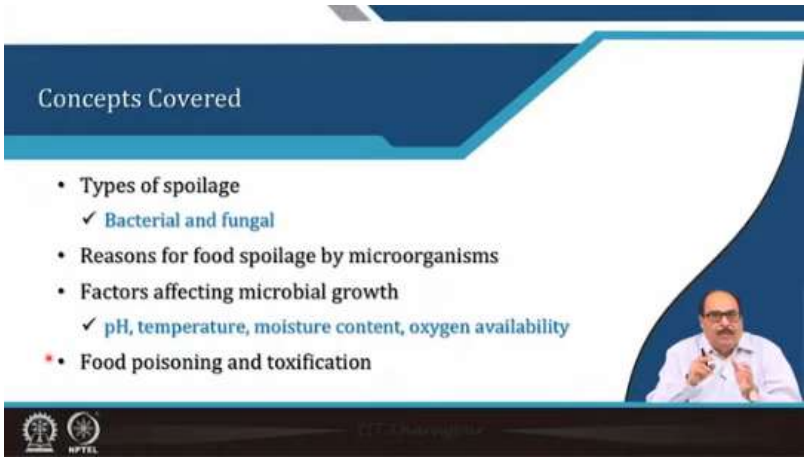
FOOD SCIENCE AND TECHNOLOGY

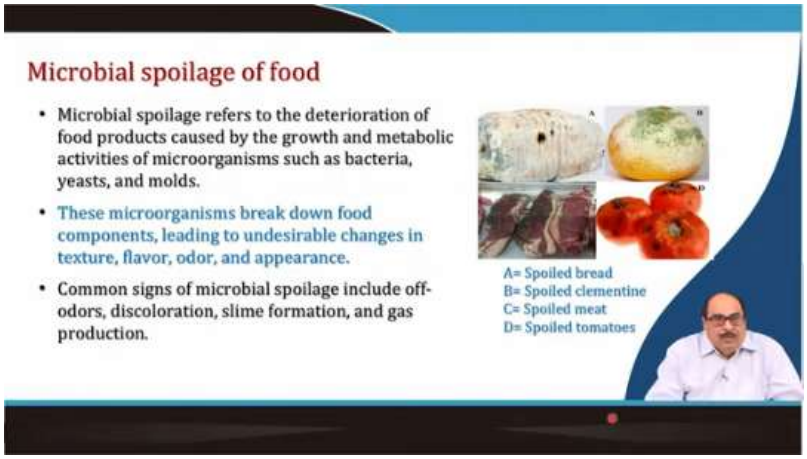
Lecture33

Lecture 33: Microbial Spoilage of Foods

Hello everyone, Namaste. Now, in this thirty-third lecture of the course, we will discuss microbial spoilage of foods.

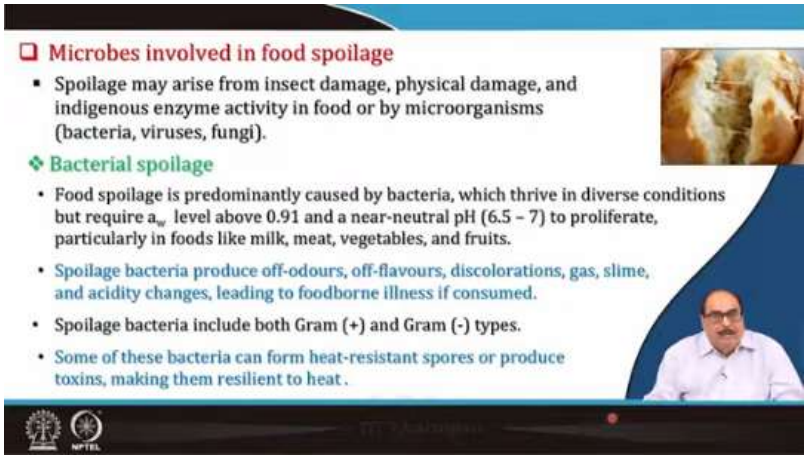


We will discuss the types of food spoilage, particularly bacterial and fungal. Also, we will discuss the reasons for food spoilage by microorganisms and the various factors that affect microbial growth. Finally, we will shed some light on food poisoning and toxification.



So, microbial spoilage of food, you know that microbial spoilage refers to the deterioration of food products caused by the growth and metabolic activities of microorganisms like bacteria, yeast, and moulds. They break down food components, leading to undesirable changes in the texture, flavour, odour, and appearance of the food, ultimately making the

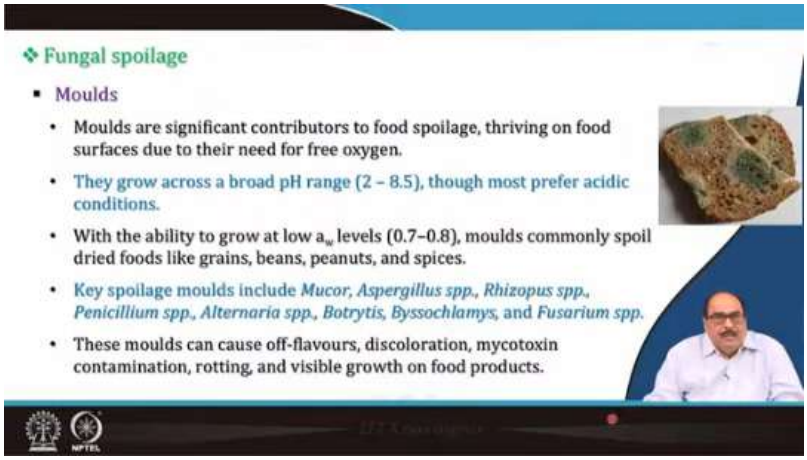
food unfit for consumption. Common signs of microbial food spoilage include off-odours, discolouration, slime formation, and gas production.



