FOOD SCIENCE AND TECHNOLOGY

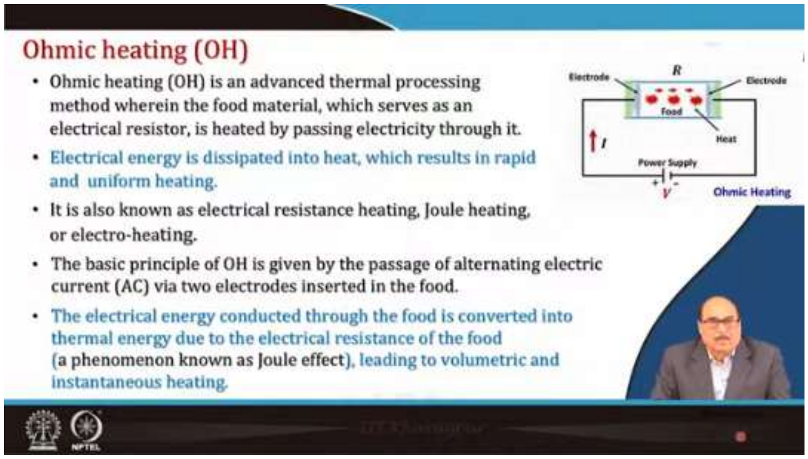
Lecture44

Lecture 44: Alternate Thermal Technologies for Food Preservation

Hello everyone, Namaskar.

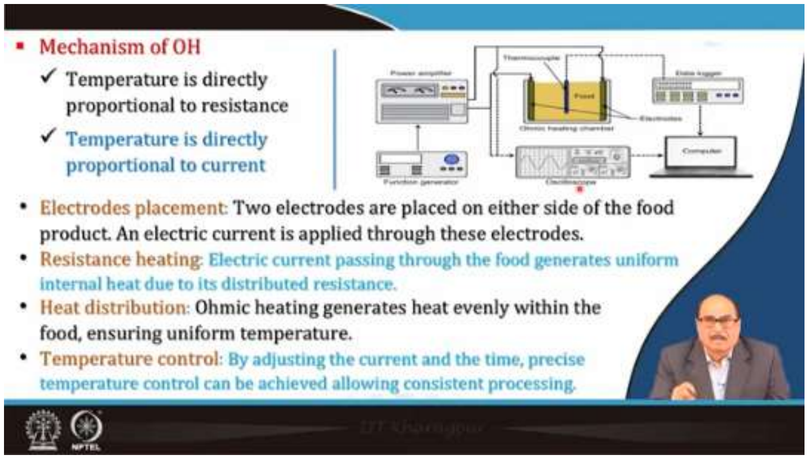
Now, in this lecture today, in the next half an hour or so, we will talk about alternate thermal technologies or advanced thermal technologies for food preservation.

The processes we will discuss here include ohmic heating, infrared heating, microwave heating, radio frequency heating, reflectance window drying, and electrohydrodynamic drying. So, you see, almost all these processes involve heat, but the heat is not produced by burning coal or by evaporating water or by steam and all those things. So, it is not a conventional heating process; instead, heat generation is an advanced or alternate method, primarily by electrical or infrared waves or radio frequency waves.



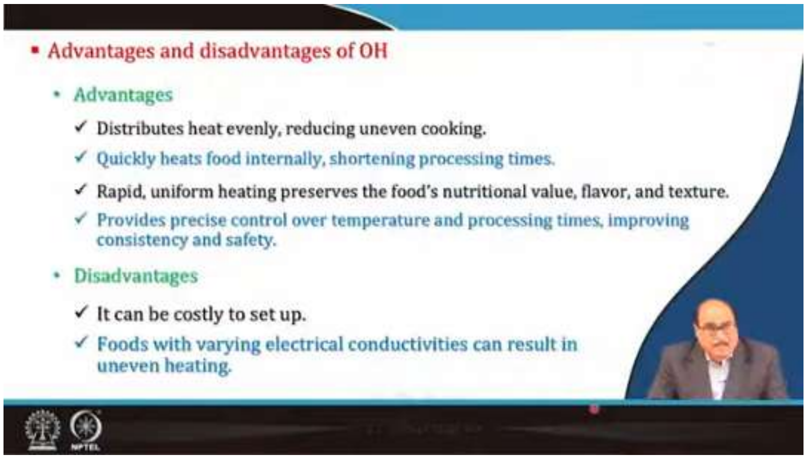
So, let us see one by one, starting with ohmic heating. So, ohmic heating is an advanced thermal processing method wherein the food material, an electrical resistor, is heated by passing electricity through it. That is supposed here the food in this food that electricity is directly passed, and then this electric energy is dissipated into heat, which results in rapid and more uniform heating of the food material. It is also known as electrical resistance heating, joule heating, or electro-heating. So, the basic principle of ohmic heating is given by the passage of alternating electric current, that is AC. There is a power supply here, and with the help of electrodes inside directly in the food, that AC current is supplied by two electrodes which are inserted into the food. So, this electrical energy conducted through the food is converted into thermal energy due to the electrical resistance of the food, which is a phenomenon known as the joule effect. this results in the volumetric and instantaneous heating of the food material, and obviously, Ohm's law is followed in this.

