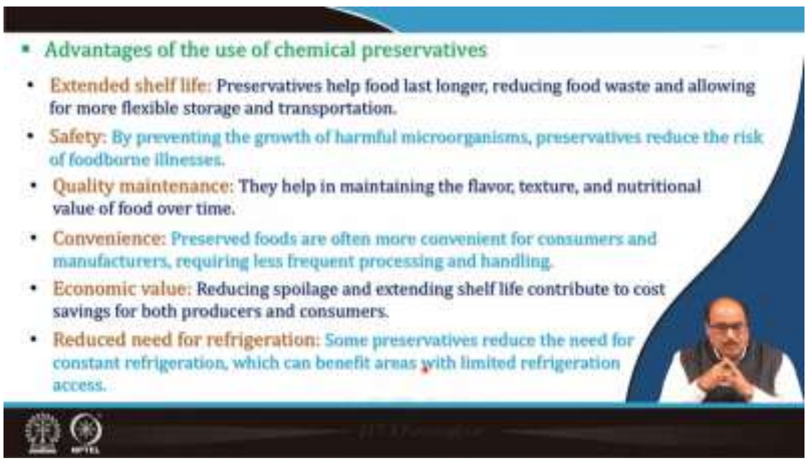
So, here you see the characteristics of antimicrobial chemical preservatives. A chemical may be bacteriostatic, bactericidal, or it may be bacteriolytic. After a certain point, you can see this bacteriostatic effect here, where the total viable cell count becomes stationary.



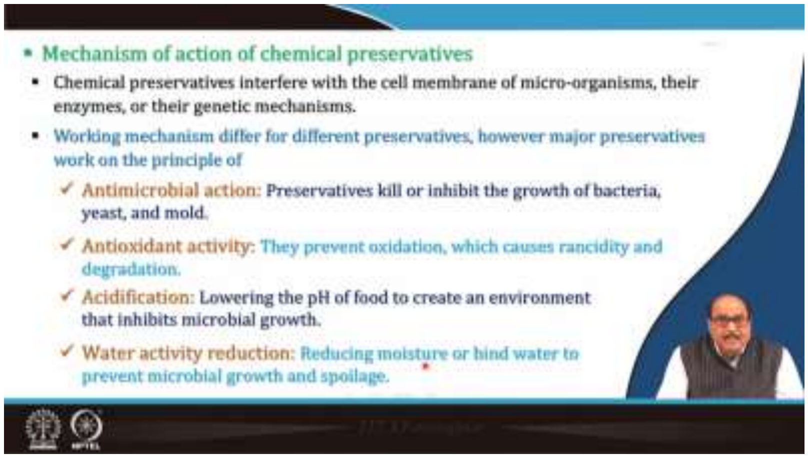
But in the bactericidal case, when the chemical is applied, you see, after a certain point, there is a decrease in the viable cell count. So, that becomes bactericidal. Bacteriolytic means that the total cell count, as well as the viable cell count, decreases after a certain time. These chemicals, particularly those used as antimicrobial agents, have another very important characteristic: they should be effective at lower concentrations. So, there is a concept of minimum inhibitory concentration, which is the lowest concentration of a chemical that prevents the visible growth of bacteria.

So, the consideration for using chemical preservatives in food involves various health concerns; the chemical should not impart any undesirable health effects, and it should not have any potentially long-term health effects on the consuming person. Consuming certain chemical preservatives, including possible links to cancers and other health issues, etcetera is a concern. So, using chemicals should not pose any risk to the consumer's health. Thus, chemical preservatives are strictly regulated and must be used within the approved limits.

Then, there are certain chemicals which can be used as a preservative. They can interact with certain nutrients in the food, and this interaction may sometimes lead to loss of the nutritional value or nutritional profile. So, that is another concern one should take care of: the chemical should be such that it does not result in any loss of nutritional value. It should be stable; that is, it should be effective, and the effectiveness of some preservatives can be influenced by factors such as temperature, pH, light, etc. So, that chemical which is used in the food as a preservative should have stability over the various factors, that is, temperature, light, etcetera, and it should not get so that it gives the maximum result benefit, and then chemical interactions I already talked about, that is the altering the quality, etcetera; these chemicals should not influence them. They should not encourage inter-ingredient interactions, etcetera, in such a way that lowers the quality.

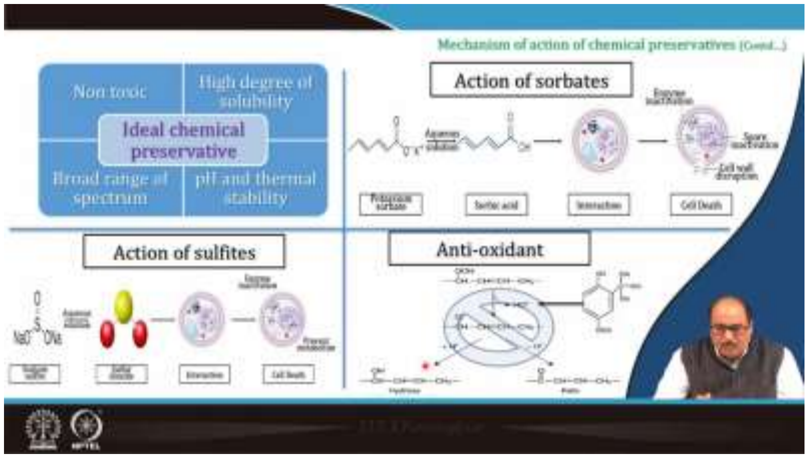


So, obviously, the advantage of using a chemical preservative is an extension in the shelf life; sometimes, you can get that by preventing the harmful microorganisms, we preserve or reduce the risk of foodborne illness. So, food becomes safe; it might improve the quality of the food and result in convenience, like preserved foods are often more convenient for consumers. It may, by preserving the food by reducing the spoilage and extending the shelf life, contribute to the cost savings for both the producers and consumers. So, it results in the economic value benefits, etcetera. And obviously, that is, it may reduce the need for refrigeration, etcetera, that is by, there are certain examples where you can, instead of going for refrigeration, you can use certain chemical preservatives, that is, but once again, one should be very careful while using these chemicals to replace the physical methods, etcetera.