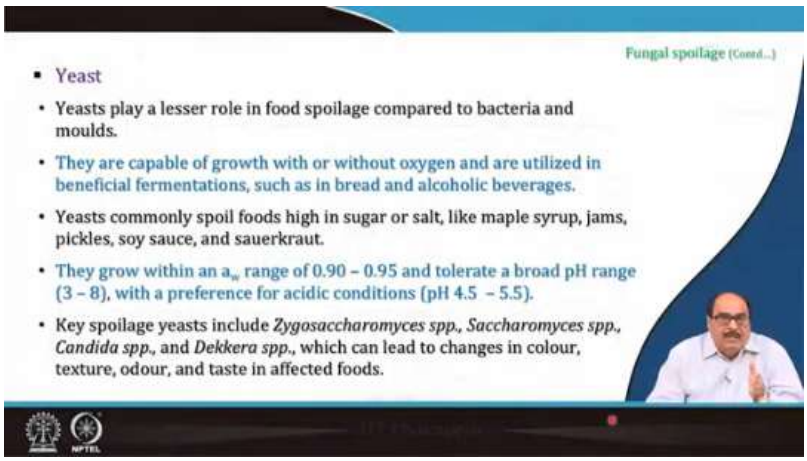
As we discussed earlier, the microorganisms involved in food spoilage may arise from insect damage, physical damage, indigenous enzyme activity in food, or microorganisms like bacteria, viruses, fungi, etc. In the last class, we discussed the potential for food contamination by microorganisms. So, we also discussed microbial growth. So, changes occur when microorganisms grow in the food, sometimes when there is physical damage or some other cause. So, it provides those microorganisms with an easy or favourable environment for their growth. They grow and consume food nutrients, producing or bringing about undesirable changes in the food that make it unfit for human consumption. So, let us talk about bacterial spoilage. Food spoilage is predominantly caused by bacteria, which thrive in diverse conditions. Still, they require water activity levels above 0.91 and a near-neutral pH, maybe 6.5 to 7, to proliferate, particularly in foods like milk, meat, vegetables, and fruit. So, the bacteria are contaminated, so environmental factors like water activity and pH become important factors. Spoilage bacteria produce off-flavours, colours, etc., bringing about acidity changes, leading to foodborne illness if consumed. They may also produce certain toxins in the food, which may cause illness. They include both gram-positive and gram-negative types. Some of these bacteria can even form heat-resistant spores or produce toxins, making them heat-resistant.

So, here in this, I have given you a summary of the foods, spoilage types and microorganisms involved. For example, in bread, there is ropey spoilage; the microorganism is Bacillus subtilis. In fish, there may be discolouration due to microbial spoilage, and the microorganisms involved may be Alcaligenes, Pseudomonas, Flavobacterium, etc. In concentrated juices, you get off-flavour; the microorganisms may be *Acetobacter, Lactobacillus,* or *Leuconostoc*. In milk or cream, ropiness again is the major spoilage type, and the microorganisms involved are *Micrococcus, Enterobacter, Lactobacillus, Streptococcus*, and so on.

Then again, there may be fat decomposition in milk and cream, which may be spoilage. Here, microorganisms like *Bacillus, Alcaligenes, Clostridium*, and *Micrococcus* can all grow and decompose the fat, causing spoilage. Similarly, *P. fluorescens* may result in the formation of alkali, alkaline flavours in milk or cream. In vegetables, you may find soft rot, again due to the growth of *Pseudomonas*. In curd, there may be slime formation, slimy curd, because of the growth of *Alcaligenes*, etc.



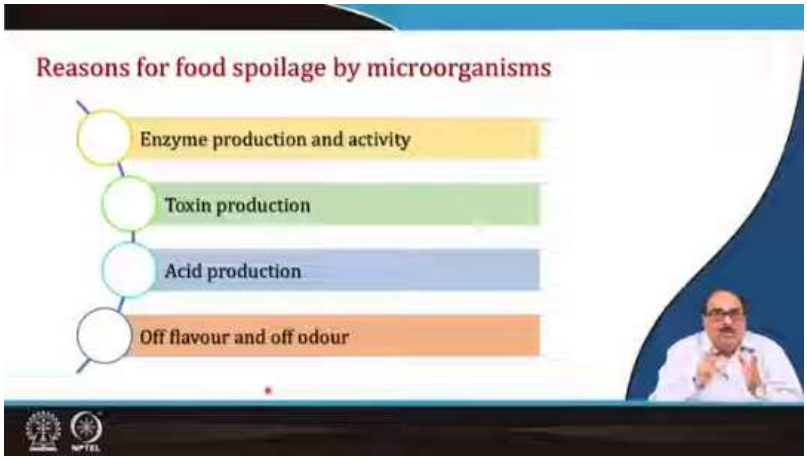
Then, fungal spoilage stocks the moulds. They significantly contribute to food spoilage, thriving on food surfaces due to their need for free oxygen. Because these moulds are fungi, they need oxygen for their growth. They grow across a broad pH range, from 2 to 8.5, although the most preferred pH is acidic conditions. With the ability to grow at a lower level of water activity, like 0.7 to 0.8, mould commonly spoils dried foods like grains, beans, peanuts, spices, etc. Key spoilage molds include *mucor*, *aspergillus* species, *rhizopus* species, *penicillium* species, *alternaria*, *protitis*, *vascochlemis* or *fusarium* species. These moulds can cause off flavours, discolouration, mycotoxin contamination, rotting and visible growth on the food products.



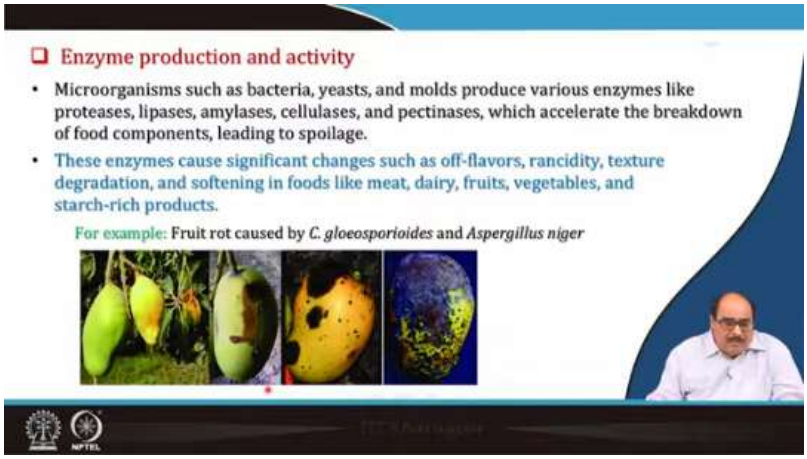
Yeasts are another class of fungi. Fungi contain mould and yeast. So, yeast plays a lesser role in spoiled food than bacteria and moulds. However, they can also grow with or without oxygen and are utilised in beneficial fermentation, such as bread, alcoholic beverages, winemaking, etc. Yeasts are utilised. So, yeasts are both. Good yeast, as well as wild yeast there are they also wild yeast come to spoiled foods high in sugar or salt like maple syrup, jams, pickles, soya sauce, sauerkraut, etcetera. They grow within a water activity range of

0.9 to 0.95. and tolerate a broad pH range that is 3 to 8, although they have a preference for acidic conditions, like pH 4.5 to 5.5, which is considered the most preferred pH for their growth. Key spoilage organisms include Saccharomyces species, candida, etc. These can lead to changes in the affected foods' colour, texture, odour, and taste.