So, the heating mechanism is that you can see the method here, which is a schematic representation of the process. Here is an ohmic heating chamber in which the food material may be liquid food is kept, and there is an electrode it is dipped into it and with

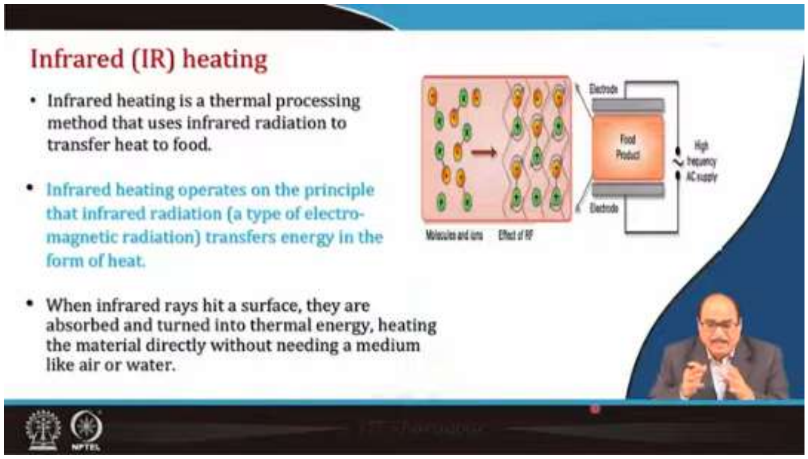


With the help of this electrical generator, a power amplifier is supplied and then may be connected to the computer to see the power regulate the process. So, here, the temperature is directly proportional to the resistance applied to the board and the current; it is also directly proportional to the current given to the board. So, there is electrode placement: two electrodes are placed on either side of the food product, and an electric current is applied through these electrodes. Electric current passing through the food generates uniform internal heat due to its distributed resistance. Ohmic heating generates heat evenly within the food, ensuring uniform temperature, and by adjusting the current and the time to be precise, temperature control can be achieved, allowing consistent processing.

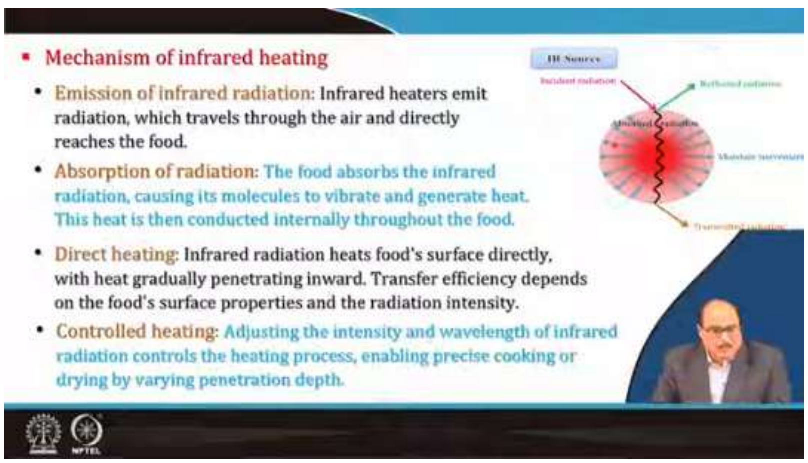
You can see that when you are giving the electrical current, the temperature rise is taking place. So, one can optimize the process so that if you want a particular temperature, it can go up to a particular level. So, how much energy, electrical current, etcetera, is to be provided, and how long can all this be regulated and properly optimized? This ohmic heating can be applied to food for pasteurization or even cooking. It can cook various food items, including meat and vegetables. It is used for sterilization, completely inactivating the microorganisms to extend the shelf life and ensure safety, especially in ready-to-eat foods and similar items, etcetera. It can also be used for blanching, that is, blanching vegetables before they are subjected to freezing treatment or even before they are subjected to drying treatments, etc. The purpose here is to inactivate the enzymes and spoilage-causing microorganisms.



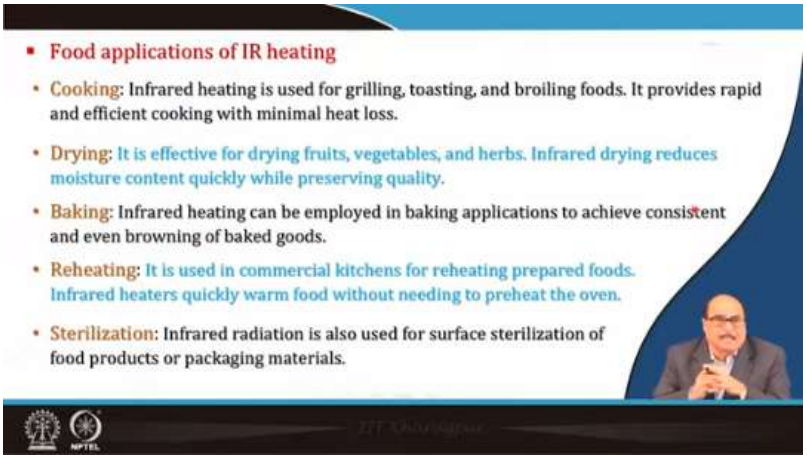
As far as the advantages of ohmic heating are concerned, it distributes the heat evenly, reducing uneven cooking. It quickly heats food internally, shortening the processing time. It is a rapid uniform heating process that preserves the food's nutritional value, flavour and texture. It provides precise control over temperature and processing times, improving the consistency and safety of the products. The major disadvantages, however, are that it can be a costly setup, and foods with varying electrical conductivity can result in uneven heating. So, that may be a major problem. Then, infrared heating means thermal processing, or, you can say, an alternate thermal processing method that uses infrared radiation to transfer heat to food. Infrared heating operates on the principle of infrared radiation, a type of electromagnetic radiation that transfers energy into the food from the heat. When infrared rays heat a surface, they are absorbed and turned into thermal energy, heating the material directly without needing a medium for transferring heat, which is an essential consideration in conventional thermal processing. But here, the material is directly there, so it does not need any medium, air, water, etcetera, for the heat transfer.



So, you can see that molecule and the effect of radiation on the food product, which directly heats internally. So, there are two electrodes, and the food is placed between these two electrodes.