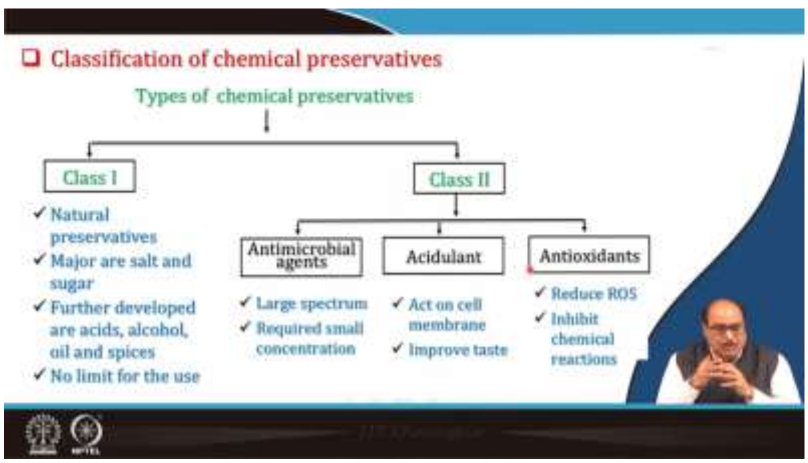


Then, the mechanism of action of a chemical preservative. The chemicals used for preservation purposes interfere with the cell membrane of microorganisms. There are microbial enzymes present inside the membrane; they are active and interfere with and are regulated by these chemicals, and the genetic mechanism of the cell is influenced and affected. So, the working mechanism may be different for different preservatives. However, the major preservatives work on the principle of antimicrobial actions; that is, they kill or inhibit the growth of bacteria, yeast, and moulds. They have antioxidant activities; they prevent oxidation, which causes rancidity. They lower the pH of the food to create an environment that inhibits the growth of microorganisms and also chemicals like salt, sugars, etcetera. They reduce the moisture or bind certain moisture in the food, lowering the water activity or raising the product's osmolality, resulting in lower microbial growth. So, these are, you can say, the mechanisms of ideal chemical preservatives, as I have already discussed.

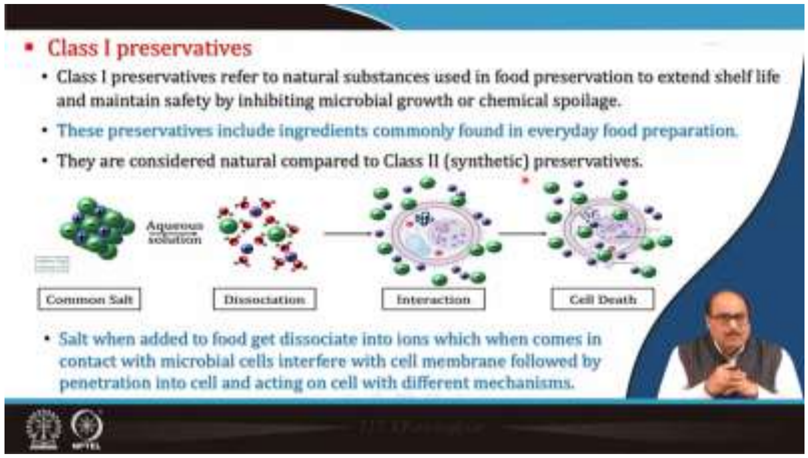
The action of sorbates like potassium sorbate, if used in an aqueous solution, produces sorbic acid, and the sorbic acid interferes with the cell materials in the enzyme inactivation, resulting in spore inactivation, cell disruption, etc., and ultimately, cell death. Similarly, potassium, sodium sulfite, etc., also produces sulfur dioxide, and the resulting interaction leads to cell death.



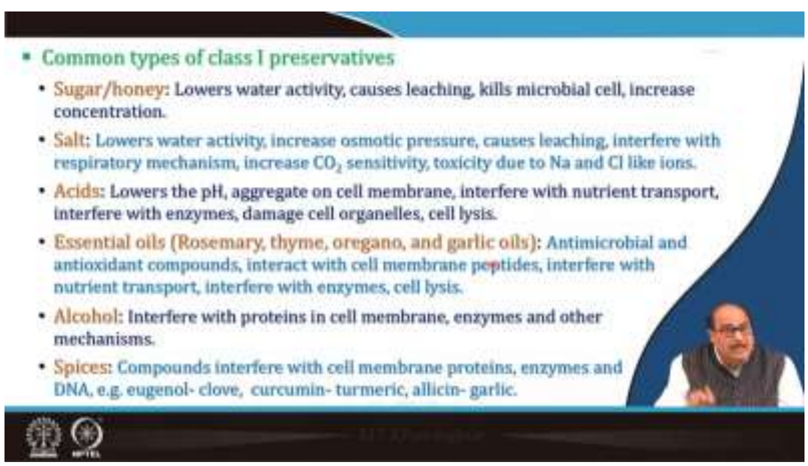
As discussed in the earlier class, antioxidants interfere with the free radical chain mechanism, converting free radicals into non-radical products, thereby reducing their activity.



