Novel Technologies for Food Processing and Shelf Life Extension

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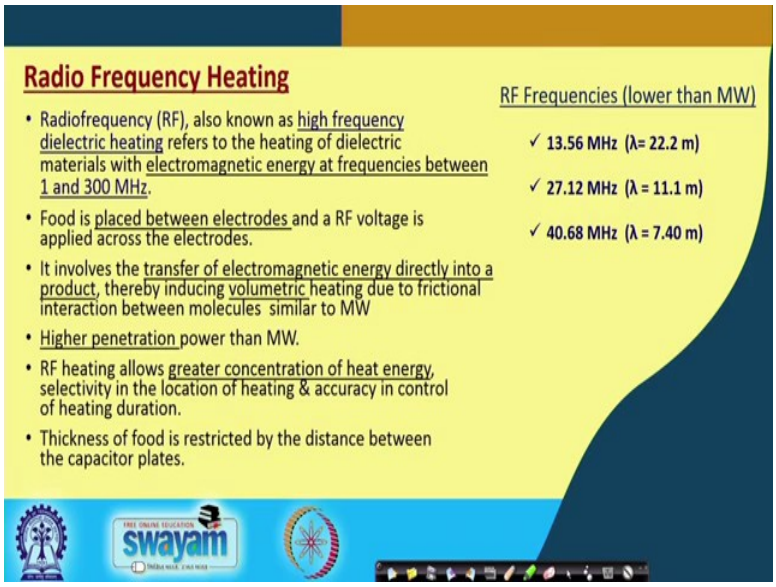
Lecture - 18
Radio Frequency Heating

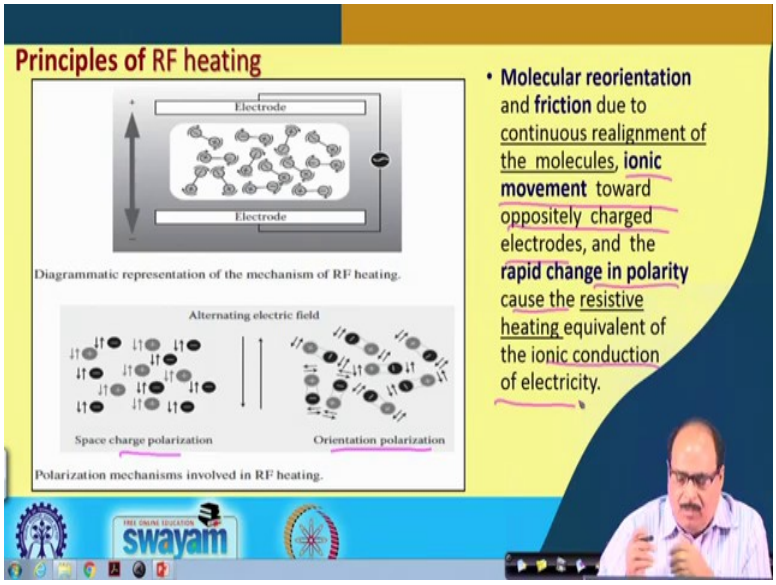
In this lecture, another form of dielectric heating which is radio frequency (RF) heating will be introduced.



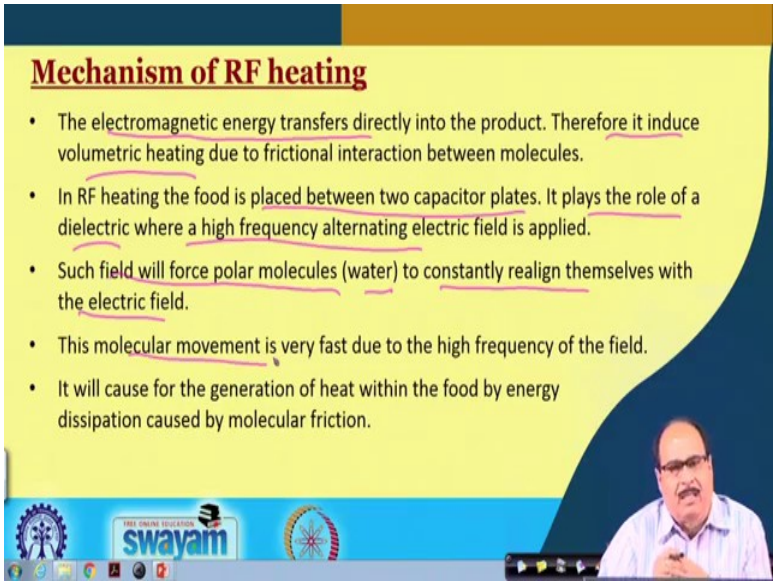
RF heating is also known as high frequency dielectric heating. It refers to the heating of dielectric materials with electromagnetic energy at frequencies between 1 and 300 MHz.