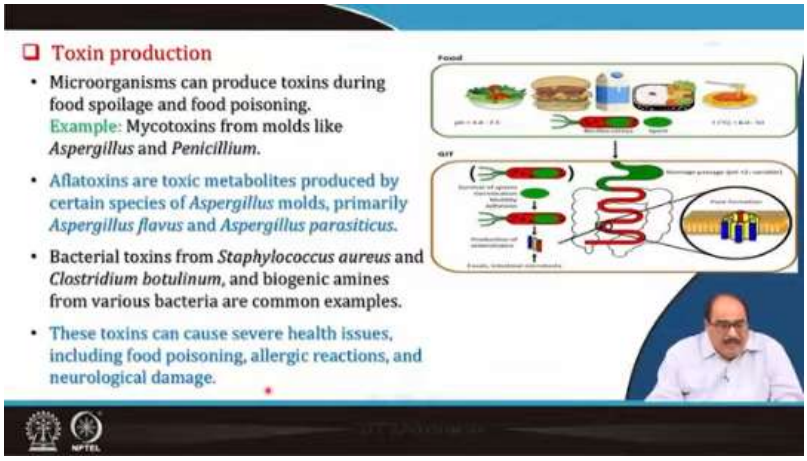
So, the foods here show spoilage types like bread mould, *Rhizopus nigricans*, or *Penicillium*, which are most involved. In fresh fruits and vegetables, *Rhizopus*, *Erwinia*, *Botrytis*, and *Aspergillus niger* grow and may cause spoilage like soft rot or gray and black mold growth. Similarly, in pickles and sauerkraut, *Rhodotorula* grows and may cause spoilage, forming film and pink yeasts. In onions, *Aspergillus* causes black rot; in fruits, Penicillium causes blue rot spoilage, and in onions, Geotrichum candidum causes sour rot spoilage. In other vegetables, *Botrytis cinerea* causes grey mold rot, and *Phytophthora* causes downy mildews. So, these are the various mold spoilage types in different foods caused by molds.



Now, let us discuss the various reasons for food spoilage by microorganisms. These include enzyme production and activity, toxin production, acid production, and off-flavour or off-odour production, as mentioned earlier, when these microorganisms grow.

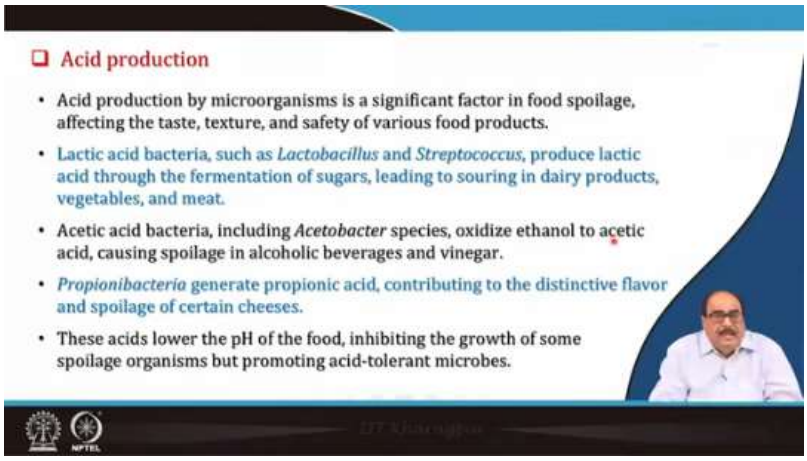


So, enzyme production and activity mean microorganisms like bacteria, yeast, and moulds. produce various enzymes like proteases, lipases, amylases, cellulases, pectinases, etc., which accelerate the breakdown of food components, leading to spoilage. These enzymes cause significant changes like off-flavor, acidity, texture degradation, and softening in meat, dairy, fruits, vegetables, and starch products. So, fruit rot caused by *C. gloeosporioides* and *Aspergillus niger*, that is, basically these fungi contain enzymes which cause this rot in the fruits.

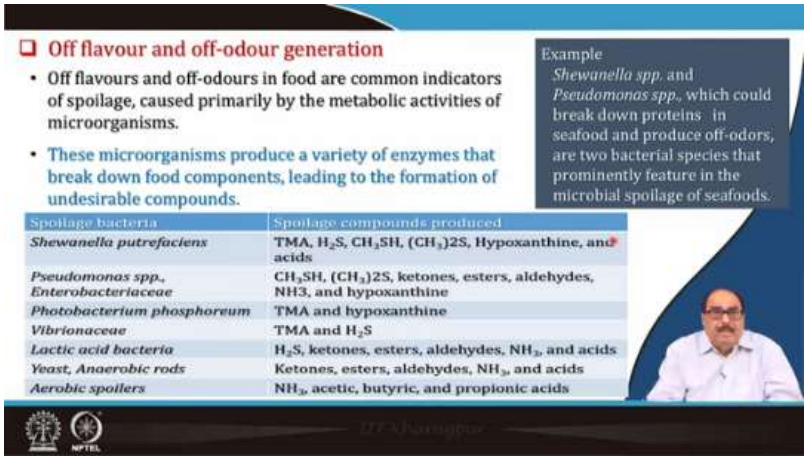


Then, toxin production again—many microorganisms can produce toxins during food spoilage, in the earlier class, we also shed some light on this aspect. These toxins may cause spoilage as well as food poisoning, like mycotoxins from moulds like Aspergillus, Penicillium, etc., which is the major problem in groundnuts, like aflatoxin. These aflatoxins

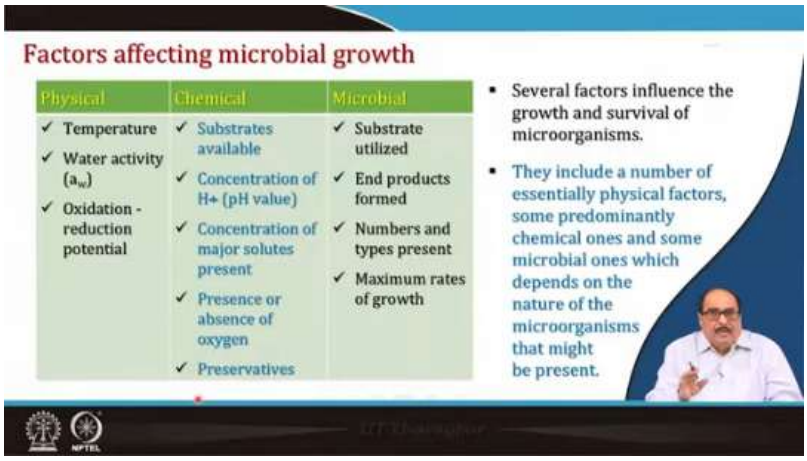
are toxic metabolites produced by certain species of *Aspergillus* molds, primarily Aspergillus flavus and Aspergillus parasiticus. Then, bacterial toxins from *Staphylococcus aureus* and *Clostridium botulinum*, as well as biogenic amines from various bacteria, are common examples of bacterial toxins. These toxins can cause severe health issues, including food poisoning. allergic reactions and neurological damage, etc. So, the picture shows that the food contains a contaminated microorganism. Sometimes it either produces toxins in the food or uses the food as its carrier material, goes and establishes itself in the large intestine or small intestine, where it causes the toxin production.