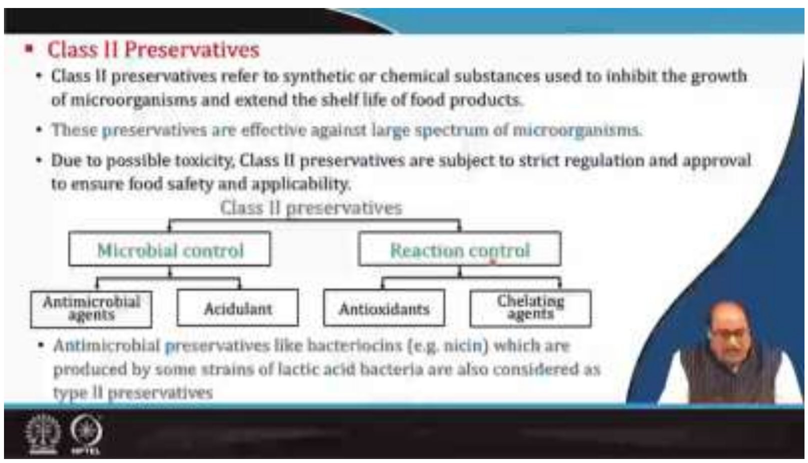
So, the different classes of chemical preservatives can be divided into two major categories: Class I chemical preservatives and Class II chemical preservatives. Class I preservatives include mostly natural preservatives like salt and sugars. They are further developed by acid, alcohol, oil, spices, etcetera. One important thing is that there is no control or limit to using class I chemical preservatives in food. It is the will and wish of the manufacturer to use them. However, the class II chemical preservatives include those listed, such as antimicrobial agents, acidulants, antioxidants, etcetera. Mostly, they are synthetic or synthesized chemicals. Antimicrobials have a broad spectrum and require a small concentration. Similarly, acidulants and antioxidants act on cell membranes. Antioxidants reduce ROS and inhibit chemical reduction.



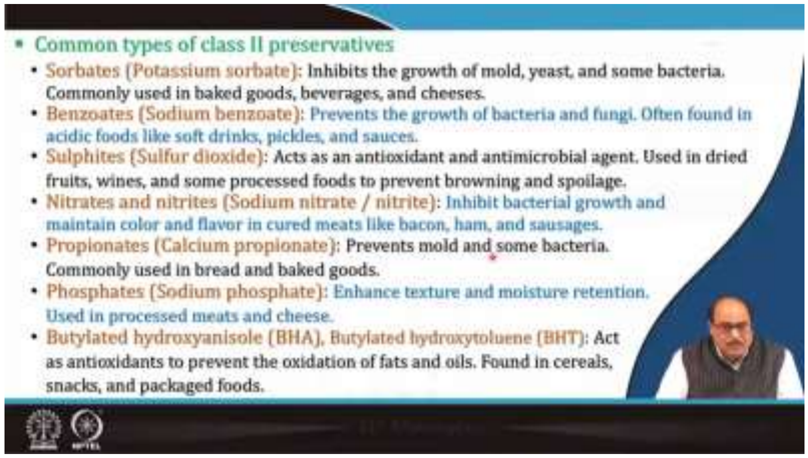
So, the class I chemical preservatives, as I already told you in the last slide, refer to the natural substances used in food for preservation purposes. These preservatives include ingredients commonly found in everyday food preparations. They are considered a natural compound compared to class II, which is synthetic. So, you can say the common salt in the aqueous solution, which we put as the macrinia voxel if you look at the common salt. So, it dissociates into sodium ions and chloride ions, and these sodium ion and chloride ions interfere with the cell and may cause the cell to. So, when added to food, salts get dissociated into the ion, which comes in contact with microbial cells and interferes with the cell membrane, followed by penetration into the cell and acting on the cell with a different mechanism. So, similarly, the various chemicals we use either in the similar way they interact with the cell, another plant cell, a microbial cell, etcetera and have their effect.



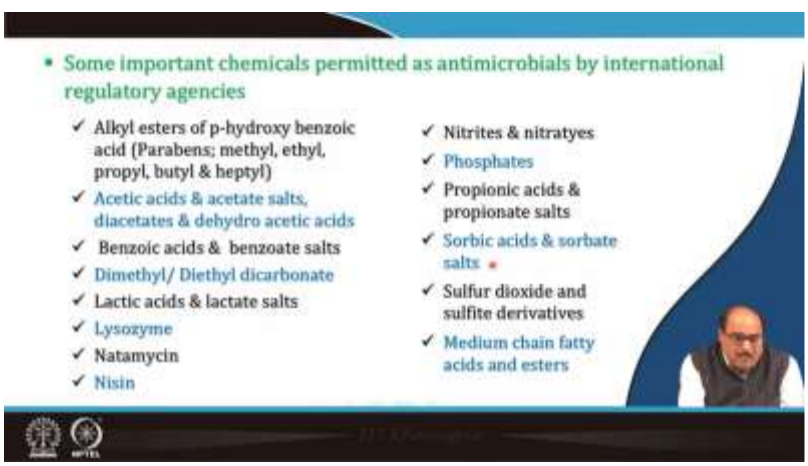
So, a common class of class 1 preservatives include sugar or honey, salt, and acids. Then essential oils like rosemary, thyme, oregano, garlic, etcetera, alcohol, and spices are also important. Like sugars and honey, all these lower water activities cause leaching, kill microbial cells, and increase concentration. Salt again lowers water activity; it increases carbon dioxide sensitivity, and its toxicity due to sodium and chloride-like ions, etcetera, might be present. Toxicity to the microbial cells. Then, acids lower the pH and aggregate the essential oils from spices, etcetera, on the cell membrane. They have antimicrobial activity. They contain antioxidant compounds, so they interfere with the cell membrane peptides, interfere with nutrient transport, and may cause cell lysis. Alcohol also interferes with the proteins in the cell membrane. Spice-like compounds present in spices interfere with the cell membrane profiles, enzymes, DNA, etc. For example, eugenol in clove, curcumin in turmeric, and allicin in garlic, etcetera, have antimicrobial or even antioxidant properties.