Here in this case, food is placed between electrodes and a radio frequency voltage is applied across the electrode. It involves the transfer of electromagnetic energy directly into the product and thereby it causes volumetric heating which is mainly because of the frictional interaction between the molecules. So, as far as the heating process mechanism is concerned, it is almost similar to that in the microwave, but in the generation, operation, or type of the system, etc., there are certain differences.

It has higher penetration power than microwaves. Radio frequency heating allows greater concentration of heat energy, selectively in the location of heating and accuracy in control of heating duration, it is better than that of the microwave in this aspect. Thickness of the food, however, is restricted by the distance between the capacitor plates.



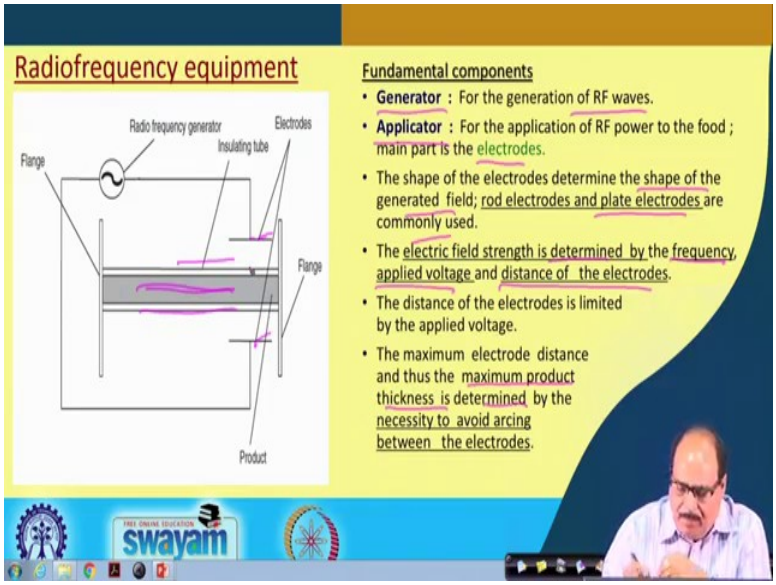
The principle of radio frequency heating is almost similar to that of the microwave heating. Here, space charge polarization or orientation polarization are the phenomena. The molecular re-orientation and friction due to continuous realignment of the molecules or ionic movement towards the oppositely charged electrodes, and rapid change in polarity cause the resistive heating equivalent of the ionic conduction of the electricity.



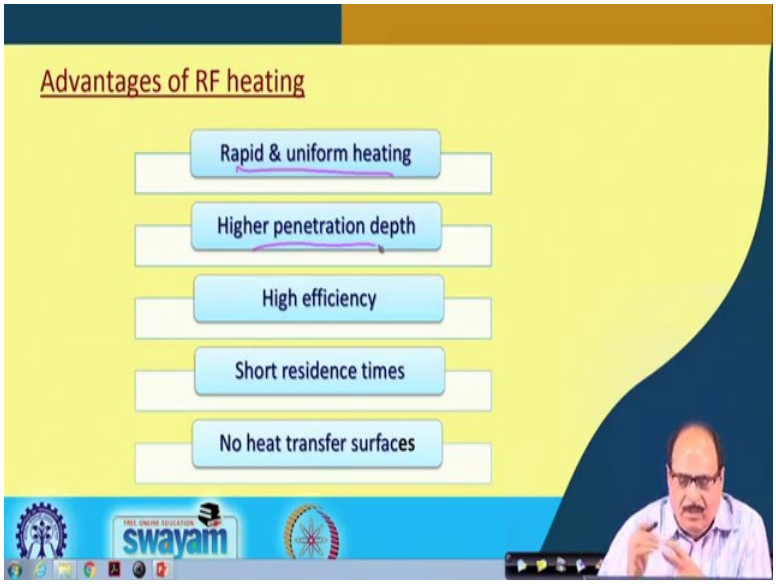
The electromagnetic energy transfers directly into the product therefore, it induces volumetric heating due to the frictional interaction between the molecules.