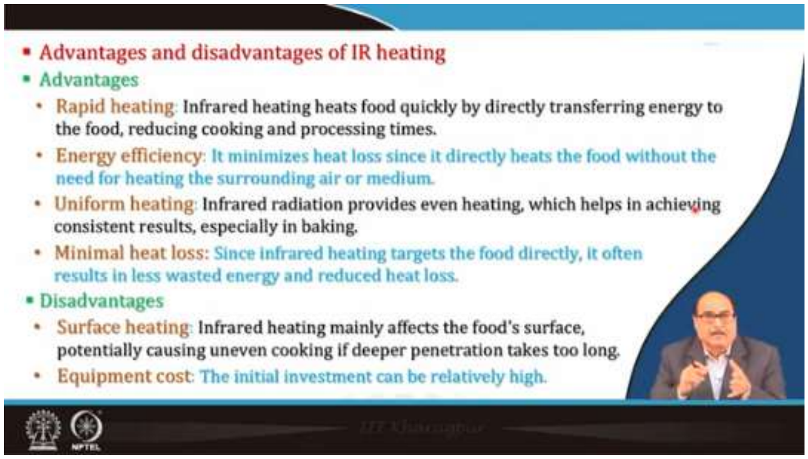


So, there is an emission when the food comes from an IR source. So, these incident radiations come onto the food, then some may be reflected, some may be absorbed inside the food, and the absorbed radiations inside the food move throughout and cause that ionization, etcetera, and then the movement of the materials results in heating. That is, infrared radiation heats the food surface directly, with heat gradually penetrating inward, and transfer efficiency depends on the food surface properties and the radiation intensity. One can control the heating process by adjusting the intensity and wavelength of the infrared radiation. enabling precise cooking or drying by varying the penetration depth. So, that is, in fact, the absorption of the infrared radiation that causes its molecules to vibrate, and this vibration generates the heat. This heat is then conducted internally throughout the surface, as you can see, and then finally, some of the transmitted radiation goes out. That is how these infrared radiations work.

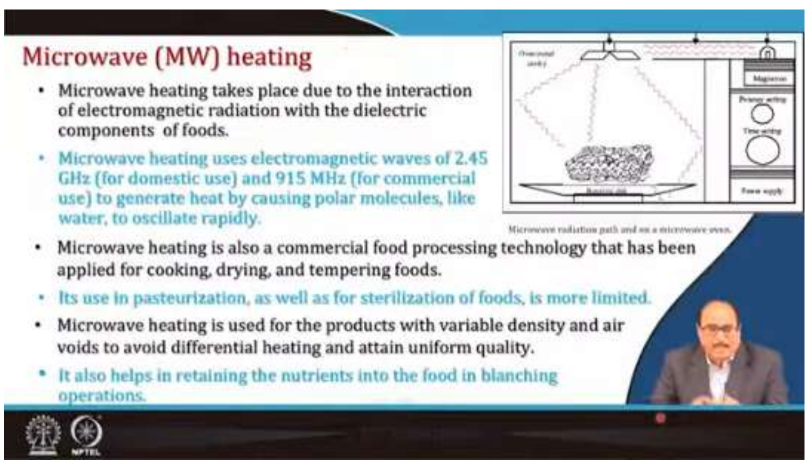


Regarding food applications, infrared heating can be used for cooking, particularly for grilling, toasting, and broiling foods. It provides rapid and efficient cooking with minimal heat involvement or minimal heat. It is an effective method for drying fruits, vegetables, and herbs, etcetera. Infrared drying reduces moisture content quickly while preserving the quality. Infrared heating can be employed in baking applications to achieve consistent and even browning of the baked goods. So, particularly in the advanced bakery units, they have this infrared ray toward the end of the baking section. So, when the material comes out extraordinary, it is under the infrared ray. So, it also results in even moisture distribution in the baked material, particularly in biscuits, etcetera, which eliminates or reduces breakage during packaging and other handling. Then infrared can also be used in commercial kitchens to reheat prepared foods. Infrared heating quickly warms the food without needing to preheat the oven. Infrared radiation is also used to surface sterilize food products or packaging materials.

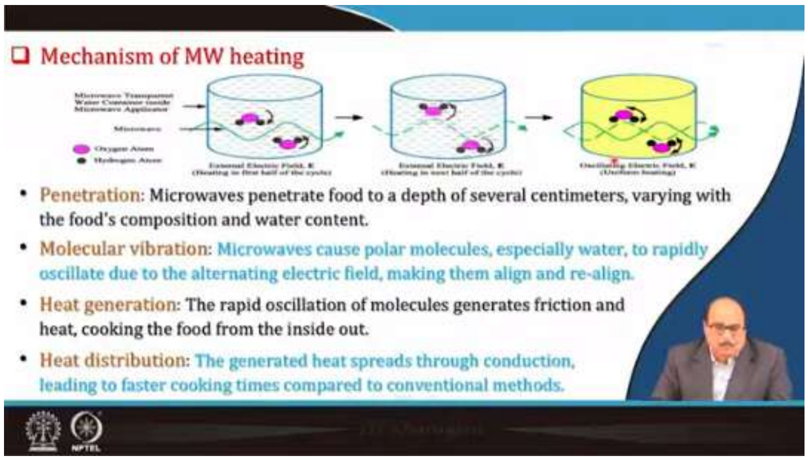
As far as the advantages of infrared heating are concerned, it is a rapid heating process; it heats the food very quickly by directly transferring energy to the food, reducing cooking and processing times. It is an energy-efficient process, minimizing heat loss since it directly heats the food without the need for any heating or surrounding air or other medium for heat transfer. And therefore, it results in uniform heating; it provides even heating. This helps achieve consistent results, especially during baking and other such processes or operations.



Since infrared heating targets the food directly, it often results in less energy waste and reduces heat loss. The disadvantages, however, are that infrared heating mainly affects the food surface, potentially causing uneven cooking if deeper penetration takes too long. So, the equipment cost and the initial investment can be relatively high.