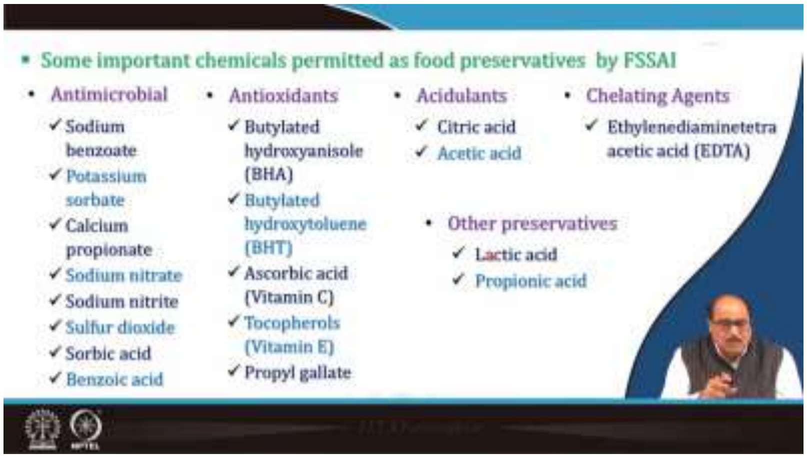
Class II preservatives are synthetic or chemical substances. These preservatives are effective against a broad spectrum of microorganisms. Due to possible toxicity, Class II preservatives are subject to strict regulations and approval to ensure food safety and applicability. There are legal control and their levels of how much this would be used, which class II preservatives should be used in a portion of food, and in what concentration that is all is regulated and concerned regulatory agency of the country's approval is required should be taken for use. So, class II preservatives can be used for microbial control, such as antimicrobial agents and acidulants, or they can be used for reaction control, such as antioxidants, chelating agents, etc. These antimicrobial preservatives, like bacteriocins produced by some strains of lactic acid bacteria, are also considered type II preservatives.



So, a common class of type 2 preservatives include sorbets, which are popularly potassium sorbets and inhibit mould, yeast, and some bacteria growth. It is commonly used in baked goods, beverages, and cheeses. Benzoate, like sodium benzoate, prevents the growth of bacteria and fungi used in acidic foods like soft drinks, pickles, and sauces. Sulfites like sulfur dioxide act as antioxidants and antimicrobial agents. It is used in dried fruits, wines, and some processed foods to prevent browning and spoilage. Nitrites and nitrates like sodium nitrite, sodium nitrate, etcetera. They inhibit bacterial growth and maintain colour and flavour in cured meats like bacon, ham, sausage, etc. Propionates like calcium propionate prevent mold and some bacteria. They are used in bread and baked goods. For example, sodium phosphate enhances texture and moisture retention. It is used in processed meat and cheese. Then, butylated hydroxyanisole or butylated hydroxytoluene act as antioxidants and are used extensively to preserve oils, fats, and such products.

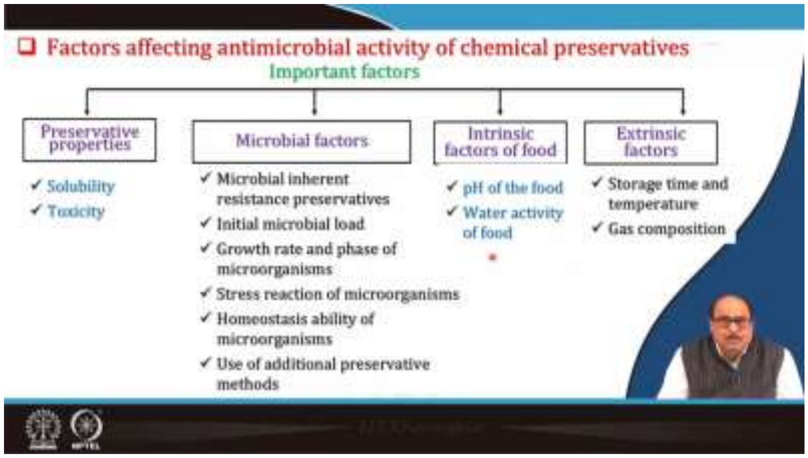


So, some of the important chemicals permitted as antimicrobials are permitted as preservatives by international regulatory agencies, including alkyl esters of para-hydroxybenzoic acids, acetic acid and their salts, benzoic acid and their salts, dimethyl or diethyl dicarbonates, lactic acid and their salts. lysozyme, natamycin, nisin, nitrites and nitrates, phosphates, propionic acids and propionate salts, sorbic acids and sorbate salts, sulphur dioxide and sulphide derivatives, and medium-chain fatty acids and esters. So, this is a list, but this list is exhaustive. These are the major ones that international regulatory agencies have approved for using the chemicals as antimicrobial agents.

