Post Harvest Operations and Processing of Fruits, Vegetables, Spices and Plantation Crop Products
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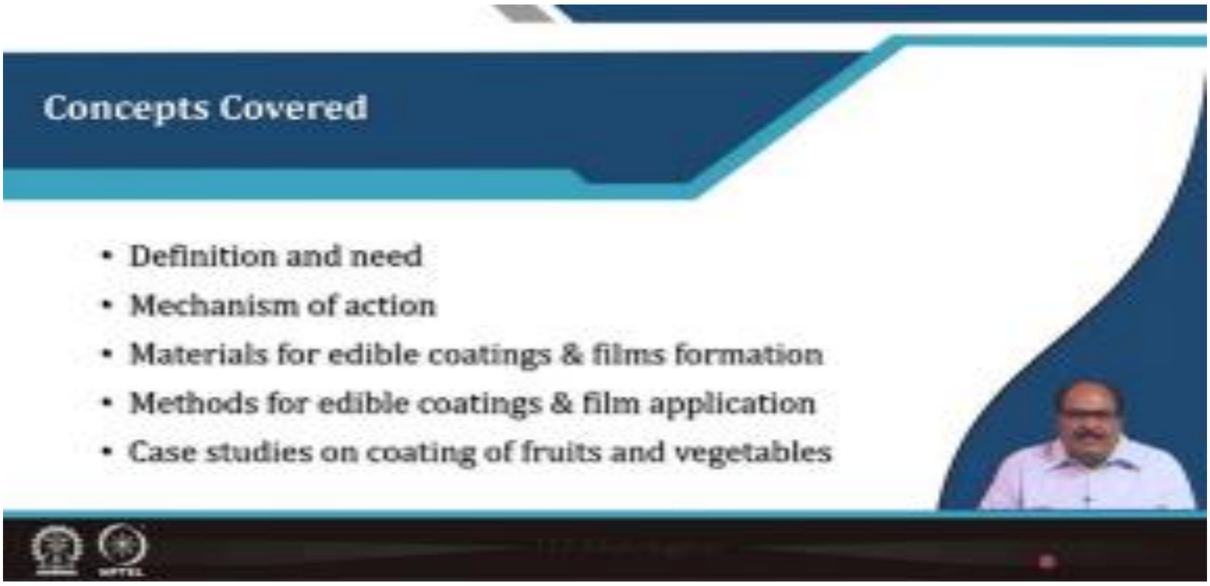
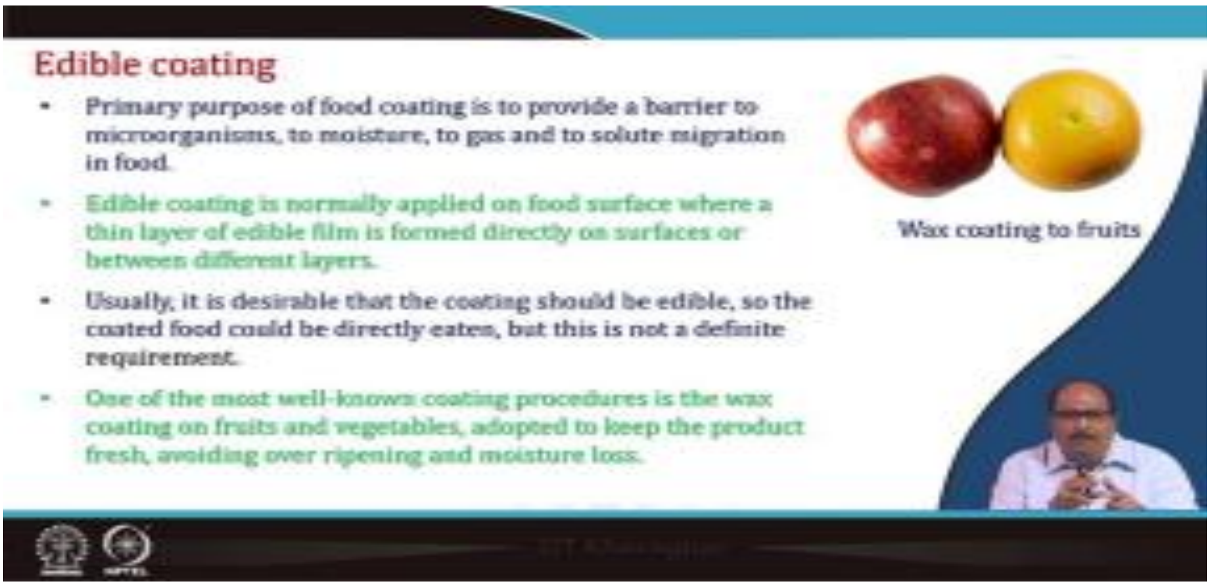
Lecture 53

Edible coatings & films



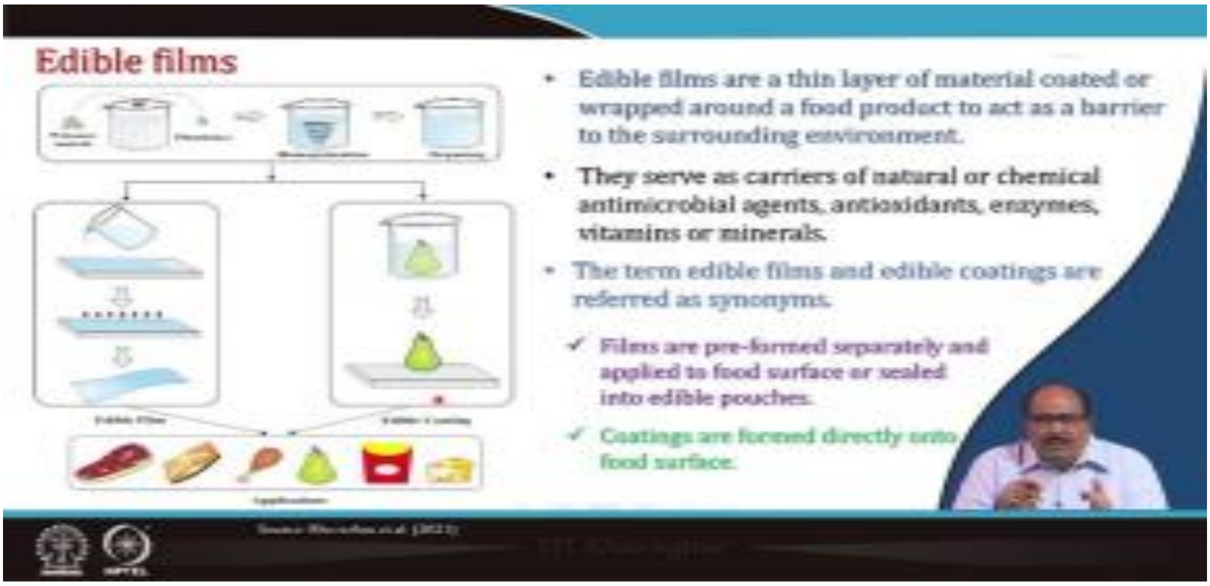
The concepts covered in this lecture are definition of edible coatings and the need for such packaging, its mechanism of action, materials used for formation of coatings and films, and methods of coating and film application. Finally, few case studies of coating of fruits and vegetables edible coating is discussed.

Edible coating



Primary purpose of food coating is to provide a barrier to microorganisms, to moisture, to gas and to solute migration in food. Edible coating is normally applied on food surface where a thin layer of edible film is formed directly on surfaces or between different layers. Usually, it is desirable that the coating should be edible, so the coated food could be directly eaten, but this is not a definite requirement. One of the most well-known coating procedures is the wax coating on fruits and vegetables, adopted to keep the product fresh, avoiding over ripening and moisture loss.