The food is placed between two capacitor plates and it plays the role of the dielectric where high frequency alternating electric field is applied. In fact, the capacitor plates are the one where the dielectric is applied and energy is passed to the food. Such field will

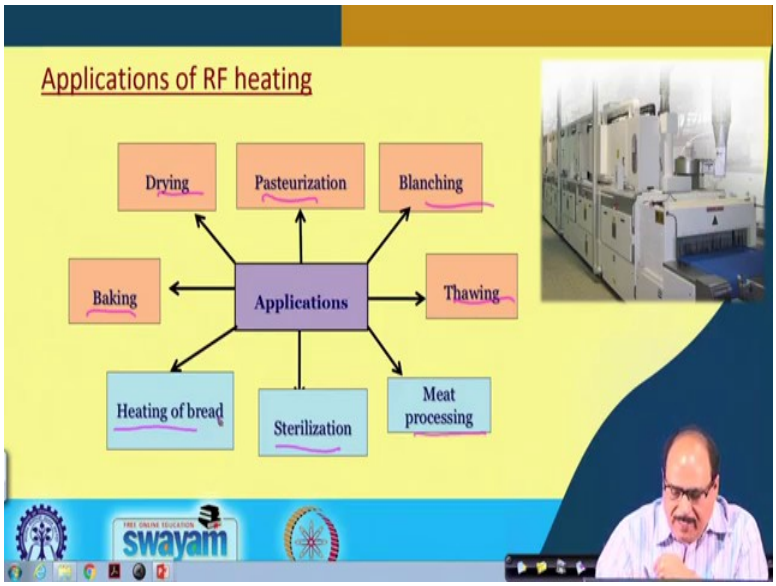
force polar molecule (water) to constantly realign themselves with the electric field and this molecular movement is very fast due to high frequency of the field. And it will cause the generation of heat within the food by energy dissipation caused by the molecular friction. So, this is how the heat is generated inside.



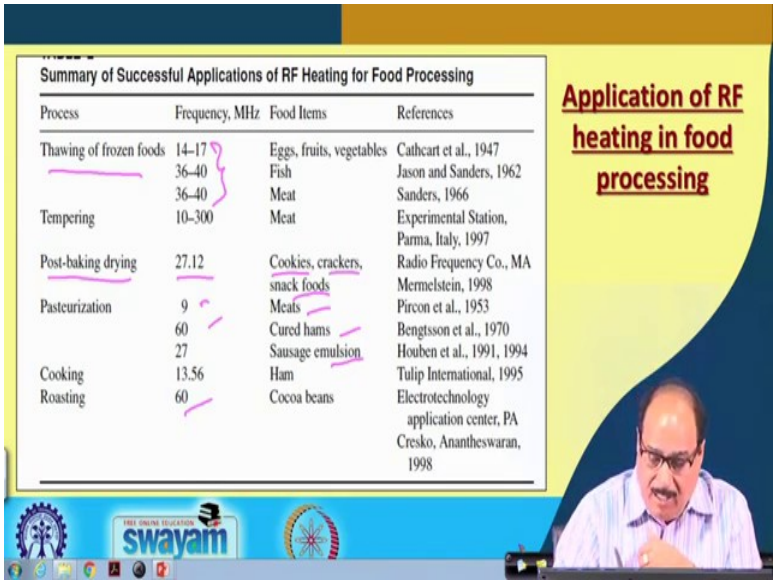
The fundamental components include a generator and an applicator. The generator is mainly for the generation of the radio frequency waves whereas, the applicator is for the application of the RF power to the food and its main part is the electrodes (Refer to the Fig. in the slide). The shape of the electrode determines the shape of the generated field. Rod electrodes and plate electrodes are the common types of electrode which are used in this radio frequency heating. The electric field strength is determined by the frequency, applied voltage and distance of the electrode. The distance of the electrode of course, is limited by the applied voltage; it cannot be kept at a very large distance so that energy can be transmitted. The maximum electrode distance, thus the maximum product thickness is determined by the necessity to avoid arcing between the two electrodes. So, these are the considerations for deciding the heating potential of the process.



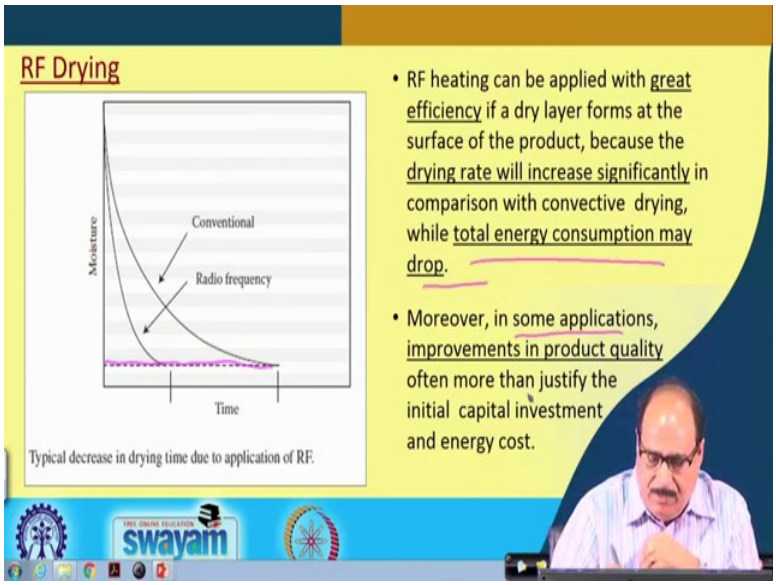
RF heating like micro heating has several advantages, it results in rapid and uniform heating process, it has a higher penetration depth, high efficiency, it results in short residence times and involvement of no heat transfer surfaces. So, it generally results into better quality products and more efficient processes.