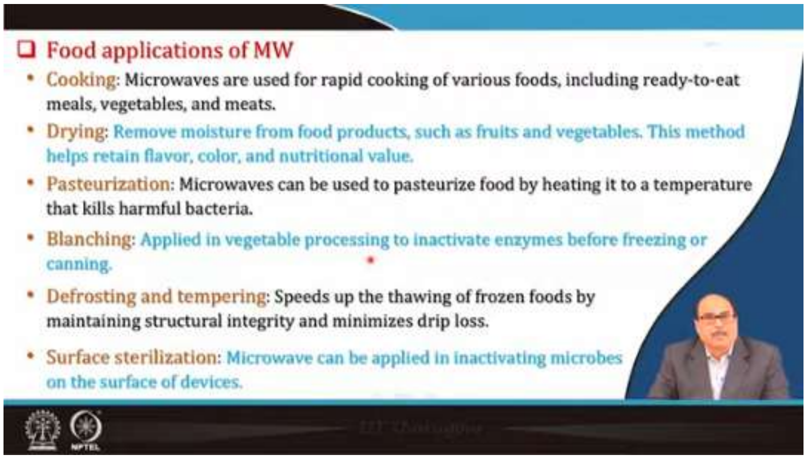


Now, microwave heating. Microwave ovens have become very common in our households as well. So, let us see how it works. So, there is a food chamber, you can say, here in the microwave oven, just to see a chamber where the food is kept. There is an all-right magnetron power supply, and this is the magnetron that produces the microwaves. Then, there is a source that microwaves directly on the food material, and the microwaves penetrate these foods. When they penetrate inside the food, then again, that causes ionization, and this oppositely charged molecule tries to realign to the oppositely charged microwaves, and in the process, there is a molecular movement that causes the frictional heat generation. So, microwave heating uses electromagnetic waves of 2.45 gigahertz for domestic use and 915 megahertz for commercial use to generate heat by causing polar molecules like water to accelerate rapidly. Microwave heating is a commercial food processing technology applied to cook, dry, and temper foods. It is used for pasteurization as well as for sterilization of foods and pasteurization. Microwave heating is used for products with variable density and air voids to avoid differential heating and attain uniform quality. It also helps retain the nutrients in the food and even for the blanching operation. Also, microwaves can be used to deactivate enzymes.

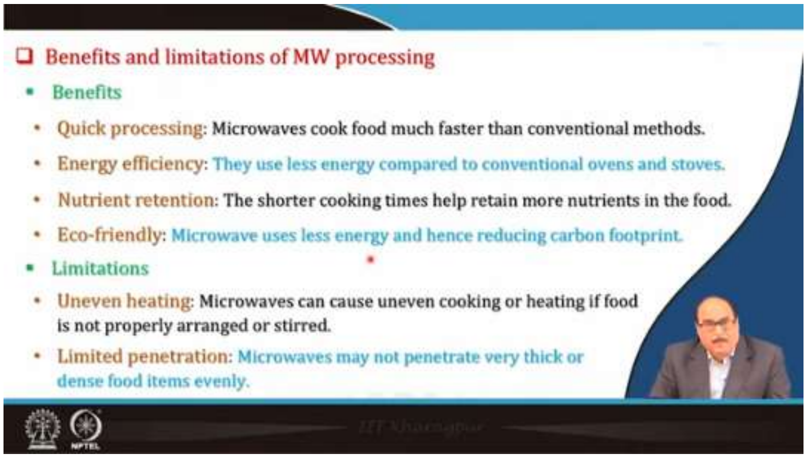


So, the mechanism I already told you how it is happening is that these microwaves penetrate the food to a depth of several centimeters, and this varies with the food's composition and water content. Then these microwaves cause polar molecules, especially water, to rapidly oscillate due to the alternating electrical field, making them align and realign to the oppositely charged field. Then, in this rapid oscillation of molecules, frictional heat is generated, resulting in the cooking of the food material directly. Then, this generated heat spreads through conduction, leading to faster cooking times than conventional methods.

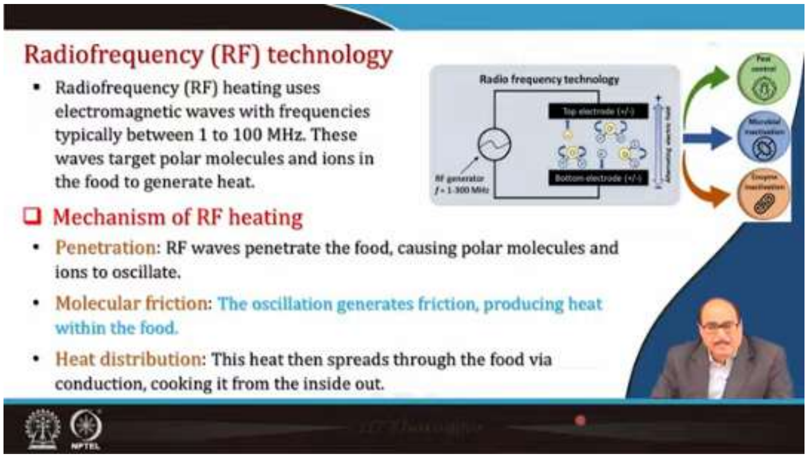
Food applications of microwaves include cooking purposes, which is very common even in households. It rapidly cooks various foods, including ready-to-eat meals, vegetables, meats, etc. It is now microwave drying, also known as microwave drying. That is, microwave and convective air drying are used to remove moisture from food products such as fruits and vegetables, mainly fruits and vegetables with sensitive and high sugar components and cannot be successfully dried using high temperatures.