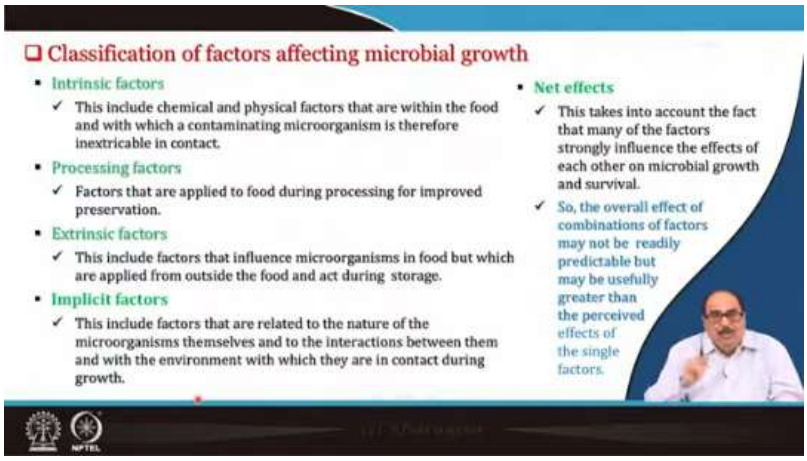
Acid production is another reason that acid production by microorganisms is a significant factor in food spoiling, affecting the taste, texture and safety of various food products. Lactic acid bacteria, such as *Lactobacillus* and S*treptococcus*, produce lactic acid through the fermentation of sugars. leading to souring dairy products, vegetables, and meat. Acetic acid bacteria, including *Acetobacter* species, oxidise ethanol to acetic acid, causing spoilage in alcoholic beverages and vinegars. Propionic bacteria generate propionic acid contributing to the distinctive flavor and spoilage of certain So, these acids there are several examples, these acids lower the pH of the food, inhibiting the growth of some spoilage organism, but promoting acid tolerant microbes particularly yeast and molds etcetera which can grow in little more acidic condition and also because of this acid the taste of the food materials gets changed.



Then, off-flavour and off-odour generation, like off flavours and odours in food, are common indicators of spoiling caused primarily by the metabolic activities of the microorganism. These microorganisms produce a variety of enzymes. that break down the food components, leading to the formation of undesirable compounds. For example, S*almonella* and *Pseudomonas* species could break down proteins in seafood and produce off flavours. These are the two bacterial species that are the best examples of the bacterial species that are predominantly featured in the microbial spoilage of seafood. So, similarly, many solera putrefactions produce TMA, H2S, CS3SH, hypoxanthine and acids, etc. *Pseudomonas* species and *Enterobacteriaceae* species again produce ketones, heesters, aldehyde, ammonia, hypoxanthin, etc., many products are. Then, many other lactic acid bacteria produce H2S, ketones, esters, aldehydes, and ammonia. Then aerobic spoilers produce ammonia, acetic acid, butyric acid, propionic acid, etc. So, all these bacteria produce various aldehyde ketonic or other acids, etc., or other organic compounds, which produce the off flavour and off odour in the food.

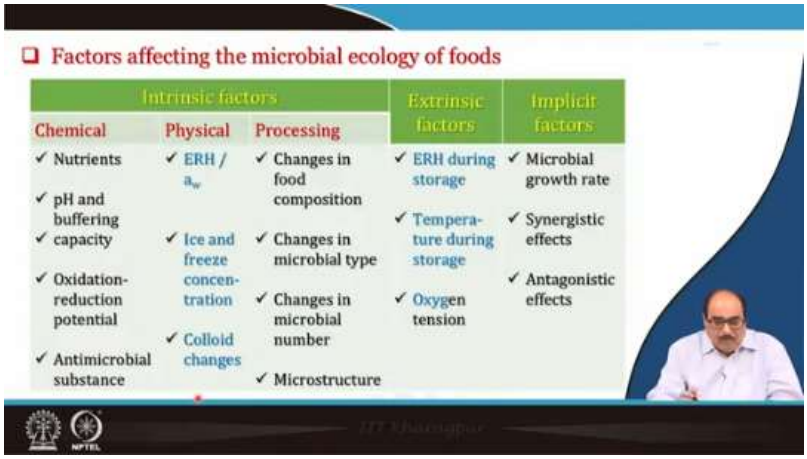


Then, let us talk about factors affecting microbial growth. Several factors influence the growth and survival of microorganisms in food. They include several factors, essentially physical factors, some predominantly chemical ones, and some microbial ones, which depend on the nature of the food microorganism that might be present. So, physical factors may be temperature, water activity, and oxidation-reduction potential. Among the chemical factors affecting microbial growth may be substrate availability, concentration of hydrogen ions (that is, the pH value), concentration of major solutes present, presence or absence of oxygen, and even various preservatives, which may also influence microbial growth. Then, factors related to the nature of the microorganism, like substrates utilised, end products formed, number and types of microorganisms present, maximum rate of growth, etc. These are the various factors.