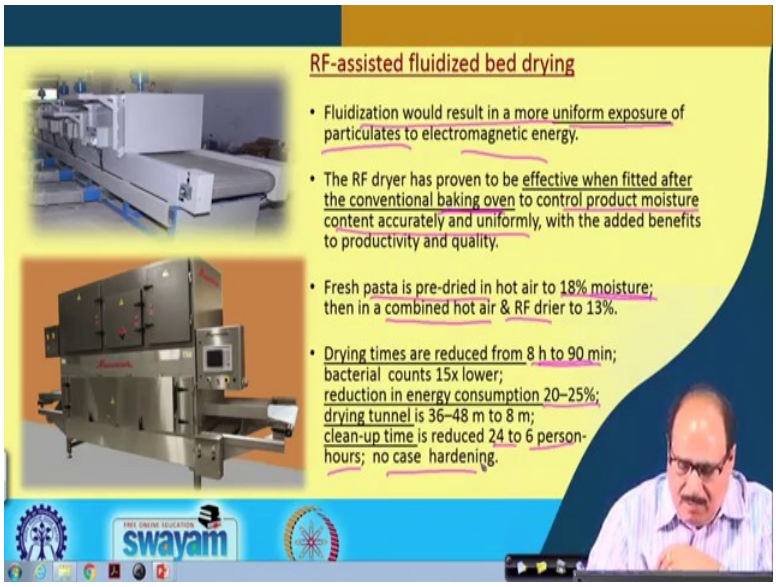
It can be applied extensively in various food process operations for preservation purposes, for preparation of products, and for improvement in the quality and process efficiency. It has common applications like in any other heat process, it can also be used for drying purposes, pasteurization, blanching, thawing, meat processing, sterilization, baking or even toasting of the bread, etc.



In the table, some literature reports show the successful applications of radio frequency heating in food processing. For thawing of the frozen foods, the frequencies ranging between 14 to 40 MHz have been applied on various products like egg, fruit, vegetable, fish, meat etc. For tempering of the meat, radio frequency in the range of 10-300 MHz has been applied. For post baking drying of the bakery products, around 27 MHz has been applied successfully, in cookies, crackers, snack, foods etc. For pasteurization of meat, cured ham, sausages, emulsion, etc., the RF ranging from 9-60 MHz has been used. For cooking purposes, in the case of ham around 14 MHz frequency is used. Electro technology application center have reported a range of 60 MHz for roasting of cocoa bean. So, these data show that RF heating can be successfully applied for different food processing operations.



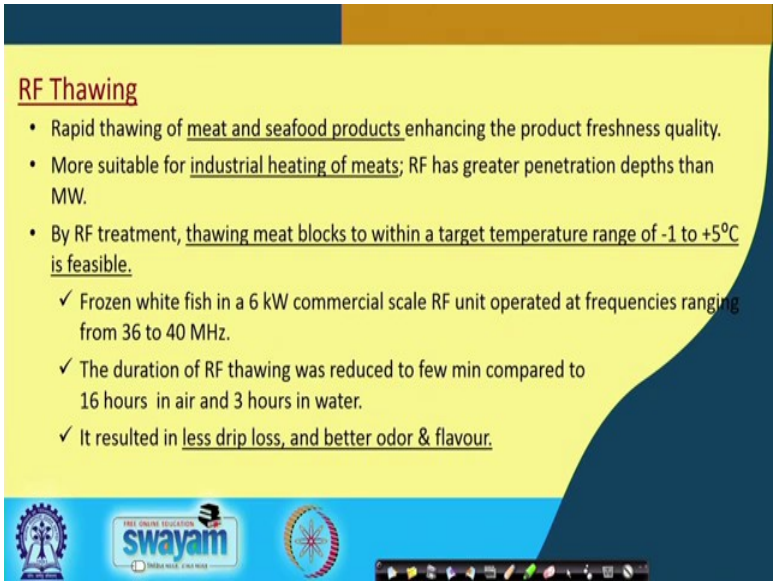
In figure, a typical decreasing drying time curve is shown. It can be seen here that the time required in radio frequency heating to remove the same level of moisture content is reduced to more than 2 - 3 times. Drying rate is increased significantly in comparison with the conventional drying processes and of course, the drying time is reduced. So, it can be the desired operation for drying, as it results in energy saving and process efficiency improvement. Moreover, in some applications it improves the product quality and the degree of improvement in the product quality actually justifies the involvement of little higher cost or capital investment.