Edible films



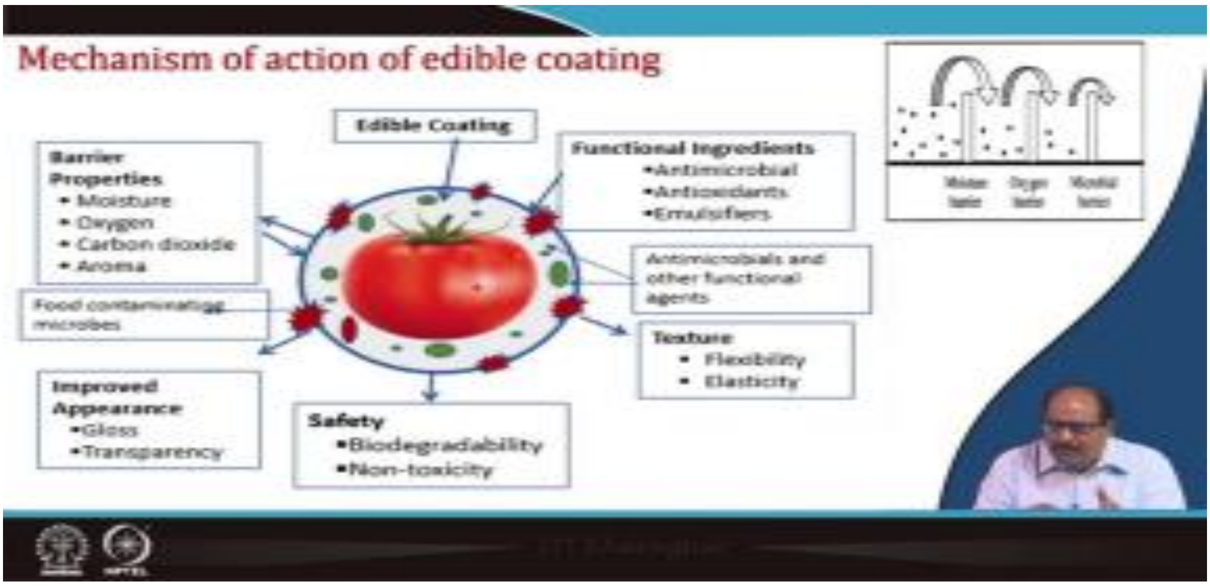
Edible films are a thin layer of material coated or wrapped around a food product to act as a barrier to the surrounding environment. They serve as carriers of natural or chemical antimicrobial agents, antioxidants, enzymes, vitamins, or minerals. The term edible films and edible coatings are referred as synonyms. Films are pre-formed separately and applied to food surface or sealed into edible pouches. Coatings are formed directly onto food surface.

The figure provided shows that edible polymer matrix and plasticizer are blended and homogenized and degassed. The mixture is poured on a thin plate or surface and dried. The thin edible film obtained can be used for wrapping of meat, fruits and vegetables. Other process is to directly dip the product in the homogenized mixture to form a coating on the product.

Edible coating and film uses

Edible coating and film could be consumed along with the packed food. It is a green technology as it reduces environmental pollution. It extends the self-life of the food by the inhibition of the microbial growth, and by the improvement of the quality of food system. It controls the diffusion rate of preservative substances from the surface to the interior of the food. It preserves bioactive nutrients and inhibits oxidation by inhibition of gas transfer. It preserves phytochemicals (texture, color) and organoleptic properties of food. It protects probiotic bacteria viability. It could be used as carrier for anti-microbial or anti-oxidant agents. It could be used in multilayer food packaging materials.

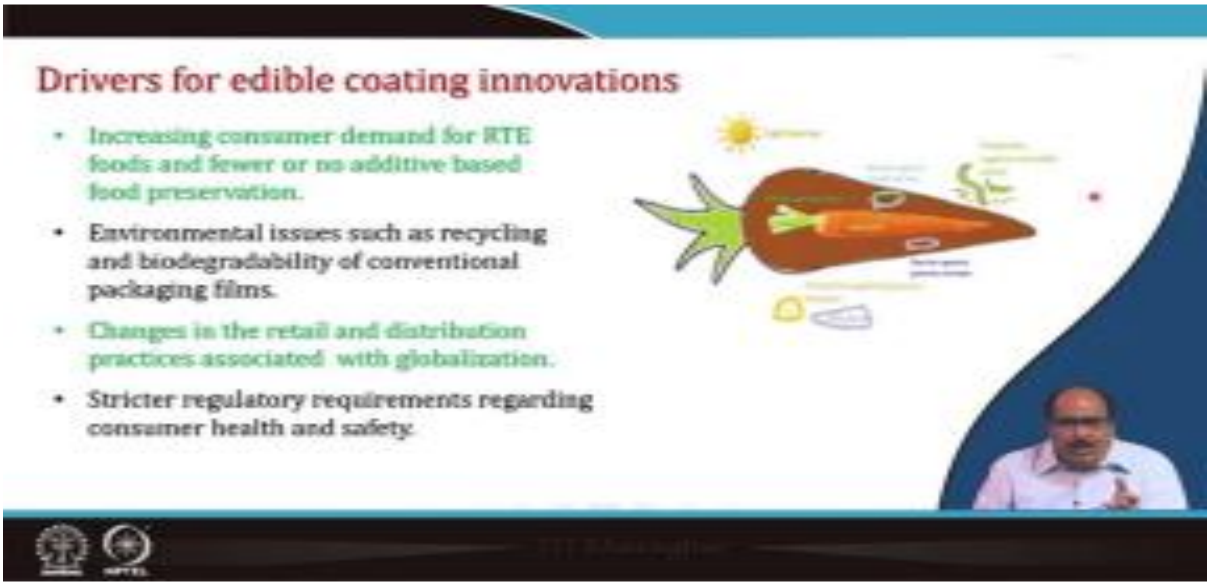
Mechanism of action of edible coating



The thin layer of edible coating is made on the surface of the tomato by wrapping and sealing or by using appropriate method direct very thin transparent film is made on it. Edible coating provides barrier properties against moisture, oxygen, carbon dioxide, aroma, etc. It protects the product against contaminating microbes. It improves the appearance of the produce by providing gloss to the product. The film could carry functional ingredients such as antimicrobial, antioxidants and emulsifiers. It could improve the texture by providing flexibility and elasticity. The edible films are safe, bio-degradable, and nontoxic.

Thus, the main mechanism of action of the edible film is to provide barrier property against moisture, oxygen, and microbial agents. It regulates the in and out of gases from the food and into the food thereby, it controls the undesirable reactions, processes even including respiration and the self-life of the food is increased.

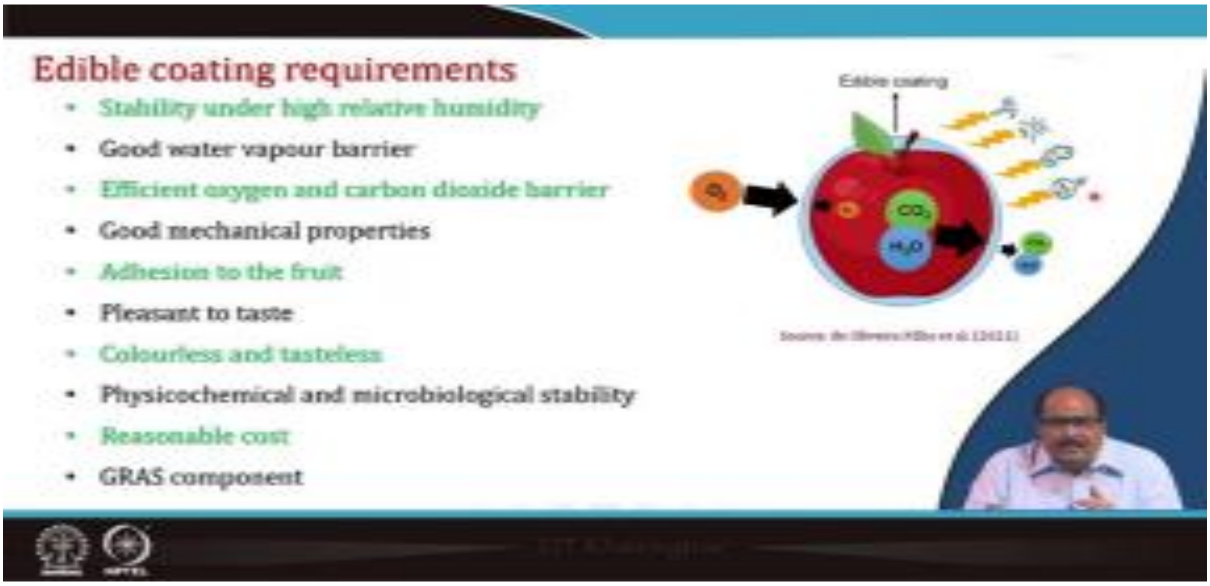
Drivers for edible coating innovations



The drivers for the edible coating innovations include increasing consumer demand for RTE foods and fewer or no additive based food preservation. Environmental issues such as recycling and biodegradability of conventional packaging films. Changes in the retail and distribution practices associated with globalization. Stricter regulatory requirements regarding consumer health and safety.