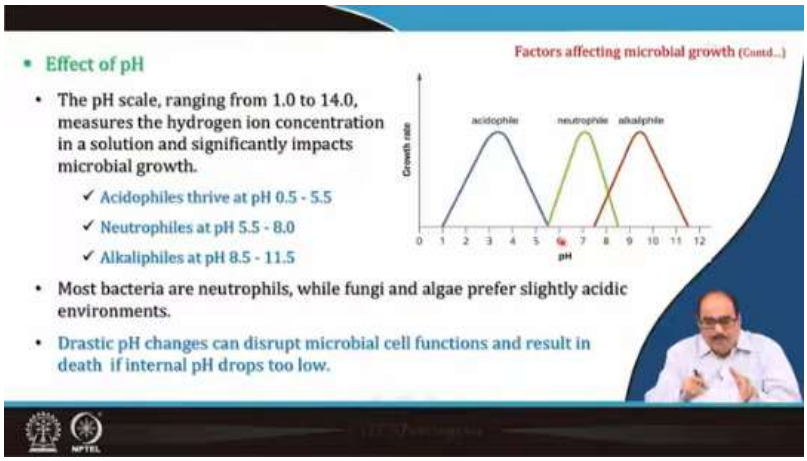


So, suppose we want to classify these factors according to their relation to microbial growth and their present environment. In that case, they can be classified—all these factors we have described earlier— into categories like intensive, extensive, processing, or implicit factors. Intensive factors include those chemical and physical factors within the food, with which a contaminating microorganism is inextricably in contact. The processing factors are applied to food during processing for improved preservation, and extensive factors include those factors that influence microorganisms in food but are applied from outside the food, particularly during storage. Implicit factors are related to the nature of the microorganism itself and the interactions between it and the environment with which they are in contact during growth and storage. So, there is one term, finally, the net effect, which considers that many of the factors strongly influence each other on microbial survival and growth. So, the overall effect of the combination of factors may not be readily predictable, but it may be more useful than the perceived effects of the single factor. factor. So, the

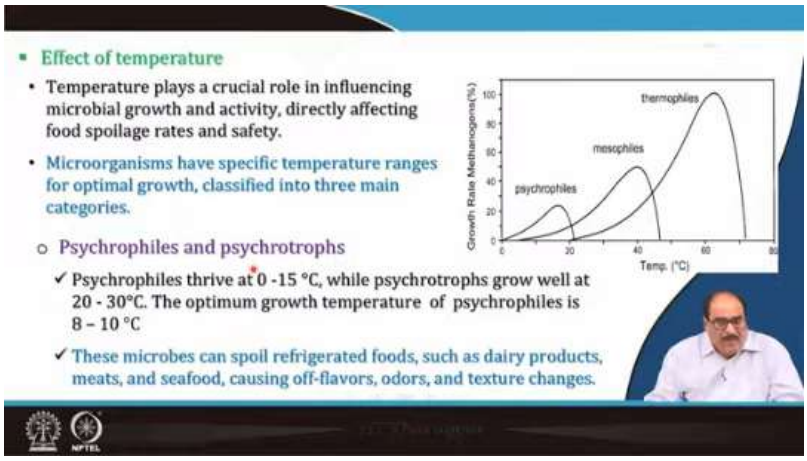
combination of factors. Therefore, in the calculation optimisation process, etc., one must include the net effect, which combines factors.



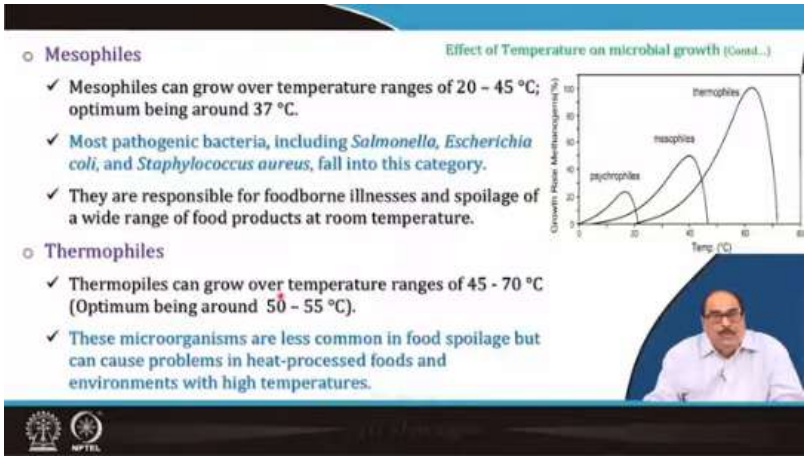
So, again, here are the intrinsic factors, which may include physical, chemical, and Processing factors, etc., in the chemical, nutrients, pH and buffering capacity are over potential antimicrobial substances. In the physical, it is ERH, a_w of the food, ice and freeze concentration, colloid changes. Processing factor means there are changes in the composition during processing, changes in the microbial type, changes in the microbial number, microstructure, etc. Then, the extrinsic factors are those that are applied from outside during storage. That is the equilibrium relative humidity of the environment during storage, the temperature of the environment, and the oxygen tension. Then, implicit factors mean microbial growth rate and synergistic factors; that is, sometimes the two microorganisms are present; they are synergistic to each other. They may be antagonistic to each other, etc. So, all these are the three factors that affect the microbial ecology of foods, and they should be properly considered during food processing and for various purposes.



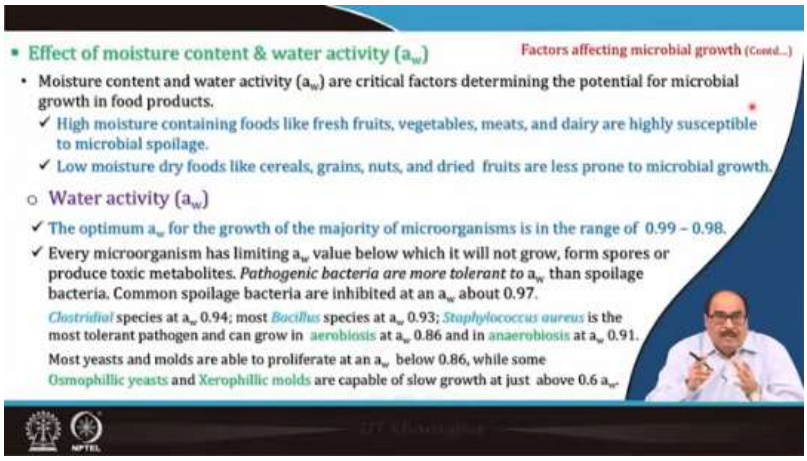
So, let us briefly discuss some important factors. Let us elaborate a little briefly, and the first is the pH. The pH scale, ranging from 1 to 14, measures the hydrogen ion concentration in a solution, and it significantly impacts microbial growth. So, the acidophile microorganisms thrive at a pH of 5 to 5.5; neutrophils thrive at a pH of 5.5 to 8, and alkaliphiles thrive at a pH of 8.5 to 11.5. So, most bacteria are neutrophils, while fungi and algae prefer a slightly acidic environment. So, drastic pH changes can disrupt microbial cell functions and result in death if the internal pH drops too low.