Another interesting application of radio frequency is the radio frequency assisted fluidized bed drying. Fluidization would result in more uniform exposure of particulates to electromagnetic energy. Some fluidized based RF drying systems are shown in these pictures. The radio frequency dryer has proven to be effective when it is fitted in the baking line after the conventional baking ovens. This controls the moisture of the product more accurately, and more uniformly, and which gives the added benefits to the product quality.

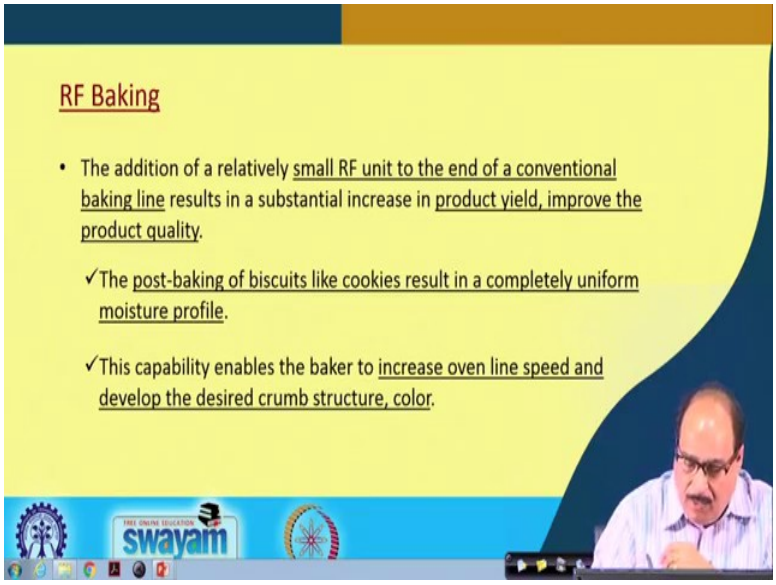
Fresh pasta is pre-dried in hot air to 18% moisture content and then it can be sent to the combined system, where both hot air as well as RF are available for drying. So, moisture content is brought down to 13% in the second stage. It has been found that the quality and characteristics of pasta are improved significantly.

Few researches have come up with the results, suggesting that drying times are reduced from 8 h to 90 min, bacterial counts reduced by 15 times. There is reduction in energy consumption to the tune of 20 to 25%, drying tunnels may be reduced from 36 - 48 m to 8 m, clean up time is reduced from 24 to 6 person hours, no case hardening in the product. This has been a better and efficient process.

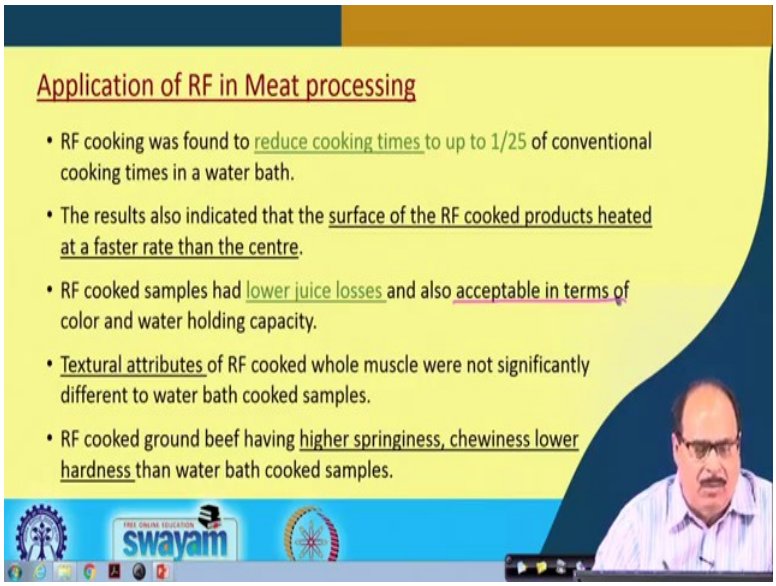


Radiofrequency assisted thawing becomes a rapid means of thawing of meat and sea foods. It enhances the product freshness and quality; it is more suitable for industrial heating of meats. Radio frequency has greater penetration depth than the microwave. By suitable RF treatment, thawing of meat block to within a target temperature range of -1 to +5 °C is feasible i.e. without much increase in the temperature of the muscle, thawing is possible.