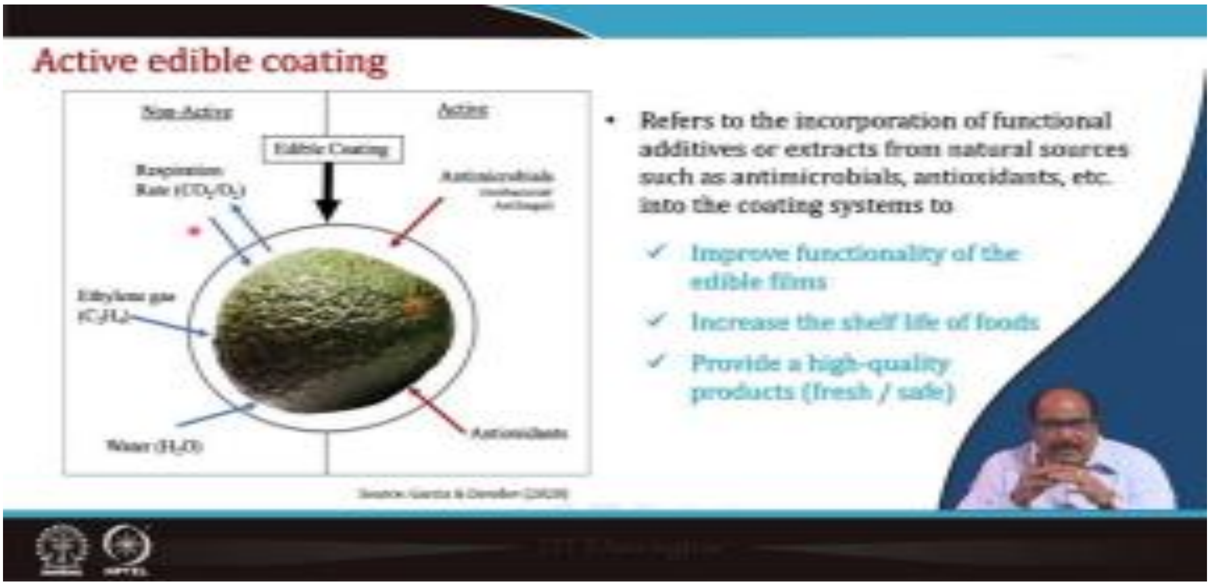
Edible coating requirements

The requirements of the edible coating films are that it should have stability under high relative humidity. It should have good water vapor barrier properties, efficient oxygen and carbon dioxide barrier properties and should have good mechanical properties. It should have better adhesion to the fruit.



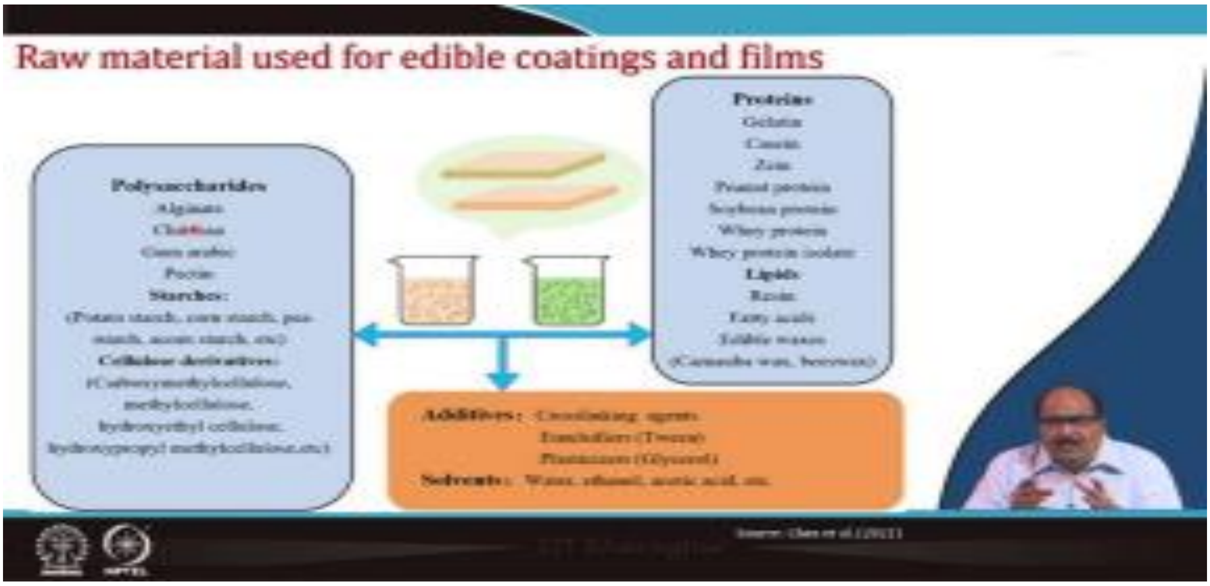
The edible coating should be pleasant to taste and should not interfere with the organoleptic property of the food produce. It should be colorless, and tasteless. It should have physiochemical and microbiological stability. The cost should be economical, viable, and cheaper. The material used should have GRAS status.

Active edible coating



The active edible coating refers to the incorporation of functional additives or extracts from natural sources such as antimicrobials, antioxidants, etc. into the coating systems to Improve functionality of the edible films increase the shelf life of foods, provide a high-quality product (fresh / safe). The non-active coating as shown in the figure provides barrier properties alone such as controls respiration rate by allowing oxygen and carbon dioxide transfer, ethylene gas transfer and prevents transfer of water vapor. The active coating along with providing barrier properties, also contains actives such as antimicrobials like antibacterial and antifungal components and antioxidant additives.

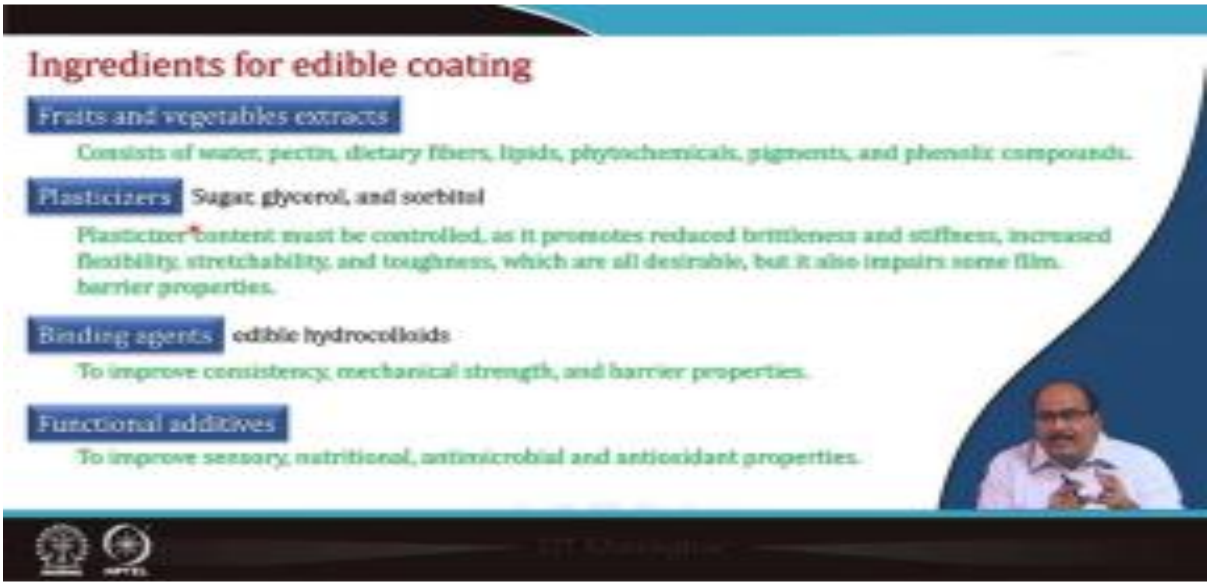
Raw materials used for edible coatings and films