Then, the effect of temperature, you can see again here in the temperature versus growth rate of the microorganisms. So, temperature, as you have seen earlier and we also discussed it, plays a crucial role in influencing microbial growth. and activity, directly affecting the food spoilage rates and food safety. Microorganisms have specific temperature ranges for optimal growth. They are classified into three main categories: psychrophiles, psychrotrophic microorganisms, or psychrotrophs. So, psychrophiles thrive at temperatures between 0 to 15 degrees Celsius or 1 to 15 degrees Celsius, while psychrotrophs grow well at 20 to 30 degrees Celsius. So, the optimum growth temperature for psychrophiles is around 8 to 10 degrees Celsius. These microbes can spoil refrigerated foods like dairy products, meats, and seafood, causing off-flavours, odours, and textural changes.

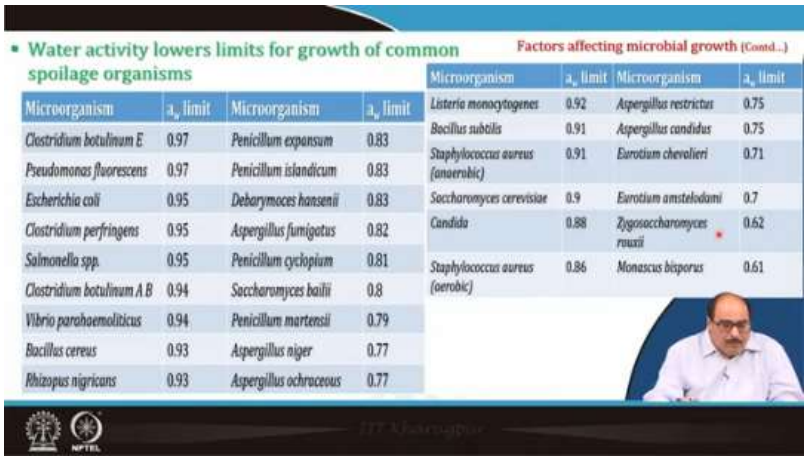


Mesophiles can grow at temperatures ranging from 20 to 45 degrees Celsius. The optimum growth temperature may be similar to human body temperature, around 37 degrees Celsius. And, because of this, the growth requirement is optimal at biological cell temperatures, so most pathogenic bacteria, including Salmonella, Escherichia, Staphylococcus aureus, etc., fall into this category—they are mesophiles. They are responsible for foodborne illnesses and the spoilage of a wide range of food products at room temperature. Then comes the third category: thermophiles, which can grow at higher temperatures. That is a temperature range of 45 to 70 degrees Celsius, with the optimum being around 50 to 55 degrees Celsius. These microorganisms are less common in food spoilage but cause problems in heat-processed foods and environments with high temperatures.



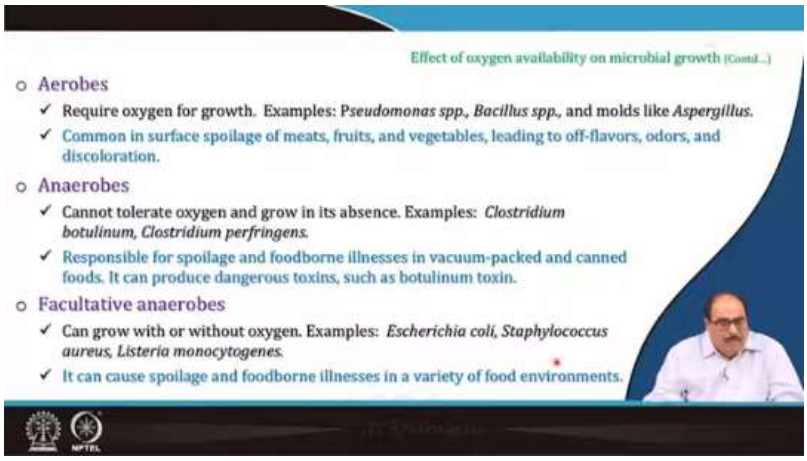
Let us see the effect of moisture content and water activity. That is, the moisture content and water activity are critical factors determining the potential for microbial growth in food products. High-moisture foods like fresh fruits, vegetables, meat, dairy products, etc., are highly susceptible to microbial spoilage. Low-moisture dry foods like cereals, grains, nuts, and dried fruits are comparatively less prone to microbial growth. The optimum water

activity for the growth of most microorganisms is in the range of 0.99 to 0.98. Every microorganism has a limiting water activity value below which it will not grow, it will not form spores, or it will not produce toxic metabolites. So, pathogenic bacteria are more tolerant of water activity than spoilage-causing bacteria. Common spoilage bacteria are inhibited at a water activity of about 0.97. *Clostridial* species are inhibited at a water activity of 0.94. Most Bacillus species will not be able to grow in food where water activity is brought to 0.93. Staphylococcus aureus is the most water activity-tolerant pathogen, and it can grow in aerobic conditions at an a_w of 0.86 and in anaerobic conditions at an a_w of 0.91. Most of the yeasts and moulds can proliferate at a water activity (aw) below 0.86, while some osmophilic yeasts and xerophilic moulds can slow growth at just above 0.6 water activity.



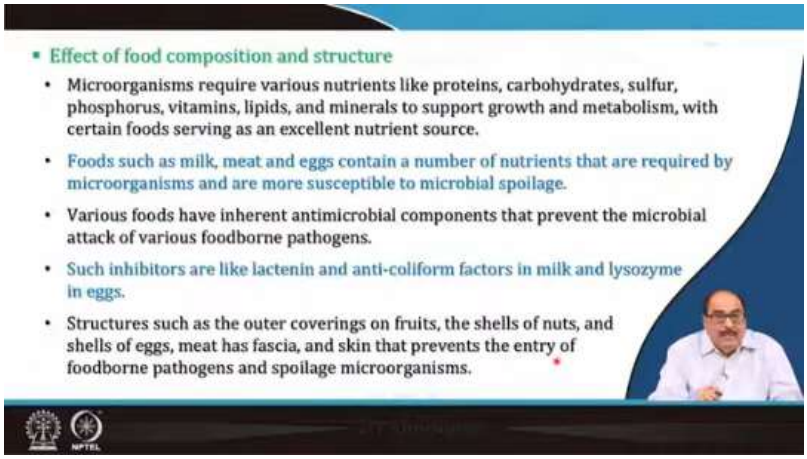
So, this table shows the water activity limit for most microorganisms associated with food. And in this table, you can see that *Clostridium botulinum*, *Pseudomonas*, etc., require entirely higher water activity, 0.97, 0.95, etc. Whereas most *Candida* and *Staphylococcus* aureus can grow under aerobic conditions, they can grow at 0.88 or 0.86, and some yeast fungi, such as *Zygosaccharomyces rouxii* and *Monascus*, can grow at lower water activity. So, that is here accordingly. If you can take this value, if you bring the water activity of a food material below 0.61, meaning that it is taken as 0.6. So, suppose the water activity is maintained at that level. In that case, the food will become completely safe from microbial growth, and microorganisms will not be able to grow and multiply in that food.