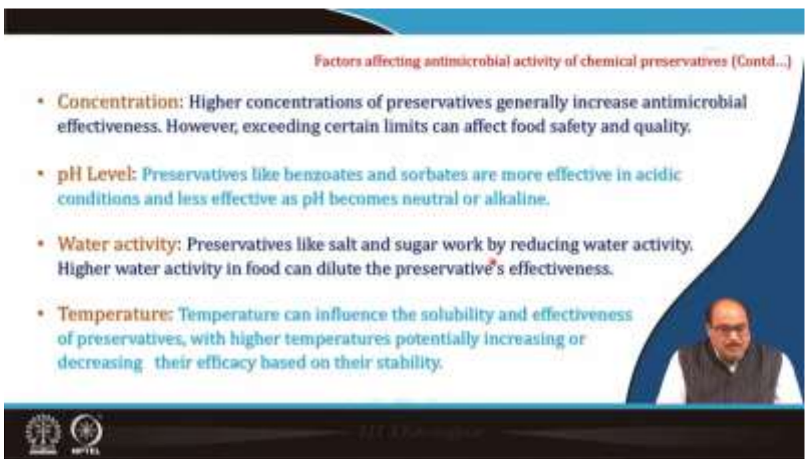


So, some of the important chemicals which are proven and permitted to be used as food preservatives by the FSSAI (Food Safety and Standards Authority of India) and that is in the antimicrobial category: sodium benzoate, potassium sorbate, calcium propionate, sodium nitrate, nitrite, sulphur dioxide. acid, sorbic acid, and benzoic acid; in the antioxidants like BHA, BHT, vitamin C, vitamin E, and propyl gallates; acidulants like citric acid and acetic acid; chelating agents like EDTA; other preservatives like lactic acid and propionic acid. Again, the list is exhaustive, and many times even if the list is not included, the manufacturer can go to the FSSAI with the required relevant data, and they can consider it for inclusion in the preservative list.

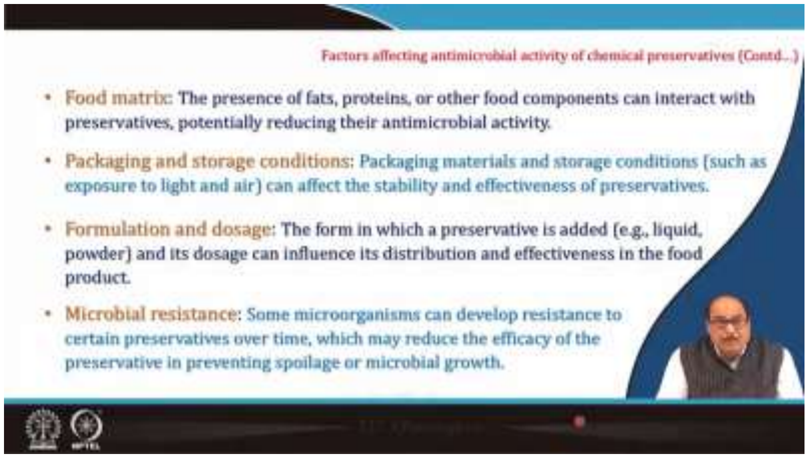
So, the factors affecting the antimicrobial activity of a chemical preservative are again here, such as Preservative properties like solubility and toxicity of the chemical. Then, microbial factors like microbial inherent resistance to preservatives, that is, initial microbial load, the growth rate and phase of the microorganism, and how it is affected by the presence of the chemical in the food.



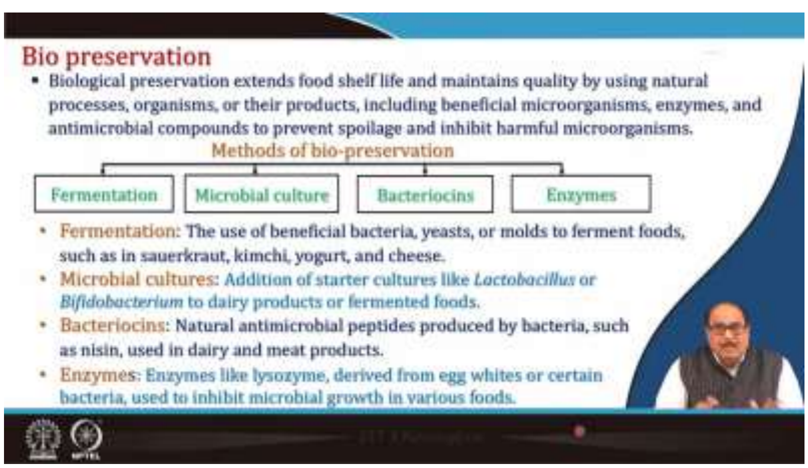
Then, the stress reaction of the microorganism, the homeostasis ability of the microorganism, is how the microorganism can act and manage itself against those stresses created by the microorganism. The use of additional preservative methods, intrinsic factors of food like the food's pH, water activity, and extrinsic factors: storage time, temperature, gas composition, and so on.



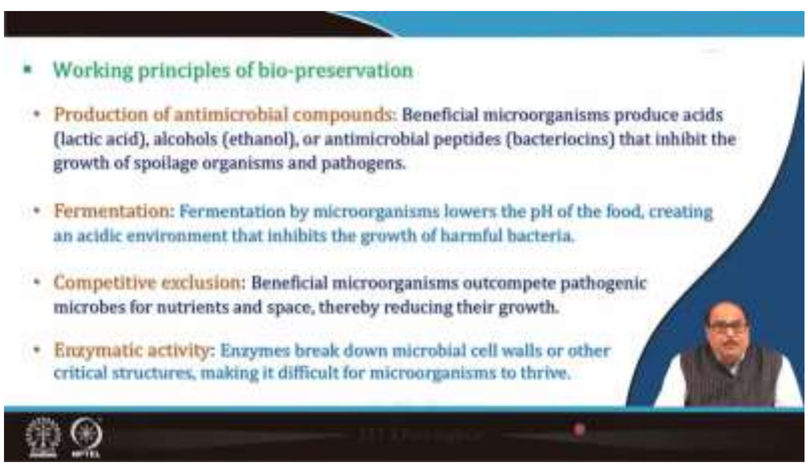
So, the concentration means a higher concentration of preservatives generally increases the antimicrobial effectiveness. However, exceeding the concentration may exceed the limit under the regulation, and it can affect the safety and quality of the food. So, one has to be careful. Then, pH levels of preservatives like benzoate and sorbets are more effective in acidic conditions and less effective as pH becomes more alkaline or even neutral. Then, preservatives like salt and sugar reduce the water activity; higher water activity in food can dilute the preservative's effectiveness. Temperature can influence the solubility and effectiveness of preservatives, with higher temperatures potentially increasing or decreasing their efficacy based on their stability. So, these factors influence the antimicrobial activity of a chemical preservative in food.