So, here, microwave and convective air drying provide a positive, reasonable alternative. This technology helps retain flavour, colour, and nutritional value, etcetera, and high-sugar foods can be dried. Microwaves can be used to pasteurize food by heating it to a temperature that kills harmful bacteria. It is applied to vegetable processing to inactivate enzymes before freezing or canning. It can also be used for defrosting and tempering, speeding up frozen foods' thawing while maintaining structural integrity and minimizing drip loss. Microwaves can be applied to inactivate microorganisms on the surface of devices, etcetera.

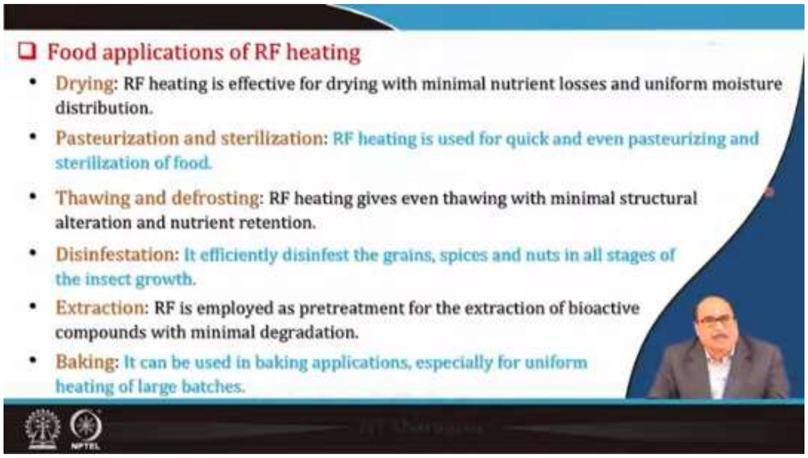


Benefits and limitations of microwave processing: The benefit is quicker processing. It can cook foods much faster than the conventional method. It is an energy-efficient process; it uses less energy than conventional ovens and stoves, resulting in better nutrient retention because of the shorter cooking times; it is an eco-friendly technology in which microwaves use less energy and hence reduce the carbon footprint. The limitation, however, is that uneven heating. Microwaves can cause uneven cooking or heating if the food is not properly arranged or stripped or if it is frozen food and where the ice pockets are of different sizes. So, that may result in uneven things. There is a limited penetration, and microwaves may not penetrate very quickly, especially for dense food items, etcetera. So, that is one major limitation.

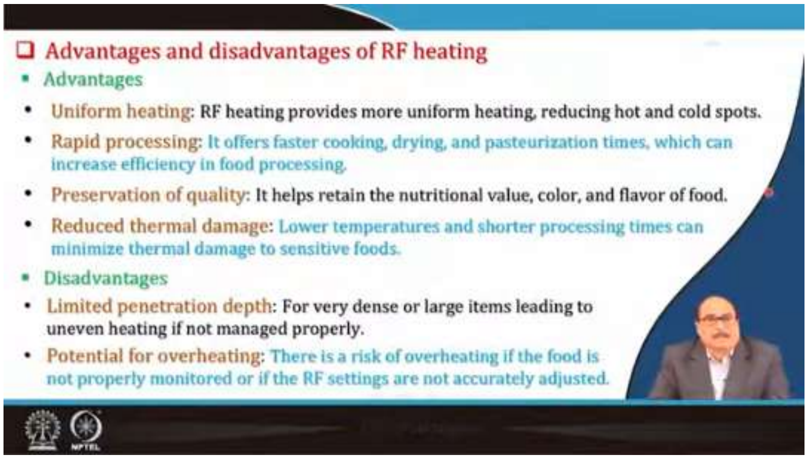


Then let us talk about radio frequency technology. Radiofrequency heating, more popularly known as again RF heating, uses electromagnetic waves with frequencies typically ranging between 1 to 100 megahertz. These waves target polar molecules and ions in the food to generate heat. As you can see here, there is the radio frequency technology that is these are the two electrodes and food material is kept inside the electrodes, and it may result in pest control, microbial inactivation, and enzyme inactivation, and the mechanism is almost similar to that of microwave heating, that is the penetration. Radiofrequency waves penetrate the food, causing polar molecules and ions to oscillate. The oscillation generates friction, producing heat within the food, and then this heat spreads through the food via conduction, cooking it from the inside out. So, it is almost similar to microwaves.

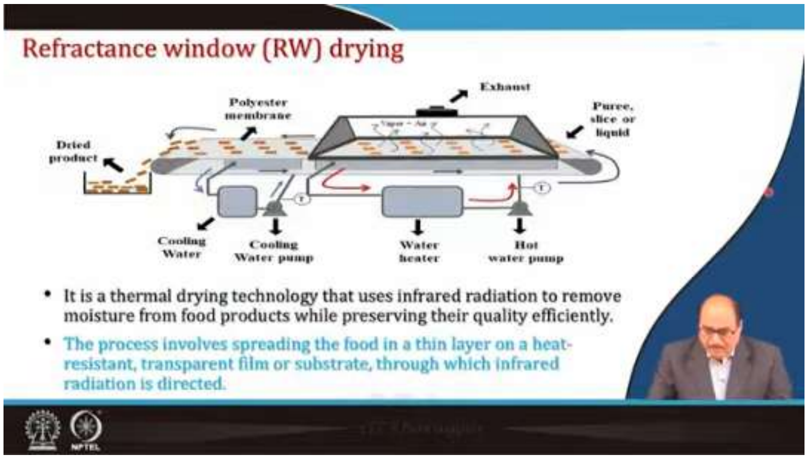
Regarding food application, radio-frequency heating is effective for drying with minimal nutrient losses and uniform moisture distribution. It can be used for quick and even pasteurization and sterilization of food. Radiofrequency heating provides even thawing with minimal structural alteration, ensuring nutrient retention. Its efficiency, or how efficiently it disinfects the grain, is in killing the insects, etcetera. Therefore, it can be used to disinfect grains, spices, and nuts in all the stages of the growth of insects.