In some experiments, when the frozen white fish was thawed in a 6 kW commercial scale RF unit operated at frequencies ranging from 36 to 40 MHz, the duration of RF heating was reduced to few min compared to 16 h in air based thawing system or 3 h in water based thawing system. This radio frequency thawing resulted in less drip loss and better odour and flavor.

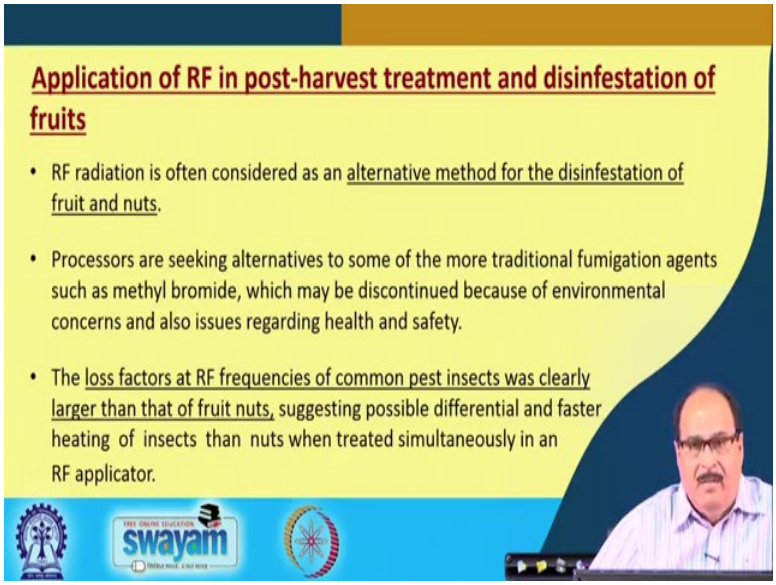


Radio frequency heating has a good application in baking industry. The addition of a small RF unit to the end of conventional baking line results in substantial increase in the product yield and improves the product quality. The post baking of biscuits like cookies etc. results in uniform moisture profile in the product. This capability enables the baker to increase the oven line speed and develop the desired crumb structure and even desired color, texture in the products.



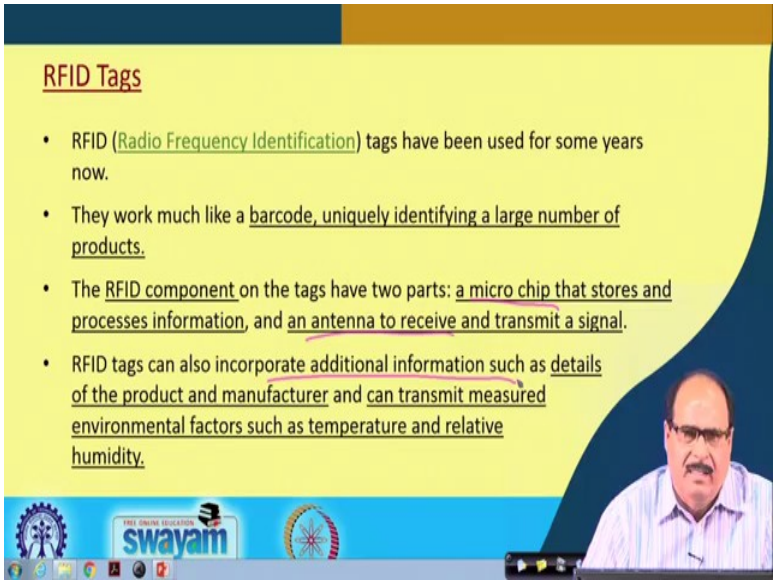
It has good application in meat processing as explained earlier. It reduces cooking times up to 1/25th of the conventional cooking times in a water bath. Results also indicated that the surface of the RF cooked products is heated at a faster rate than the centre. The RF cooked samples had lower juice losses and better acceptability in terms of colour,

water holding capacity, etc. The textural attributes of the RF cooked whole muscle meat are significantly better than that of the water bath cooked samples. The RF cooked ground beef had higher springiness, chewiness, lower hardness than that in the water bath cooked samples.