So, another factor is the availability of oxygen. Oxygen availability significantly influences the growth and activity of microorganisms in food. According to oxygen requirement for growth, microorganisms are grouped into aerobes, anaerobes, and facultative anaerobes. And accordingly, you see here that obligate aerobes require oxygen, while obligate anaerobes are killed by oxygen. Whereas facultative anaerobes grow better with O_2 but can live without it. Aerotolerant anaerobes are unaffected by oxygen levels. That is, aerobes require oxygen for growth *Pseudomonas, Bacillus*, molds like *Aspergillus*, etc.

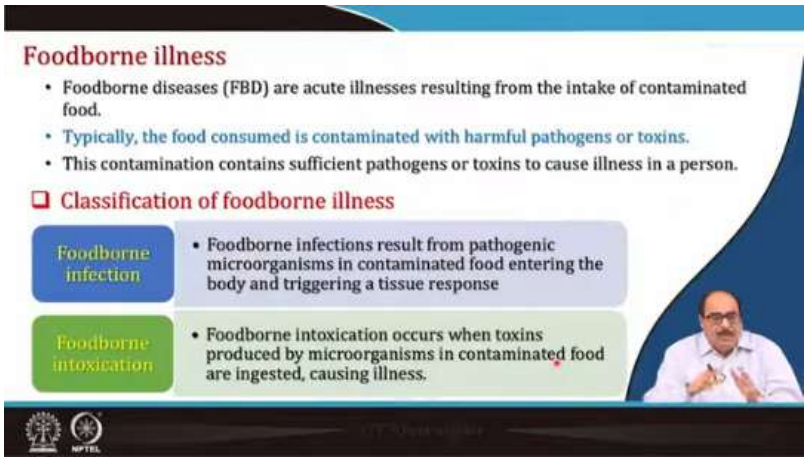


They are common in surface spoilage of food because the surface of food has plenty of oxygen, and in fruits, vegetables, etc. Anaerobes cannot tolerate oxygen and grow in its absence, like *Clostridium botulinum*, *Clostridium perfringens*, etc. They cannot grow in an oxygen environment. So, for their growth, they need a complete vacuum. So, these anaerobic microorganisms are responsible for food spoilage and illness in vacuum-packaged or canned foods, etc. They can produce dangerous toxins like botulinum toxin, etc., in canned food. Then, facultative anaerobes like *E. coli*, *Staphylococcus aureus*,

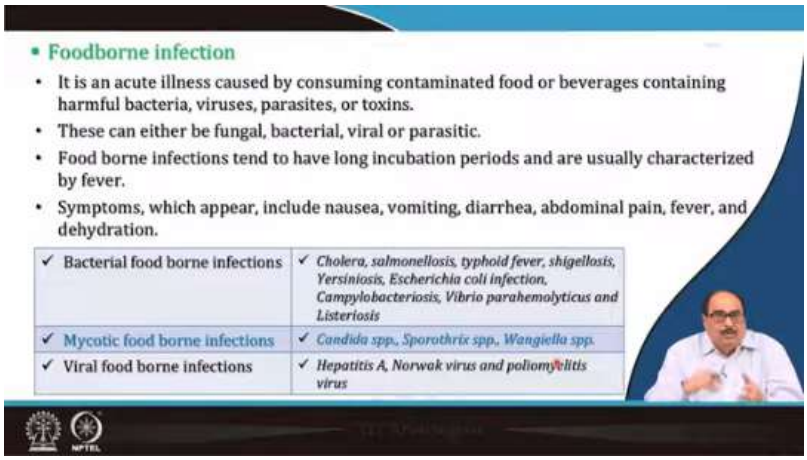
Listeria monocytogenes can grow with or without oxygen. These can cause spoilage and foodborne illness in a variety of food environments.



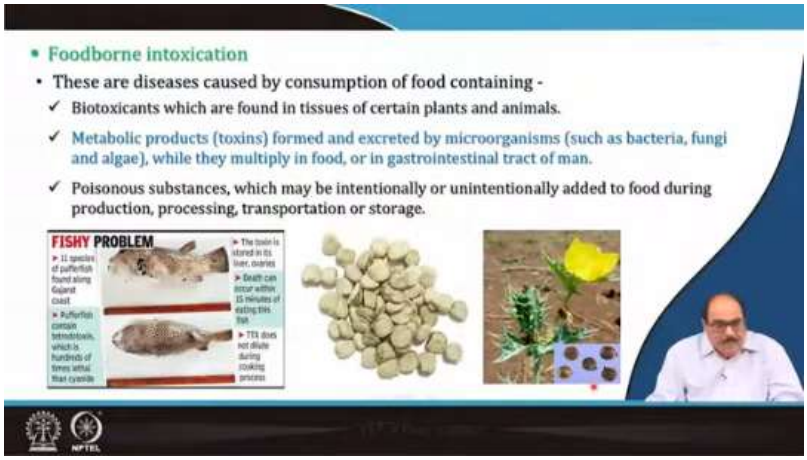
Then, the effect of food composition and structure: microorganisms require nutrients like protein, carbohydrate, sulphur, phosphorus, vitamins, lipids and minerals to support their growth and metabolism, with certain foods serving as excellent nutrient sources. So, foods such as milk, meat, and eggs contain many nutrients required by microorganisms, and therefore, they are more susceptible to microbial spoilage. Various foods have inherent antimicrobial components that prevent microbial attack by various foodborne pathogens. Such inhibitors include leptinine and anti-coliform factors in milk, lysozyme in eggs, etc. So, some of the biological materials are food if they contain certain antimicrobial agents, etc. Like in the egg, the outer shell prevents microbial contamination of the inner material and other such things. Then, structures such as the outer covering of fruits, the shell of nuts, and the shell of eggs, etc., and meat have fascia and membranes that prevent the entry of foodborne pathogens and spoilage microorganisms. So, food composition and its structure are again very important factors.