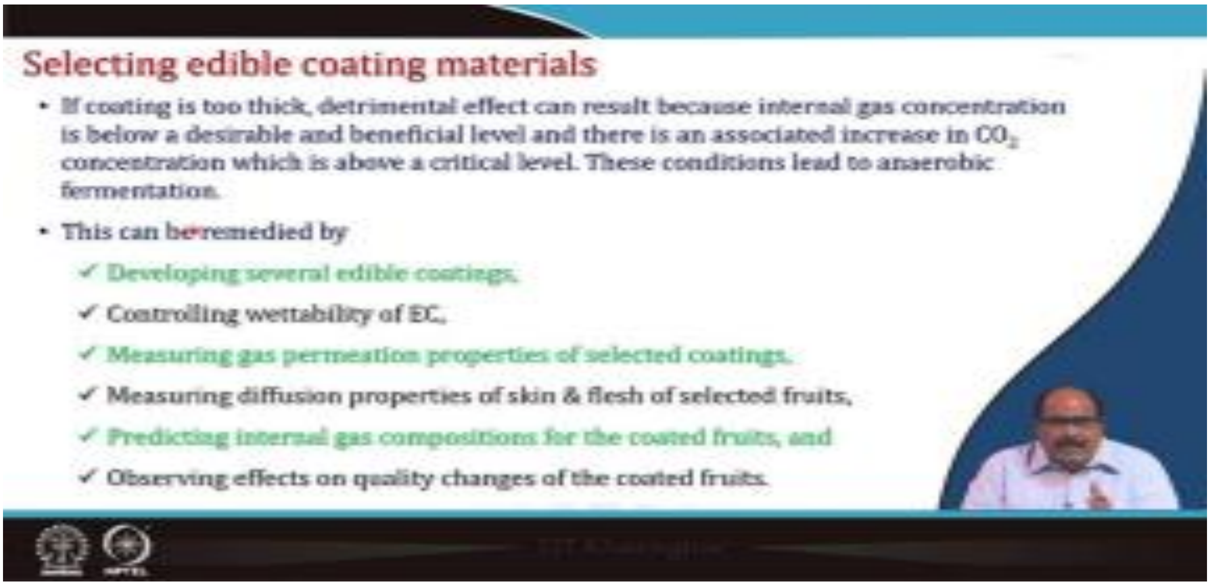
Raw materials that are used for making coatings and films may be polysaccharides, protein, or lipids. The polysaccharides used may be alginate, chitosan, gum arabic, pectin etc. It also includes starches like potato starch, corn starch, pea starch, acorn starch etc. The cellulose derivatives such as carboxymethylcellulose, methyl cellulose, hydroxyethyl cellulose, hydroxy methylcellulose, etc are also used. In case of protein-based coatings or films, proteins like gelatin, casein, zein, peanut protein, soyabean protein, whey protein and whey protein isolate are used. Lipids like resins, fatty acids, edible waxes such as carnauba and bees wax are also used as coating material. Additives like crosslinking agents, emulsifiers (Tween) and plasticizers like glycol are used to get a stable emulsion with the solvents. The solvents used are water, ethanol, acetic acid, etc.

Ingredients for edible coating

The ingredients may be a fruit or vegetable extract, which consists of water pectin, dietary fibre, lipids, phytochemicals, pigment, and phenolic compounds. Plasticizer like sugar, glycerol, and sorbitol. Plasticizer content must be controlled, as it promotes reduced brittleness and stiffness, increased flexibility, stretchability, and toughness, which are all desirable, but it also impairs some film. barrier properties. Binding agents like edible hydrocolloids are used to improve consistency, mechanical strength, and barrier properties. Functional additives are used to improve sensory, nutritional, antimicrobial and antioxidant properties.



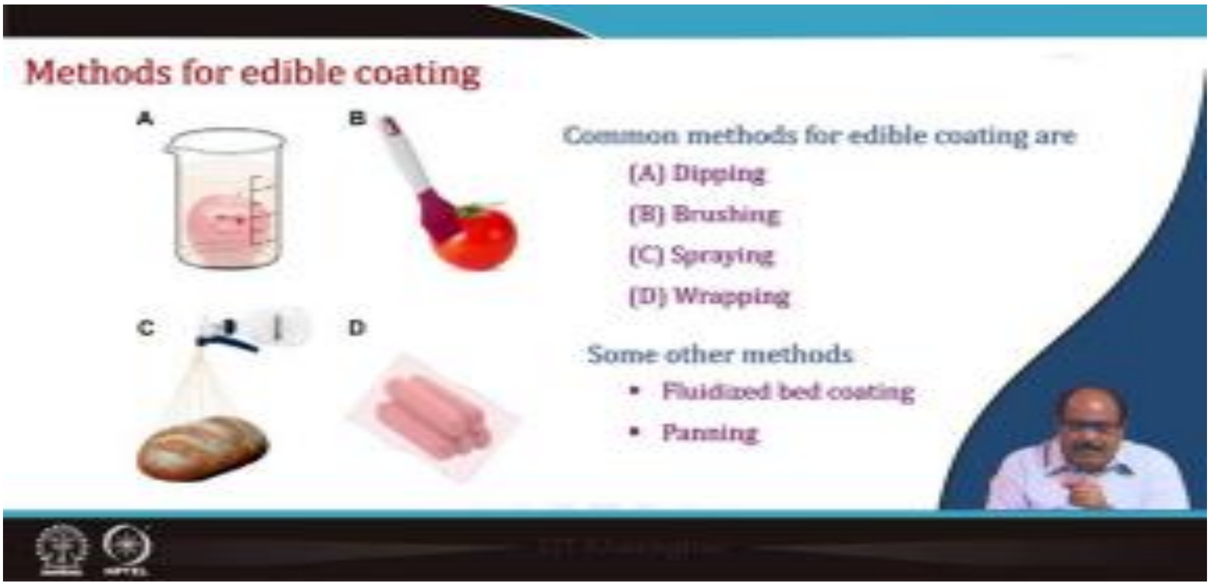
Selecting edible coating materials



If coating is too thick, detrimental effect can result because internal gas concentration is below a desirable and beneficial level and there is an associated increase in CO_2 concentration which is above a critical level. These conditions lead to anaerobic fermentation.

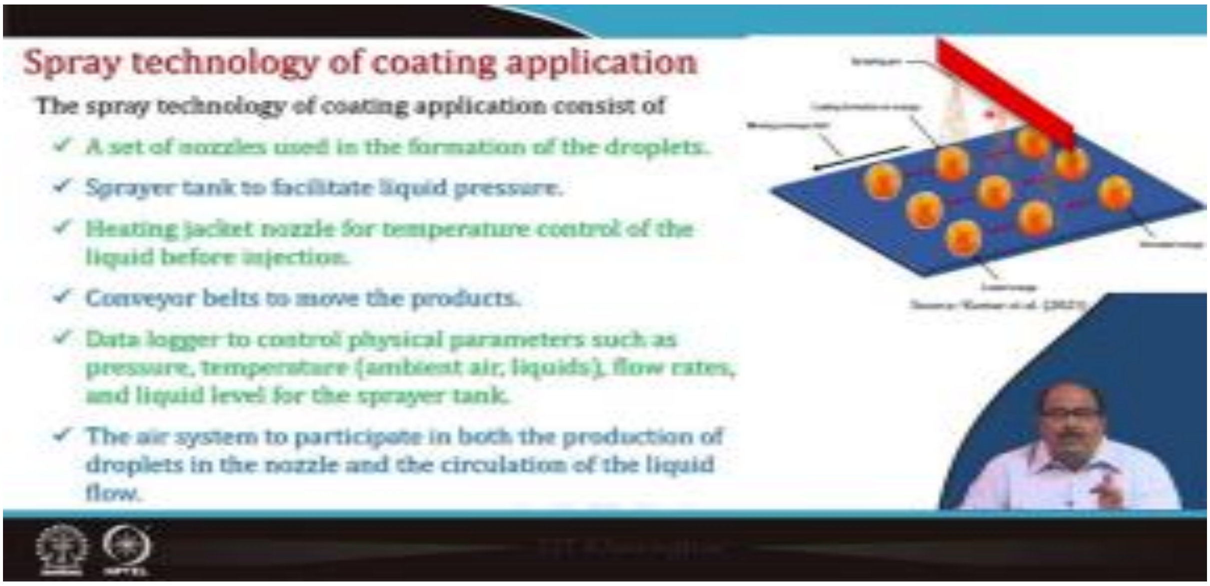
This can be remedied by developing several edible coatings, controlling the wettability of the edible coating, measuring gas permeation properties of selected coatings, measuring diffusion properties of skin & flesh of selected fruits in which coating is to be applied, predicting internal gas compositions for the coated fruits and finally, observing effects of this coating on quality changes of the coated fruits and vegetables.