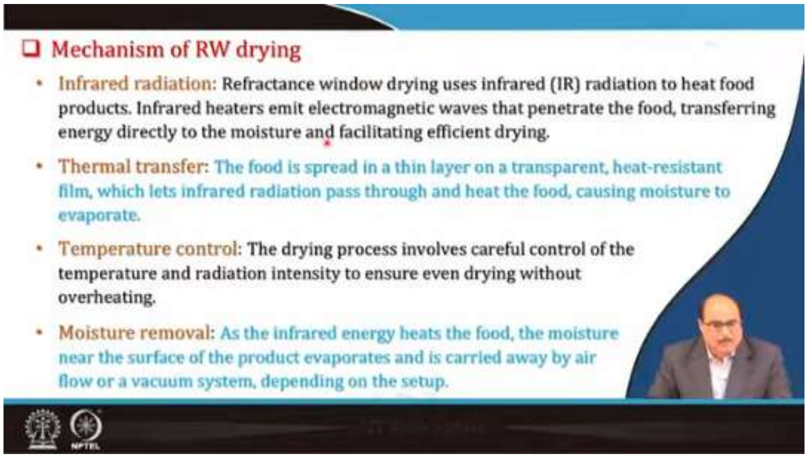
Radiofrequency heating or radio frequency waves are employed as a pretreatment for extracting bioactive compounds with minimal degradation. It can be used in baking applications, especially for uniform heating of large batches, etcetera.



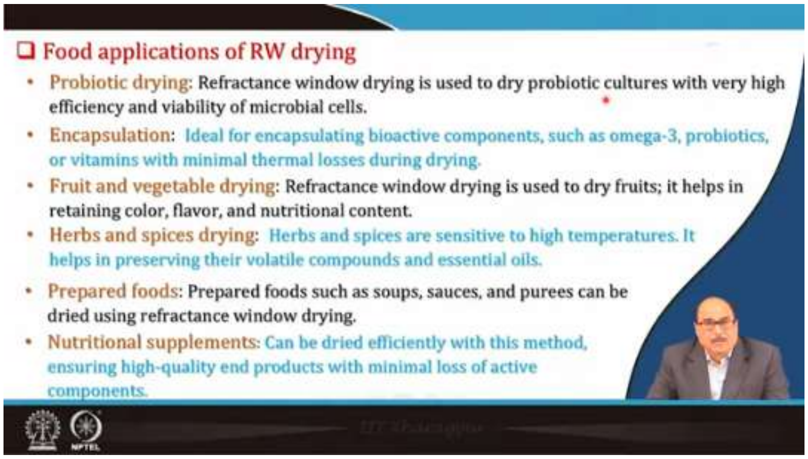
Now, let us talk about the advantages of radio frequency heating. It results in uniform heating, providing more consistent heating and reducing hot and cold spots. It is a rapid process, providing faster cooking, faster drying, and shorter pasteurization times, which can increase efficiency in food processing. Like any other non-thermal process, this alternative thermal process preserves the quality of the food with reduced damage compared to thermal processing. Those damages are not present here due to the lower involvement of temperature and minimum processing times. So, sensitive components, etcetera, are retained to a greater extent. The disadvantages of the radio frequency process relate to limited penetration depth, that is, for very dense and large items, leading to uneven heating if not appropriately managed, then potential for overheating. Overheating is risky if the food is not adequately monitored or the radio frequency settings are not accurately adjusted.



Then, talk about reflectance window drying; RW drying is a thermal or alternate or advanced thermal drying technology that uses infrared radiation to remove moisture from food products while preserving their quality efficiently. The process involves spreading the food on a thin layer; you can say there is a thin layer conveyor belt on a heat-resistant transparent film or substrate through which the infrared radiation is directed. So, here, the material moves, and there is an infrared radiation chamber.

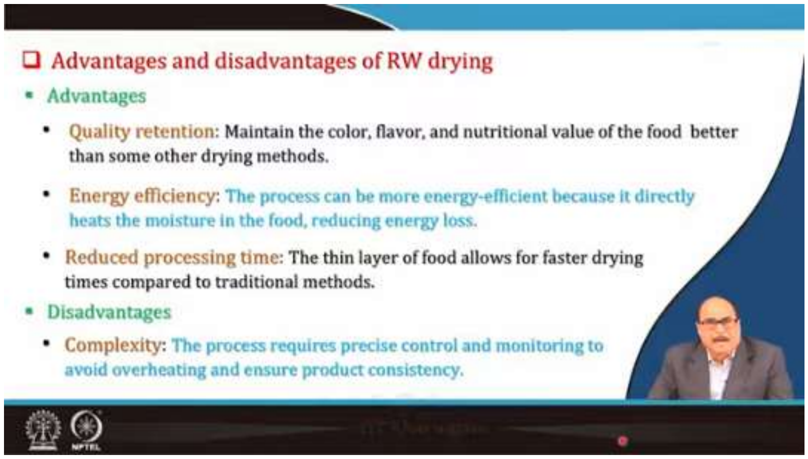


So, the mechanism of reflectance window drying uses infrared radiation to heat food products. Infrared heaters emit electromagnetic waves, as seen in the last figure in the last slide, that penetrate the food, transferring the energy directly to the moisture and facilitating efficient drying. The food is spread in a thin layer on a transparent heat-resistant film, which lets infrared radiation pass through the heat pass through and heat the food, causing moisture to evaporate. The drying process involves careful control of the temperature and radiation intensity to ensure even drying without overheating. So, as the infrared energy heats the food, the moisture near the product's surface evaporates and is carried away by airflow or a vacuum system, depending upon the setup and the instruments, etcetera.