Even in the food matrix, the presence of certain components of materials like food, fats, proteins, or other components can interact with the preservatives and potentially reduce their antimicrobial activities. The packaging materials and storage conditions like exposure to light and air, etcetera, can affect the stability and effectiveness of preservatives. The form in which a preservative is added, whether it is a liquid or a powder form, and its dosage can influence its distribution and effectiveness in the food product. Then, some microorganisms can develop resistance to certain preservatives over time, that is, if you are using chemicals in the food. So, continuously, microbial resistance development takes place, which may reduce the efficacy of the preservative in preventing spoilage or microbial growth, etc. So, these need to be considered and taken into account.



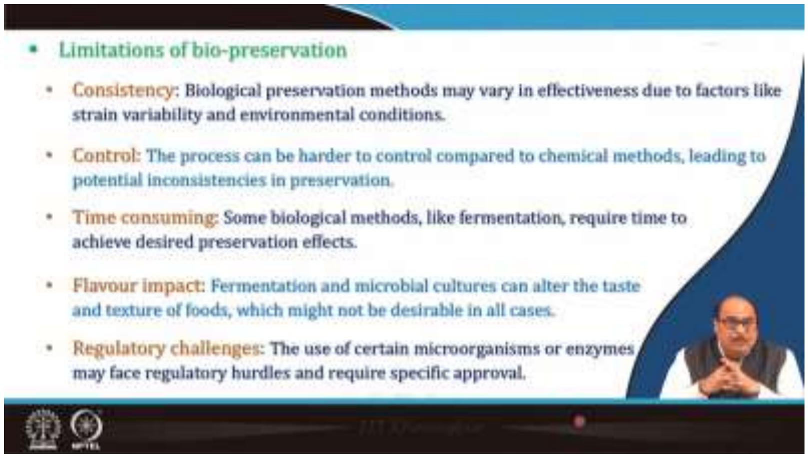
Now, let us talk about biopreservation. Biological preservation extends the shelf life and maintains quality by using natural processes and natural microorganisms or their products, including beneficial microorganisms, enzymes, and antimicrobial compounds, to prevent spoilage and inhibit harmful microorganisms. Biopreservation includes fermentation, use of microbial cultures, bacteriocins, or even enzymes. Like in fermentation, live bacteria or beneficial bacteria are used, such as yeasts in fermented foods like sauerkraut, kimchi, yoghurt, and cheese, and when these microorganisms in fruits, vegetables, etcetera, are inoculated with certain bacteria like lactic acid bacteria, Streptococcus, or even thermophilus in the dahi or yoghurt, etcetera. So, these foods are inoculated with microorganisms and given the required conditions for their fermentation. These bacteria grow, multiply in number, and bring about desirable changes in such products, and that is the taste, color, texture, flavor, etcetera. The food is changed, and we get a more valuable product, food with more value and a higher shelf life. Then, microbial culture, that is, the addition of starter cultures like lactobacillus or bifidobacterium to dairy products in fermented foods. So, these microbial cultures are used sometimes; that is, the dairy products are even taken, and where these microorganisms are grown, these extracts are used as preservatives in some other foods. Then, bacteriocins, which are the natural antimicrobials produced by bacteria such as niacin, are used in dairy and meat products. Then finally, enzymes like lysozyme, derived from egg whites or certain bacteria, are used to inhibit microbial growth in various foods.



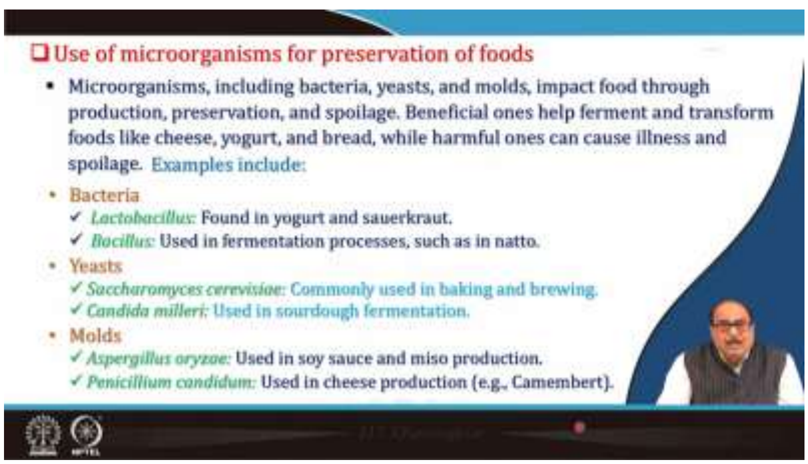
If you talk about the working principles of bio-preservation technologies, it obviously means the production of antimicrobial compounds. That is, beneficial microorganisms produce acids like lactic acid in the case of dairy products, alcohols, ethanol, and antimicrobial peptides like bacteriocins, and these compounds these metabolites inhibit the growth of spoilage microorganisms and pathogens. Then, fermentation by microorganisms lowers the pH of the food, creating an acidic environment that inhibits the growth of harmful bacteria. Then there is competitive exclusion: beneficial microorganisms outcompete pathogenic microbes for nutrients and space, thereby reducing the growth of pathogenic microorganisms. Then, enzyme activity: enzymes break down the microbial cell walls or other structural or critical structures, making it difficult for microorganisms that are undesirable spoilage or pathogenic microorganisms to thrive in the food.