Methods for edible coating



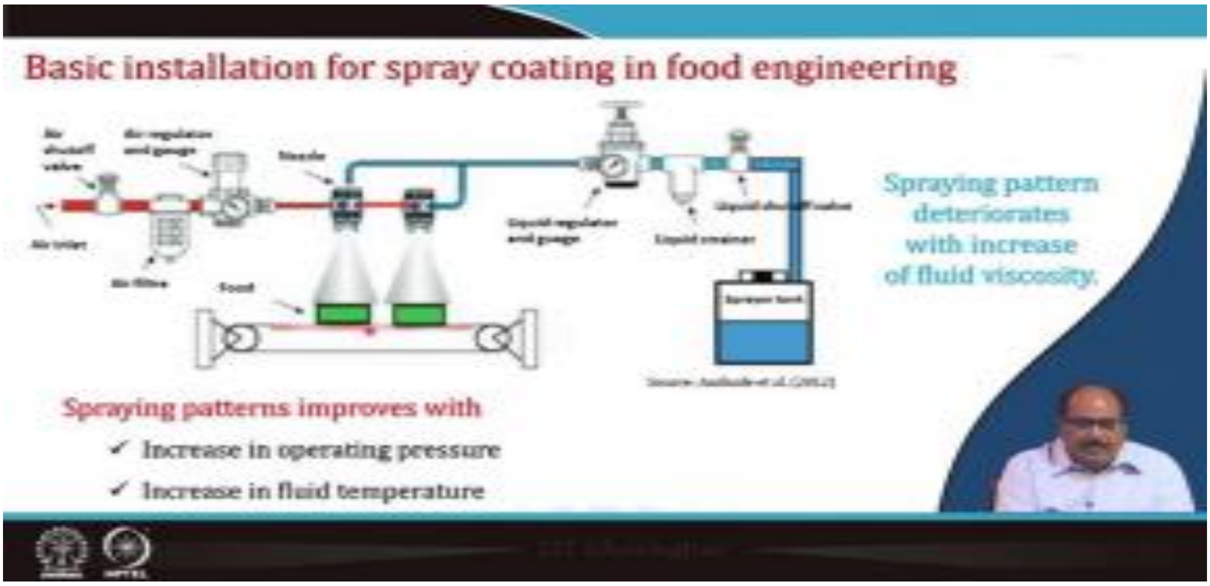
The common methods used for edible coating are dipping, brushing, spraying, or wrapping. Some other methods like fluidized bed coating as well as pan coating or panning are also used. The process of dipping, brushing, spraying, and wrapping are shown in the figures provided.

Spray technology of coating application



The spray technology of coating application consists of a set of nozzles used in the formation of the droplets, sprayer tank to facilitate liquid pressure, heating jacket nozzle for temperature control of the liquid before injection, conveyor belts to move the products, data logger to control physical parameters such as pressure, temperature (ambient air, liquids), flow rates, and liquid level for the sprayer tank. The air system to participate in both the production of droplets in the nozzle and the circulation of the liquid flow. The figure shows the coating of orange by spraying. The uncoated oranges are passed under spray gun through a conveyor. As it passes under the spray gun, its sprayed and coated with the edible film coating.

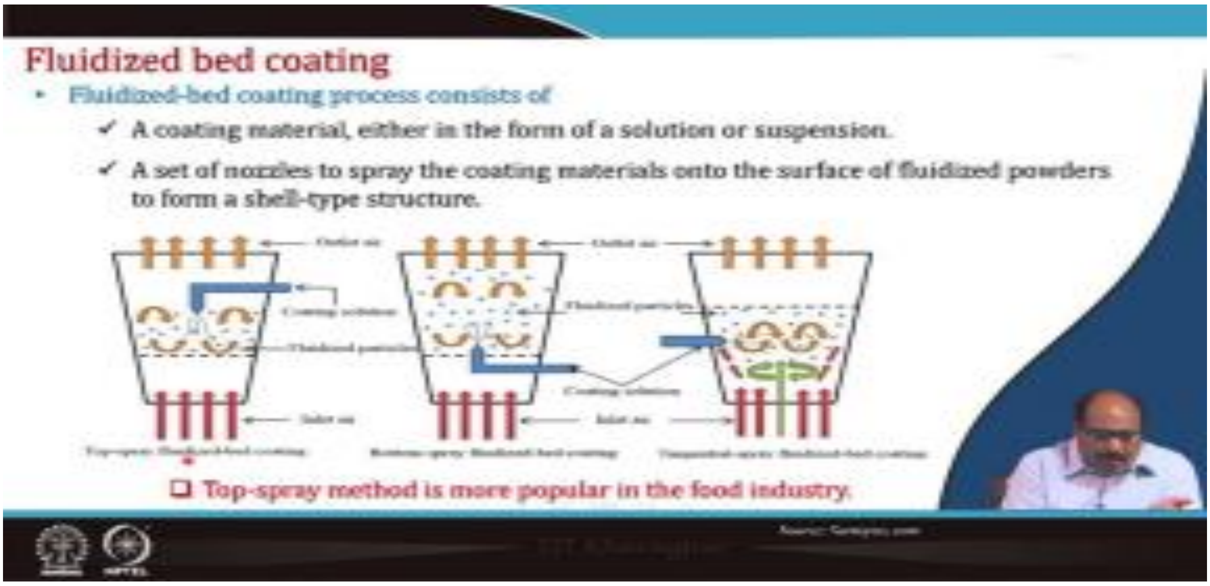
Basic installation for spray coating in food engineering



The figure provided shows the basic installation for spray coating system. The figure shows a sprayer tank with the homogenized emulsion to form the coating material. The material is pumped into the spray nozzle via liquid shutoff valve, liquid strainer and liquid regulator and gauge. A a calculated and controlled amount of the emulsion flows to the sprayer nozzle, through this nozzle it is sprayed over the food material on a conveyor belt. To ensure uniform coating of the food products the spray system consists of air shutoff valve and air regulator gauge. The air enters through the air inlet and filtered before entering the nozzle. Spraying pattern improves with increase in operating pressure and fluid temperature, while it deteriorates with increase of fluid viscosity.

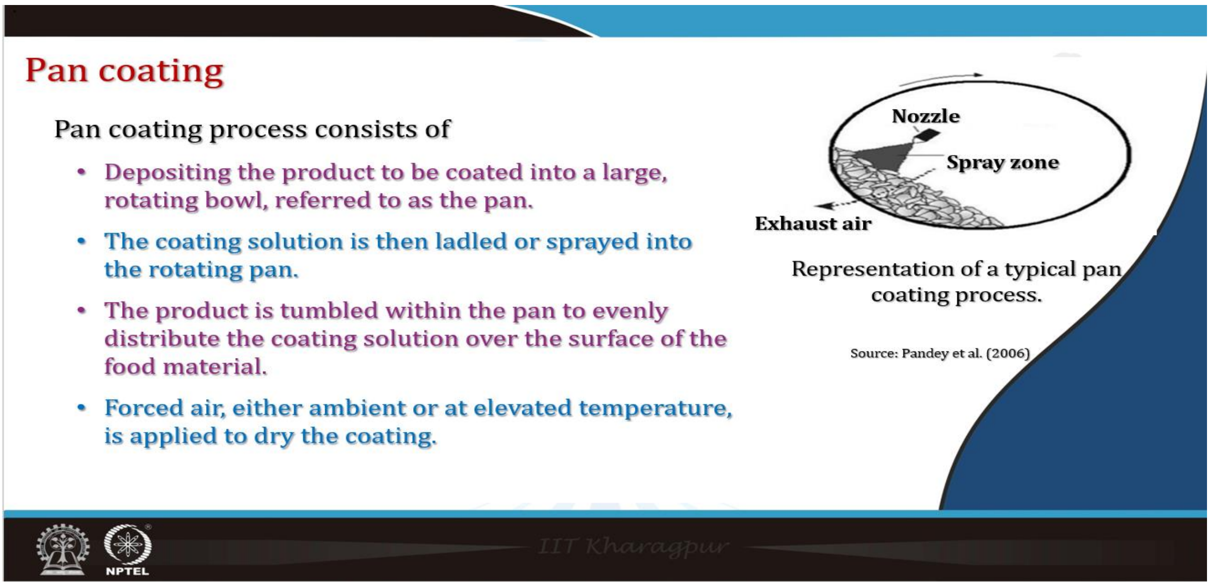
Fluidized bed coating

Fluidized-bed coating process consists of a coating material, either in the form of a solution or suspension, a set of nozzles to spray the coating materials onto the surface of fluidized powders to form a shell-type structure. The figure shows the types of fluidized bed coating, that are top spray fluidized bed coating, bottom spray fluidized bed coating, and tangential spray fluidized bed coating.