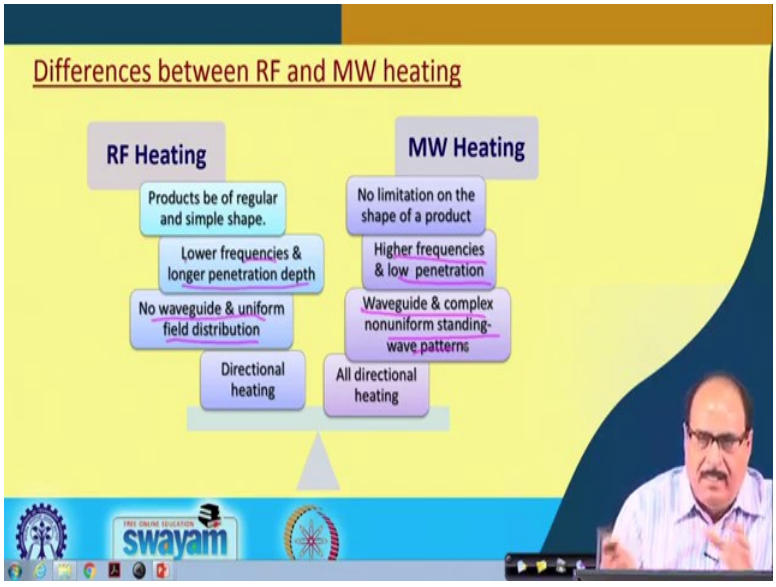
Similarly, it can be used for the post-harvest treatment and dis-infestation of fruits. Several results indicate that the insects can be easily killed by the RF heating, and therefore, they can be used for increasing the shelf life of the grains. They can be used for fumigation of all those commodities which are likely to be spoiled by the infestation. The better application will be the dried fruits that sometime support the growth of insect in it. So, the processors in fact, are seeking alternative to some more traditional fumigation agents. So, here this RF heating provides an alternative source.

The loss factors at RF frequencies of common pest, insects are larger than that of the fruit nut. So, it shows that without causing the heating of the fruit nut, one can kill the insect and then it becomes a good preservation without destroying its bioactive.

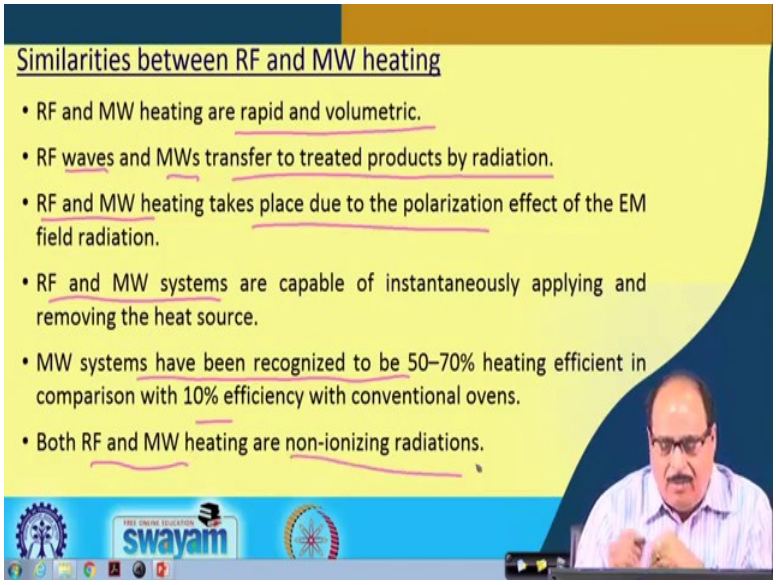


RFID tags have wide ranging application not only in food processing industry but also in other industries. Radio frequency identification tags work much like a barcode or uniquely identify a large number of products. The RFID component of the tag has two parts: a microchip that stores and processes the information, and an antenna which receives and transmits a signal. They can incorporate additional information like details of the product, and manufacturer, they can transmit the measured environmental factors such as temperature, relative humidity, etc. They can be used for tracing the products and recording the information. So, for various useful operations, this can be used in different food processing industries.