The benefits of biopreservation include that it is obviously a natural method, utilizes natural bioprocesses and organisms, and avoids synthetic chemicals and other additives. It has a lot of health benefits, like fermented foods, which can provide probiotics and other health benefits such as improved digestion and immune functions even if the probiotic bacteria microorganisms are used. They modulate the gut microbiota and other things than sustainability. Often, they are more environmentally friendly compared to chemical preservatives. These preservatives enhance the flavour that the fermentation can enhance the flavour, texture and nutritional value of foods and, more importantly, the safety. They are effective at preventing the growth of harmful microorganisms and thereby reducing the food burn illnesses caused by biopreservation.

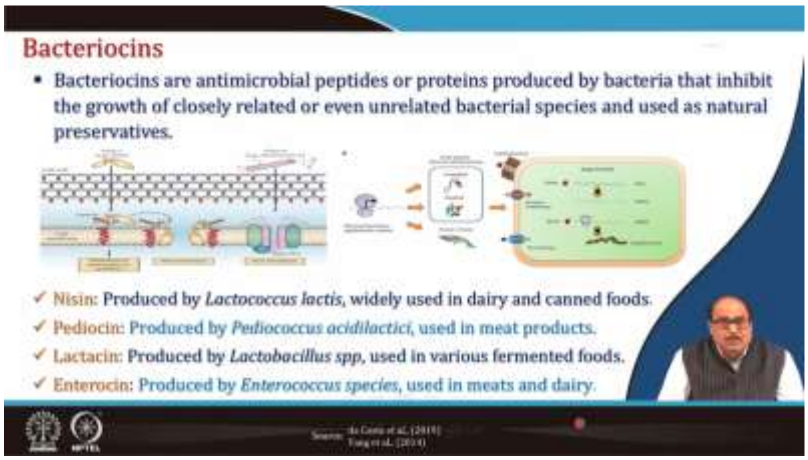
However, consistency is one major limitation. Biological preservation methods may vary in effectiveness due to factors like strain variability and environmental conditions. Then, the process can be harder to control than chemical methods, leading to potential inconsistency in preservation. It may require better control equipment, like fermentation chambers or certain environmental control chambers, that may add to the cost.



Then, time-consuming biological methods like fermentation require time; they need more time to achieve the desired preservation effect or desired value in the food. Then, fermentation and microbial cultures can alter the taste and texture of food, which might not be desirable in all cases. Then, certain regulatory challenges exist; using certain microorganisms may face regulatory hurdles and require specific approvals. For example, many times, if you use these bacteriocins, etcetera, they are extracts and natural forms. So, they are treated as chemicals. So, regulatory approval has to be obtained. So, these are some of the limitations in the use of biopreservation.

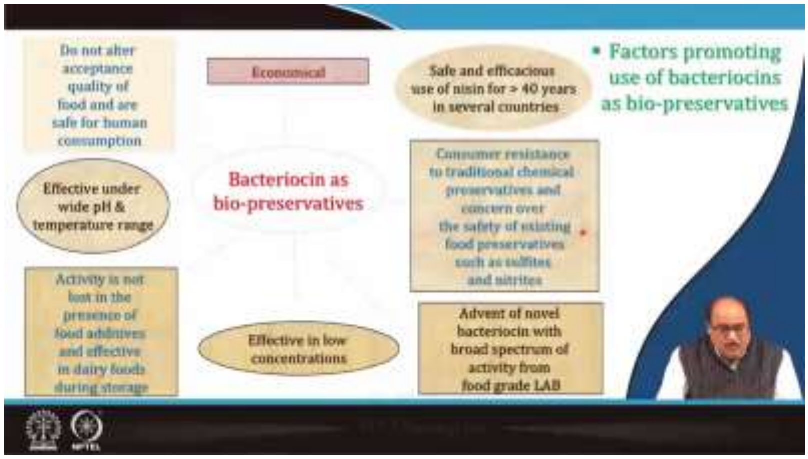


Now, let us talk about the use of microorganisms for the preservation of foods, like microorganisms, including bacteria, yeast, and moulds, which impact food through production, preservation, and spoilage. So, beneficial microorganisms help ferment and transform foods like cheese, yoghurt, and bread, while harmful ones can cause illness and spoilage. So, for example, in the case of bacteria, lactobacillus is found in yoghurt and sauerkraut. The bacillus group of bacteria is used in fermentation processes to produce natto. Yeast is very popular; I hope you all know saccharomyces cerevisiae is commonly used in bread-making, brewing, or wine-making. Then candida milleri is used in sourdough fermentation. Molds like *Aspergillus oryzae* are used in soy sauce and miso production and *Penicillium candidum* is used in cheese production like camembert cheese. So, these many microorganisms have beneficial effects and are used to preserve foods.



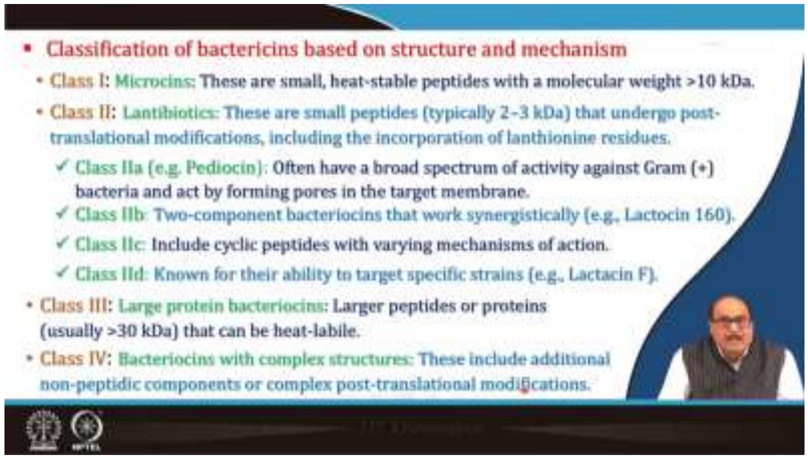
So, the bacteriocins are antimicrobial peptides. They are proteins produced by bacteria that inhibit the growth of closely related or even unrelated bacterial species and are used as natural preservatives. Some common bacteriocins include nisin, which is produced by *Lactococcus lactis* and widely used in the dairy industry and canned food. Pediocin is produced by *Pediococcus acidilactici*, it is used in meat products. Lactacin produced by *Lactobacillus* species is used in various fermented foods and enterocin is produced by *Enterococcus* species and used in the meat and dairy industry.