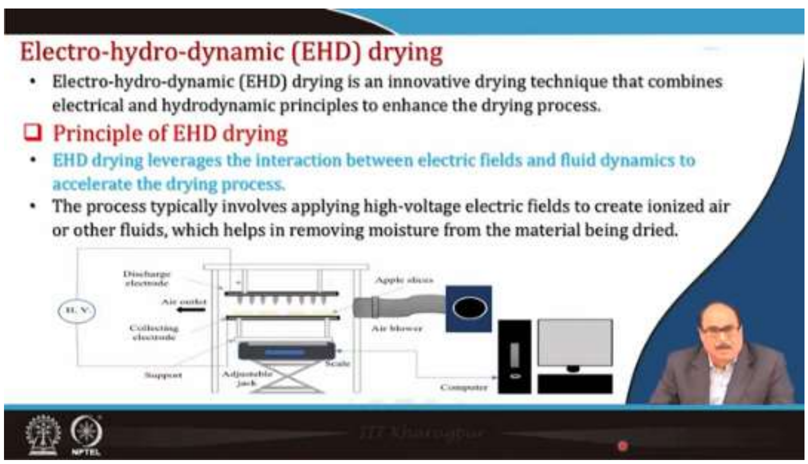


Food applications of the refractive window drying: it can be used efficiently for the drying of probiotic microorganisms, etcetera, like drying to dry probiotic cultures with very high efficiency and viability of microbial cells are used for the encapsulation technology, which is ideal for encapsulating bioactive components such as omega-3 oils, probiotics, or vitamins with minimal thermal losses during drying. It can be used for drying fruits and vegetables and helps retain the colour, flavour, nutritional content, bioactivity, etc., present in the fruits. It can be used for drying herbs and spices because they contain essential oils and other components sensitive to high temperatures. So, this RW drying helps preserve the volatile compounds and essential oils in herbs and spices. Prepared foods such as soups, sauces, and puris can be dried efficiently using reflectance window drying, and nutritional supplements can be dried efficiently with reflectance window drying, ensuring high-quality end products and minimal loss of active components.

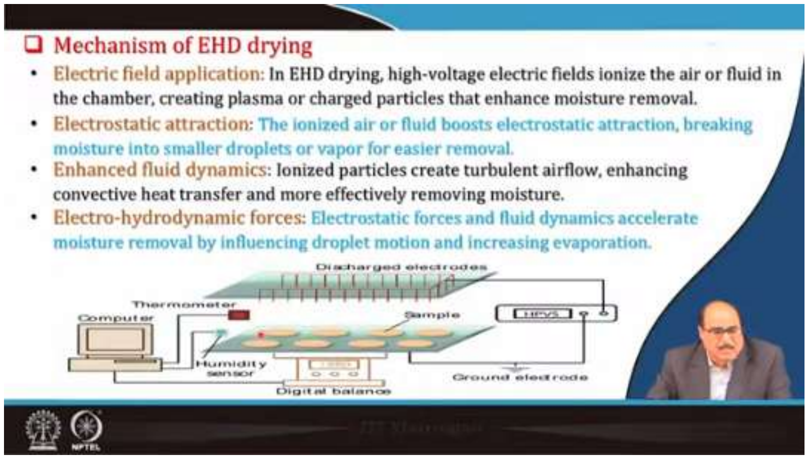
The advantages and disadvantages of reflectance window drying are obvious, like other methods we discussed. It also results in quality retention, maintaining the colour, flavour, and nutritional value of the food better than some other conventional drying technologies.



It has good energy efficiency; the process can be more energy efficient because it directly heats the moisture in the food, reducing energy loss. There is a reduced processing time. The thin layer of food allows for faster drying times than traditional methods. Its disadvantage, however, is the complexity of the process. The process requires precise control and monitoring to avoid overheating and ensure product consistency.

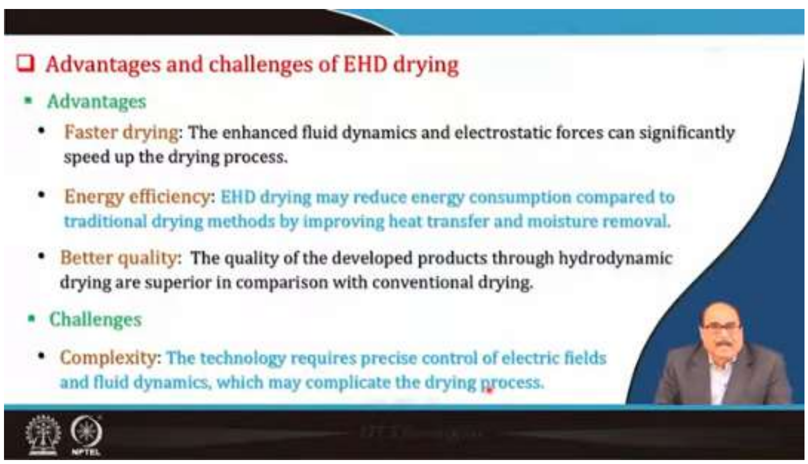


Now, let us talk about electrohydrodynamic drying or EHD drying. So, this electrohydrodynamic drying is an innovative drying technology that combines electrical and hydrodynamic principles to enhance the drying process. So, if you look at the principles of EHD, it leverages the interaction between electric fields and fluid dynamics to accelerate the drying process. The process typically involves applying high-voltage electric fields to create ionized air or other fluids, which help remove moisture from the dried material. You can see a high-voltage power supply system in the figure. And these are the electrodes, etcetera, which are kept here. There is a scalable adjustable jack, and the food material is kept here. There are air blowers. So, the apple slices or other food material is kept. So, electrical energy is passed, and it results in drying.