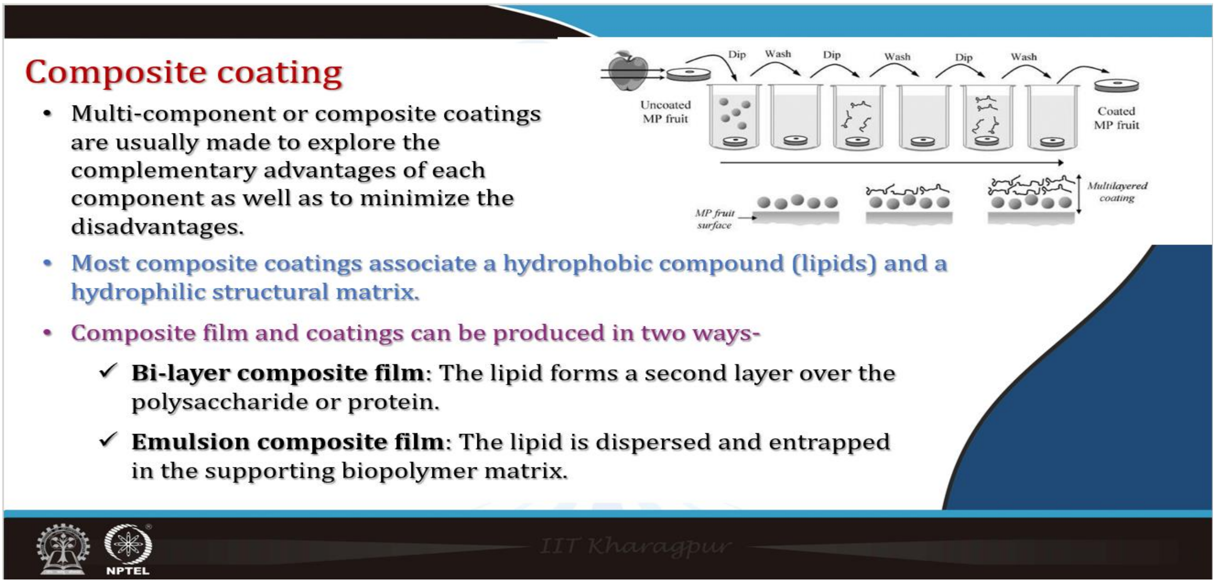
In case of top spray dried fluidized bed coating, the fruits, or vegetables, which is to be coated is fluidized in the air and coating solution is spread from the top. In case of the bottom and tangential fluidized bed coating, the coating material is applied from middle and from a tangential direction, respectively. Top spray method is more popular in food industry.

Pan coating



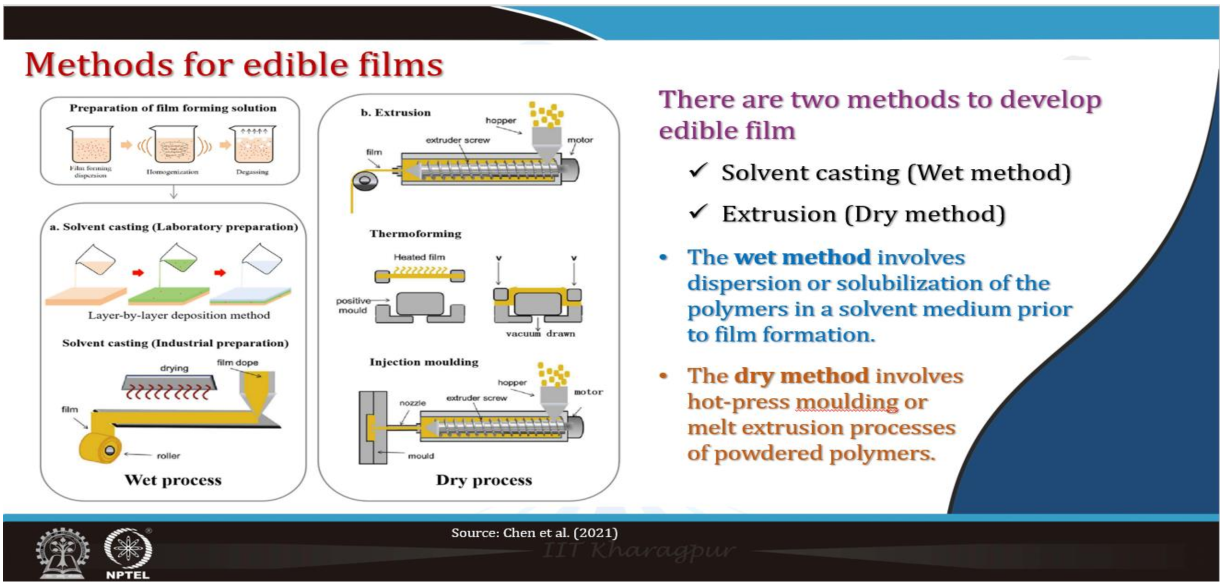
Pan coating process consists of depositing the product to be coated into a large, rotating bowl, referred to as the pan. The coating solution is then ladled or sprayed into the rotating pan. The produc t is tumbled within the pan to evenly distribute the coating solution over the surface of the food material. Forced air, either ambient or at elevated temperature, is applied to dry the coating. The figure provided shows representation of a typical pan coating process. The nozzle is used to spray the coating material inside the pan and excess air removed via air exhaust.

Composite coating



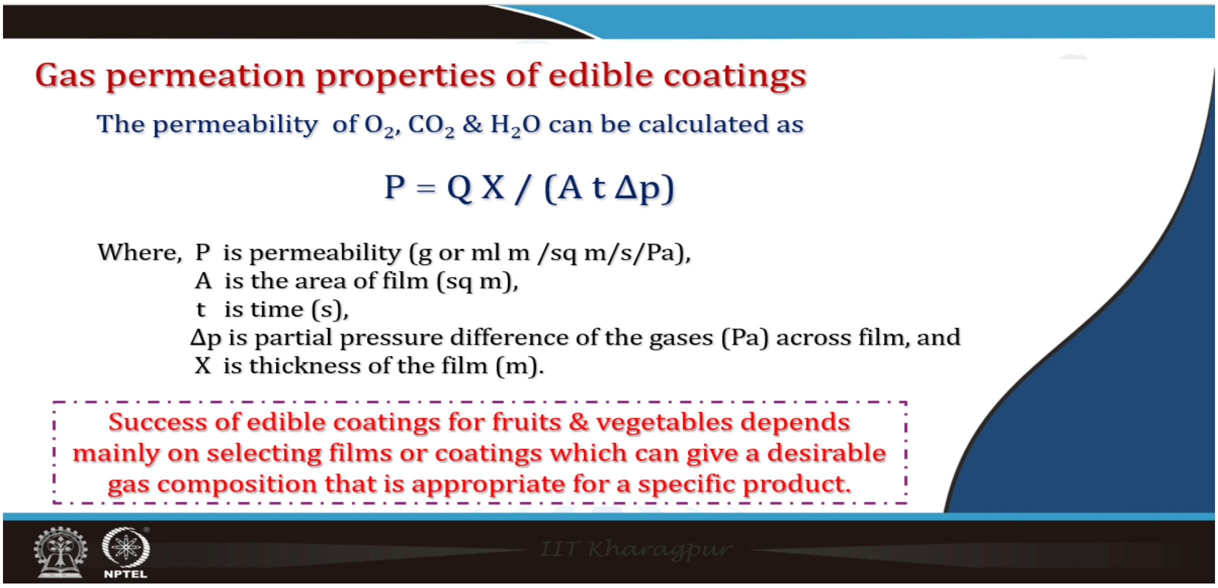
Multi-component or composite coatings are usually made to explore the complementary advantages of each component as well as to minimize the disadvantages. Most composite coatings associate a hydrophobic compound (lipids) and a hydrophilic structural matrix. Composite film and coatings can be produced in two ways namely bi-layer composite film and emulsion composite film. In bi-layer composite film, the lipid forms a second layer over the polysaccharide or protein. In emulsion composite film, the lipid is dispersed and entrapped in the supporting biopolymer matrix. The figure depicts the process of composite coating, the fruit or produce to be coated is dipped into the coating material and washed and then again dipped, this process is repeated till a multilayer of the coating material is formed.