So, these bacteriocins cause the inhibition of peptidoglycan synthesis; there may be poor formation in the cell walls, etcetera, and then these can cause cell lysis. They interfere with the cellular reactions inside the cell. So, these bacteriocins, as preservatives, are safe, and the efficacious use of niacin for more than 40 years is now in several countries. Consumer resistance to traditional chemical preservatives and concern over the increasing safety of existing food preservatives, such as sulphide and nitrides, have led to the use of bacteriocins.



More and more use of bacteriocins as food preservatives, the advent of novel bacteriocins with a broad spectrum of activity against food-grade lactic acid bacteria. These bacteriocins are very effective at low concentrations. The activity of bacteriocins is not lost in the presence of food additives, and it is effective in dairy foods during storage. It is effective under a wide pH and temperature range. Bacteriocins do not alter the acceptance quality of foods, are safe for human consumption, and are economical to use in foods.

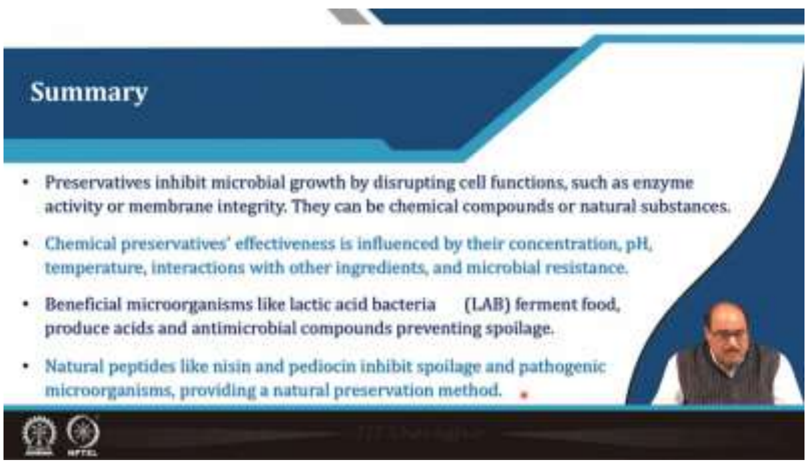
So, the benefits of using bacteriocins as food preservatives are that they are natural and safe. Bacteriocins are produced by naturally occurring bacteria and are generally considered safe for human consumption. They selectively inhibit harmful bacteria while often being less effective against beneficial bacteria, allowing selective preservation. Bacteriocins effectively preserve or prevent spoilage and extend the shelf life of various foods, including dairy products, meat, and processed foods. These bacteriocins can reduce or eliminate the need for synthetic preservatives, appealing to consumers seeking natural food products.



Classification of bacteriocins is based on their structural and functional mechanisms. They can be classified into four major categories: class I, II, III, and IV. Class I are the microcins. They are small, heat-stable peptides with a molecular weight of more than 10 kilodaltons. Class II bacteriocins include lantibiotics, which are small peptides, typically 2 to 3 kilodaltons, that undergo post-translational modifications, including incorporating lanthionine residues. Then, these class II preservatives have further classified as class IIa that is pediocin often have this class IIa has a broad spectrum of activity against gram (+) bacteria and acts by forming pores in the target membrane. Class IIb has two component bacteriocins that work synergistically, like lactocin 160. Class IIc includes cyclic peptides with varying mechanisms of action. Class IId is known for its ability to target specific strains like lactacin F. Class III bacteriocins include large protein bacteriocins. They are larger peptides or proteins, usually more than 30 kilodaltons, that can be heat labile. Class IV includes bacteriocins with complex structures. These include additional non-peptide components or complex post-translational modifications.

As far as the application of bacteriocins in food preservation is concerned. They are actively used nowadays in dairy products. For example, niacin is commonly used in cheeses and milk to inhibit spoilage and pathogenic bacterial growth. In meat products, pediocin and other bacteriocins are used to prevent microbial contamination and spoilage. Bacteriocins are used in some ready-to-eat canned foods to extend their shelf life.

In fermented foods, bacteriocins can enhance the safety and quality of fermented foods by controlling the growth of unwanted microorganisms.



Finally, I would like to summarize this lecture by saying that preservatives inhibit microbial growth by disrupting cell functions such as enzyme activity or membrane integrity. They can be chemical compounds or natural substances. Chemical preservatives' effectiveness is influenced by their concentration, pH, temperature, interaction with other ingredients, and microbial resistance. Beneficial microorganisms like lactic acid bacteria ferment foods and produce acid and antimicrobial compounds, which prevent spoilage. Natural peptides like niacin and pediocin inhibit spoilage and pathogenic microorganisms, providing a natural preservation method. So, this opens a large aspect, which is the wide application of these natural compounds for preserving food, or bacteriocins, or microorganisms for preserving food.

So, these are the references used in this lecture.

Finally, I thank you for your patient attention. Thank you very much.