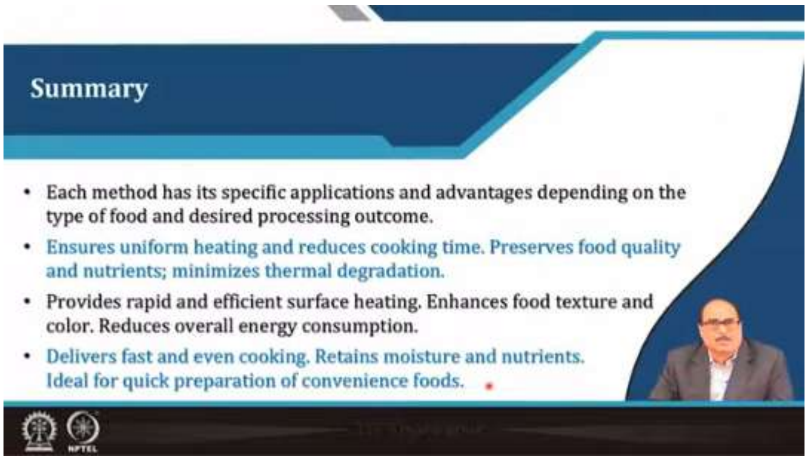


There is a mechanism. If you look here, there is an electric field application in the ESD drying high-voltage electric field. There are the discharge electrode and HVPS (high-voltage power supply) systems. The high-voltage power supply system is there; through it, there are electrodes. The power is given through these electrodes. So, the high-voltage electric fields ionize the air. or fluid in the chamber, creating plasma or charged particles that enhance moisture removal, resulting in an enhanced moisture removal process. Then, there is also electrostatic attraction. There is the ionized air or fluids. boosts electrostatic ready attraction breaking moisture into a smaller droplet for vapour or for easier removal as you can see here in this process this is the here and there may be various sensors like a ground lactose, humidity sensor, temperature sensors, etcetera that can be incorporated into the food to operate the process to control the process correctly. Then, enhanced fluid dynamics, that is, ionized particles, create a turbulent airflow, enhancing convective heat transfer and, more effectively, removing moisture. And then finally, electrohydrodynamic forces, that is, these forces and fluid dynamics, accelerate moisture removal by influencing motion and increasing evaporation. So, there are electric field applications, electrostatic attraction enhanced fluid dynamics and electrohydrodynamic forces. So, these factors result in the final moisture removal from the heated material.

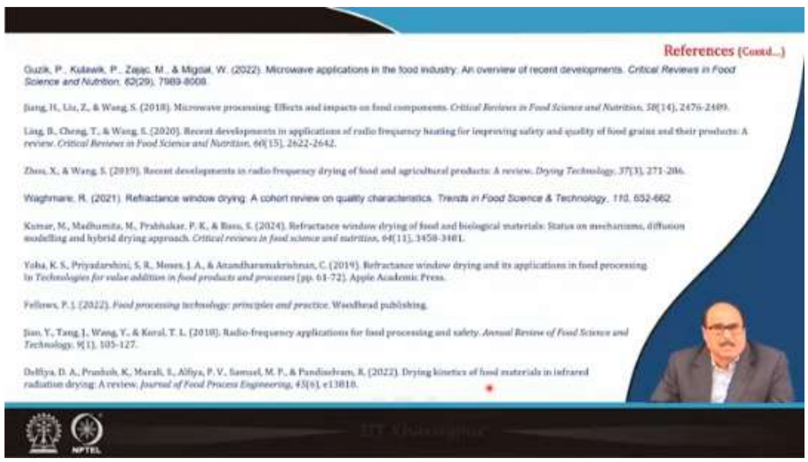
Application of EHD drying: EHD drying can be used to dry fruits and vegetables, which can produce fruit and vegetables more quickly and efficiently compared to the traditional method, and this can help preserve their nutritional value and flavour. Even for herbs and spices, this can be an effective process that often requires careful handling to maintain their essential oils and aroma. So, in meat and fish drying, EHD can provide a faster drying process that can help retain the moisture and taste of the product. Then, for powdered food products, EHD drying can improve the consistency and quality of the material by providing a more uniform drying process.



Regarding the advantages and disadvantages of EHD drying, the advantage is the faster drying process; the enhanced fluid dynamic and electrostatic forces can significantly speed up the drying process. Again, it is also an energy-efficient process, and it may reduce energy consumption compared to the traditional drying method by improving heat transfer and moisture removal and product quality. Drying using this technology results in a good product with superior quality compared to those obtained with conventional drying methods. The challenges, however, are that the technology requires precise control of electrical fields and fluid dynamics, which may complicate the drying process and require a suitable HVPS system and a high-voltage power supply system is required. So, one has to make this process a little complex.



So, finally, I would like to summarize this lecture by saying that each method has its specific application and advantage, depending upon the type of food and the desired processing outcome, that is, whatever method we have discussed here—various alternate thermal technologies, so, if you compare the thermal technologies, non-thermal technologies, and alternate thermal technologies that we have discussed. So, each of them has a specific requirement and outcome, and depending on that, what type of food is more suitable should be chosen. That is, what is the process for which it is being used? What are the characteristics of the food product, etc.? Accordingly, one should choose the process. So, these processes ensure uniform heating, reduce cooking time and preserve food quality. Nutrients, minimize thermal degradation, etcetera. This provides rapid and efficient non-thermal processes, and these advanced and alternate thermal processes result in rapid and efficient surface heating. This non-thermal advanced thermal process, an alternate thermal process, enhances food texture and colour, and reduces overall energy consumption. So, this technology delivers fast food and even cooking, retains moisture and nutrients, and is ideal for quick preparation of convenience foods, etc. Even with some of these, most of the technologies, like microwaves, reflective windows, RF radio frequency drying, etc., are now being commercially used in our country also for various applications for various purposes.



So, these are the references that were used here.

I thank you very much for your patience in hearing. Thank you.