Methods for edible film



Two methods are used for formation of the edible film, there are solvent casting known as wet method or extrusion known as dry method. The wet method involves the dispersion or solubilization of the polymers in a solvent medium prior to film formation. The film forming ingredients are mixed to form a homogeneous solution and the film is formed by layer-by-layer deposition method in the laboratory scale or smaller scale. In industry, the film dope is poured into a thin layer on a moving conveyor and dried by applying air over the film. The dried film is finally rolled into a film roll. The dry method involves hot-press molding or melt extrusion processes of powdered polymers. The figure shows extrusion, thermoforming and injection molding of the films. In thermoforming the polymer powder are passed through an extruder and the screw pushes the molten mass through a die. The hot film is pressed by a positive mold and vacuum is applied on other side to form the shape. In injection molding, the extruded film is injected into a mold and the shape is formed.

Gas permeation properties of edible coatings



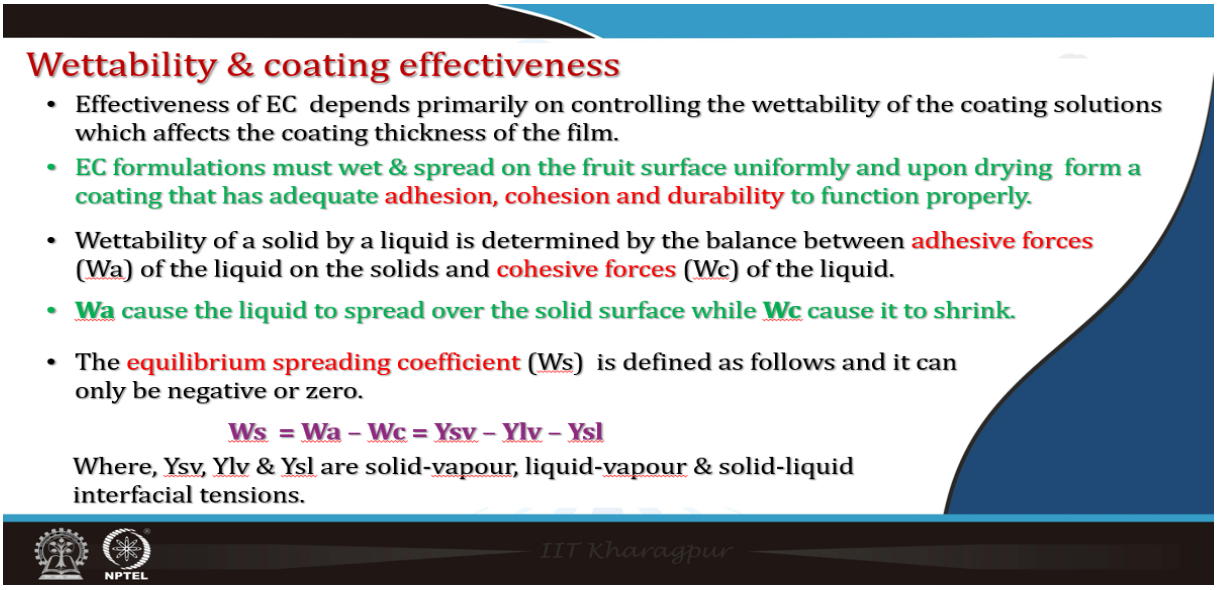
The permeability of oxygen, carbon dioxide and water vapor can be calculated as,

$$P = \frac{QX}{(At\Delta p)}$$

Where, P is permeability (g or ml m /sq m/s/Pa), A is the area of film (sq m), t is time (s), Δp is partial pressure difference of the gases (Pa) across film, and X is thickness of the film (m). Success of edible coatings for fruits & vegetables depends mainly on selecting films or coatings which can give a desirable gas composition that is appropriate for a specific product.

Wettability and coating effectiveness

Effectiveness of EC depends primarily on controlling the wettability of the coating solutions which affects the coating thickness of the film. EC formulations must be wet & spread on the fruit surface uniformly and upon drying form a coating that has adequate adhesion, cohesion and durability to function properly.

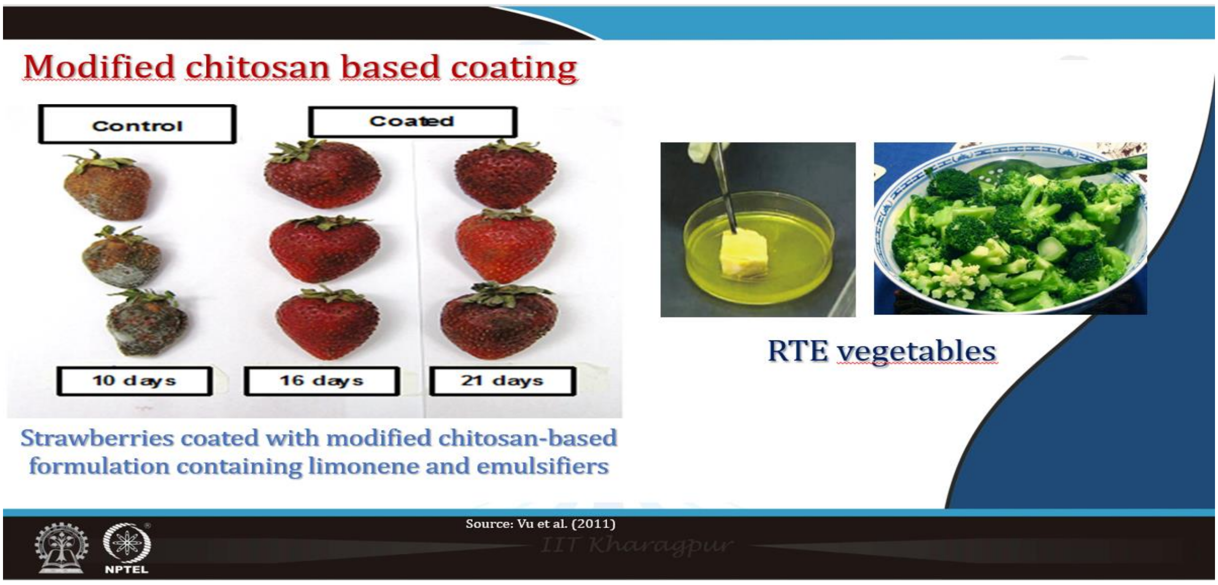


Wettability of a solid by a liquid is determined by the balance between adhesive forces (Wa) of the liquid on the solids and cohesive forces (Wc) of the liquid. **Wa** causes the liquid to spread over the solid surface while **Wc** cause it to shrink. The equilibrium spreading coefficient (Ws) is defined as follows and it can only be negative or zero.

$$\mathbf{Ws = Wa - Wc = Ysv - Ylv - Ysl}$$

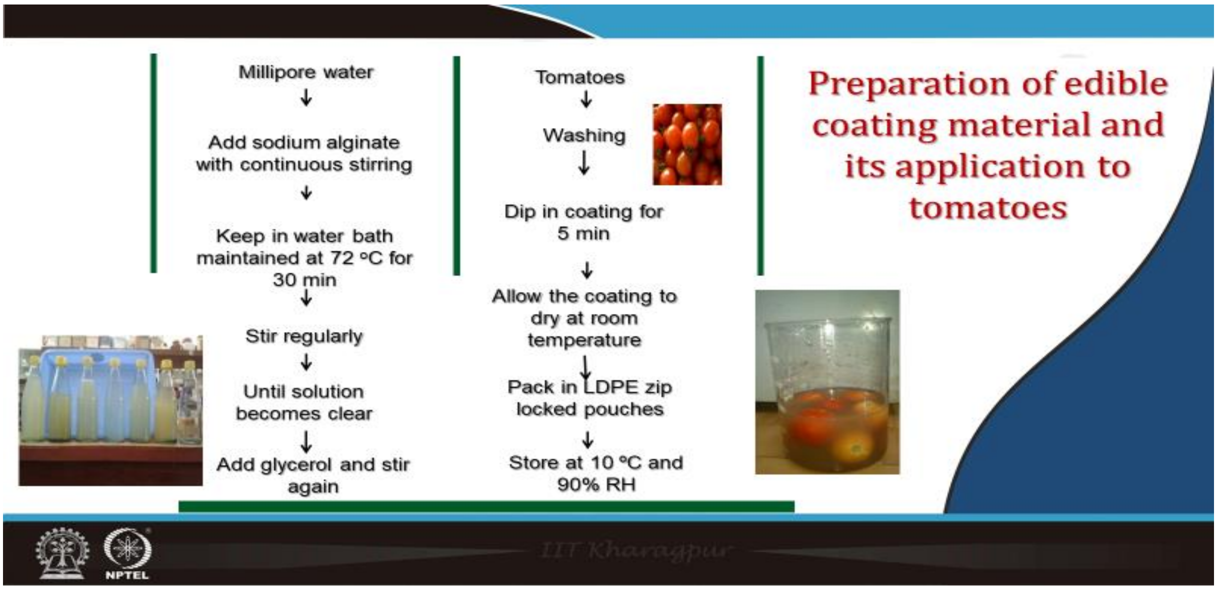
Where, Ysv, Ylv & Ysl are solid-vapor, liquid-vapor & solid-liquid interfacial tensions.