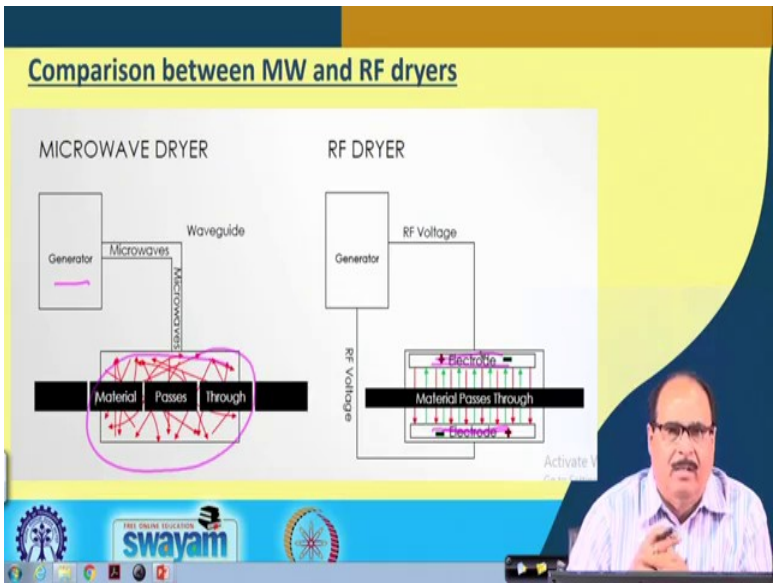
The RFID tag has the potential to increase efficiency of operations, improve asset visibility, traceability, decrease reliance on manual processes, reduce operational cost and provide useful data for business analytics. And in fact, theoretically it is possible to trace the product back all the way of every raw material that went into the product, what are the characteristics, all these things might be possible by application of the RFID.



Comparison between RF and microwave (MW) heating: The RF heating product should be of regular and simple shape whereas, in the case of MW heating, there is no limitation of the shape of the product. In RF heating, normally lower frequencies and longer penetration depth are there; in the microwave, higher frequencies and lower penetration depth are involved. In case of RF heating, no wave guide and there is uniform field distribution, in the case of MW heating, there is wave guide and complex non-uniform standing wave patterns. RF heating is normally a unidirectional heating, and microwave is an all-directional heating.

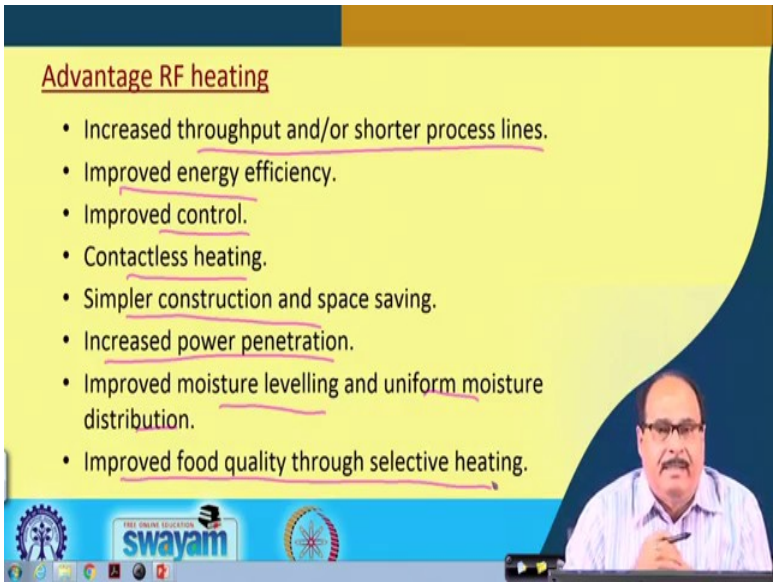


Also, there are similarities between radio frequency and microwave heating. RF and MW heating both are rapid and volumetric. Radio frequency waves and microwaves are transferred to treated products by radiation. Both RF and MW heating take place due to the polarization effect of the electromagnetic field radiation. Both RF and MW systems are capable of instantaneously applying and removing the heat source. Microwave systems have been recognized to be 50 to 70% heating efficient in comparison with 10% heating efficiency with the conventional ovens. Both MW and RF heating are non-ionizing radiations.



It is a pictorial comparison between the microwave and radio frequency dryers. MW dryer has a generator and through this, microwaves are generated with the help of

waveguide and they are passed to the material and thus internal heating is created. Whereas, in the case of RF dryer, there is an RF generator, the RF voltage is passed through the two electrodes and the food is held between these two electrodes. So, it is electromagnetic radiation which enters into the food and then it gets heated internally. So, this shows the clear-cut differentiation between the working principles of these two processes.



Radio frequency heating is advantageous in many ways; it results in increased throughput and shorter process lines. It has improved energy efficiency, improved control, and is a contactless heating. The equipment is simpler in construction, and provides space saving. It has increased power penetration, improved moisture leveling, uniform moisture distribution, and improved food quality through selective heating. So, the best thing is that the quality of the heated processed products can be maintained.

So, both the radio frequency heating and microwave heating can be used for various purposes in the food industry. They can be used successfully with the advantages to both industry and the consumer. They can be used for processing, improving product quality, extending the shelf life of the food materials, value addition to the product, improving the process efficiency and so on. However, the equipment etc. should be properly designed and properly constructed and these processes need to be applied with the caution.