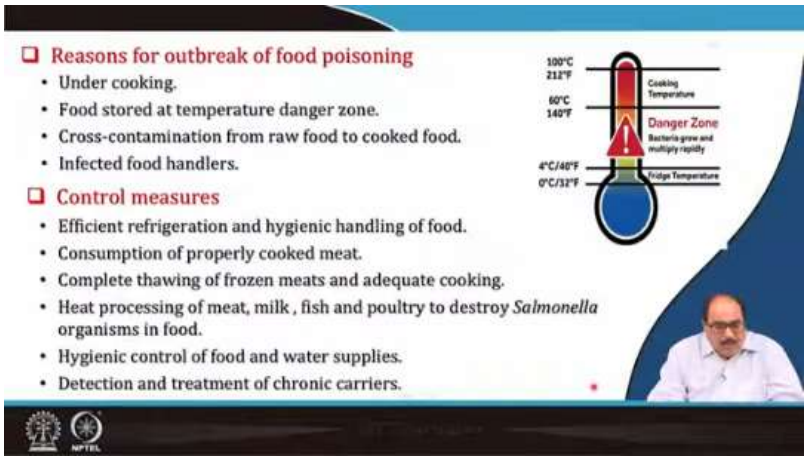
Now, let us talk about foodborne illness. Briefly, foodborne illness or FBD (foodborne diseases) are acute illnesses resulting from the intake of contaminated or infected food, typically food consumed is contaminated with harmful pathogens or toxins. This contamination contains sufficient pathogens or toxins to cause illness in a person. So, there may be two types of foodborne illness: infection and intoxication. Foodborne infections result from pathogenic microorganisms in contaminated food entering the body and triggering a tissue response. Foodborne intoxication occurs when toxins produced by microorganisms in contaminated food are ingested, ultimately causing illness.



So, to elaborate a little, let us discuss foodborne infection, as I told you earlier, it is an acute illness caused by consuming contaminated food or beverages containing microorganisms like bacteria, viruses, or parasites, where food and water act as carriers. These can be fungal, bacterial, viral, or parasitic. Foodborne infections have long incubation periods and are usually characterised by fever. Symptoms may include nausea, vomiting, diarrhoea, abdominal pain, fever, and dehydration. So, bacterial foodborne infections, where bacteria are responsible, include cholera, salmonellosis, typhoid fever, shigellosis, acrimoniasis, E. coli infection, campylobacteriosis, Vibrio parahaemolyticus, and listeriosis. These are the various infections and diseases caused by bacterial foodborne infections. Mycotic foodborne infections include *Candida* species, *Sporothrix*, and *Wangiella* species. Viral foodborne infections include *Hepatitis A*, *Norovirus*, *Poliomyelitis* virus, etcetera.

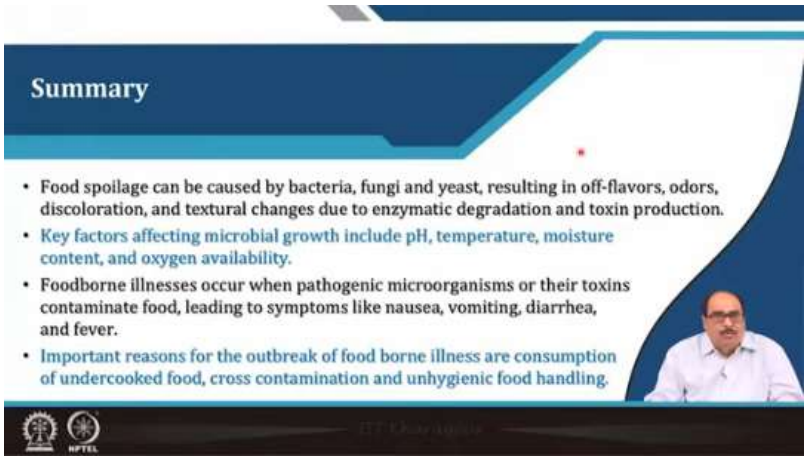


Then, foodborne intoxication refers to diseases caused by consuming food containing toxins, which may be biotoxins found in certain plants and animals or metabolic toxin products formed and excreted by microorganisms such as bacteria, fungi, and algae. while they may multiply in the food or the gastrointestinal tract, or produce poisonous substances. These foods may also contain poisonous substances intentionally or unintentionally added to food during production, processing, transportation, storage, etc. For example, 11 species of puffer fish are found along the Gujarat coast, and these puffer fish contain tetrodotoxin, which is hundreds of times more lethal than cyanide. So, the toxin is stored in the liver or ovaries of these fish, and death can occur within 15 minutes of eating such fish. So, TTX does not dilute during the cooking process, etc.. So, one has to be very careful with these types of toxins, and there are many other such examples, such as various varieties of mushrooms. That is a fungal toxin or a microbial, such as *Clostridium botulinum*. They produce Salmonella poisoning, so many things.



So, the reasons for the outbreak of food poisoning, you can say, are undercooking, temperature in the danger zone, particularly, for example, 4 degrees Celsius to 60 degrees

Celsius. This is considered the danger zone from the pathogenic organism's growth point of view. This is the period where they can grow or cross-contamination from raw food to cooked food occurs. Even infected food handlers, etcetera. And also, we have seen earlier that there are various reasons for food contamination, and if the food gets contaminated, if that particular contaminating bacteria is pathogenic or toxin-producing, if proper care is not taken, it grows, multiplies, and produces toxins. So, what are the control measures? Some of these toxins are enterotoxins; some are exotoxins. Some toxins may be heat-resistant, while others are heat-labile. So, accordingly, one has to take control measures, such as efficient refrigeration and hygienic handling of the food, consumption of properly cooked food, cooked meat, etc., complete thawing of frozen meats, and adequate cooking. Then, heat processing of meat, milk, fish, and poultry is used to destroy salmonella organisms in food. Hygienic control of food and water supplies, detection and treatment of chronic carriers, etcetera. So, one has to undertake good manufacturing practices, good hygienic practices, and good sanitary practices to control contamination as well as to control or detoxify the toxin if it is already produced.



So, finally, I summarise this lecture: food spoilage can be caused by bacteria, fungi, and yeast, resulting in foul flavour, foul odour, discolouration, and textural changes due to enzymatic degradation and toxin production. Key factors affecting microbial growth in food include pH, temperature, moisture content, and oxygen availability. Foodborne illnesses occur when pathogenic microorganisms or their toxins contaminate food, leading to symptoms like nausea, vomiting, diarrhea, and fever. Important reasons for outbreaks of foodborne illnesses are the consumption of uncooked foods, undercooked foods, cross-contamination, and unhygienic handling of food. So, this should be taken care of properly to have safe food.

These are the references used in this lecture.

Thank you. Thank you very much for your patient hearing