Modified chitosan based coating

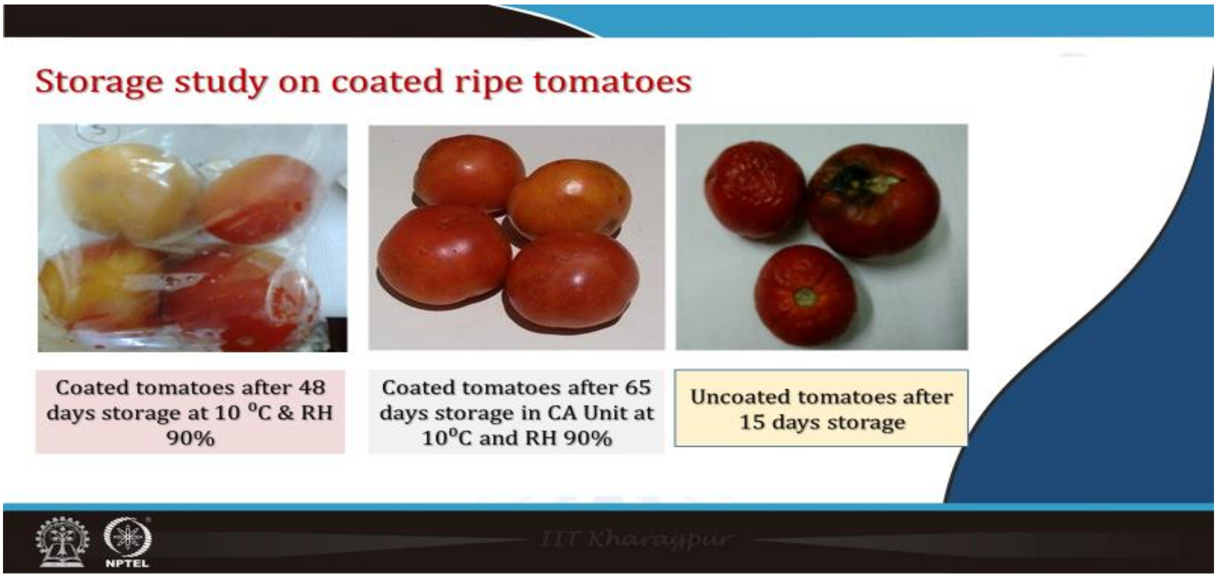


The figure shows strawberries coated with modified chitosan based formulation containing limonene and emulsifiers. The coated strawberries retained the color and shape even after 16 and 21 days compared to the control. The control sample developed mold and got deformed and decolored after 10 days. RTE vegetables could be coated with edible coating which will maintain the color, shape and freshness of the vegetables.

Preparation of edible coating material and its application to tomatoes



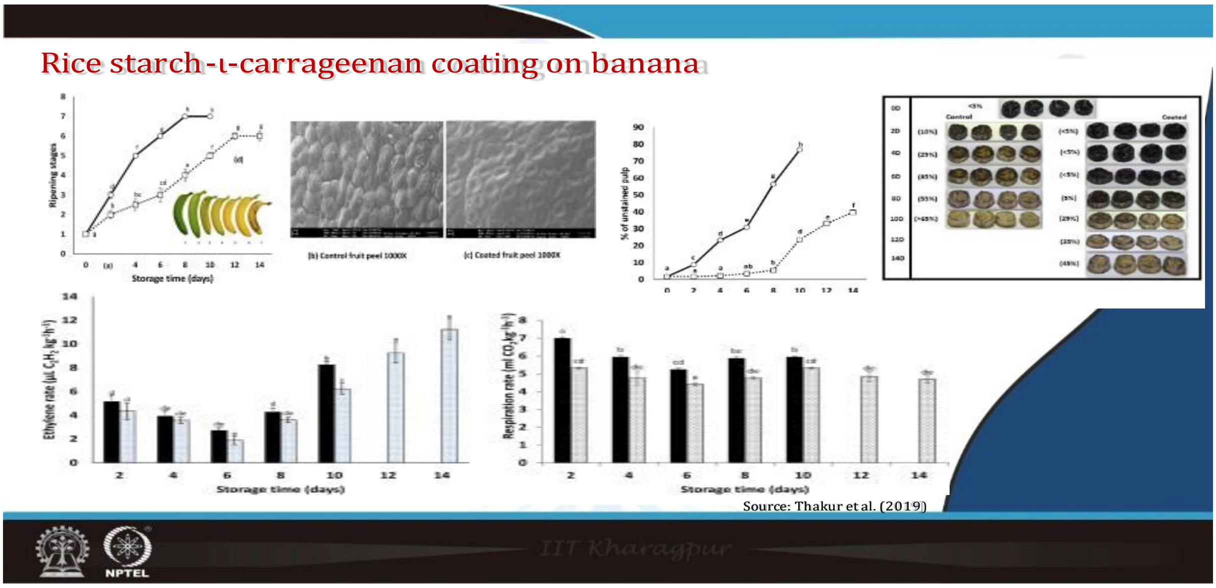
Sodium alginate is added to millipore water with continuous stirring. It is kept in water bath maintained at 72°C for 30 min. The solution has to be stirred regularly util the solution becomes clear. Then glycerol should be added and stirred. This solution forms the dipping solution of the coating material. Tomatoes to be coated are washed and dipped in coating for 5 min, after coating the tomatoes are dried at room temperature. The coated tomatoes are packed in LDPE zip locked pouches and stored at 10°C and 90% RH.



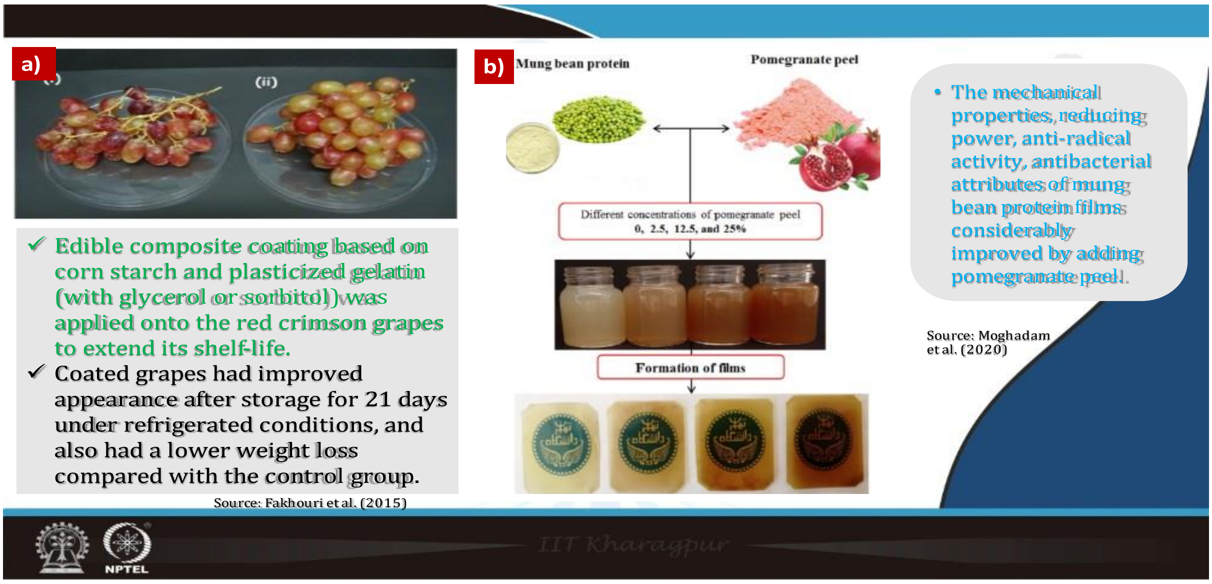
Storage study on coated ripe tomatoes

The coated tomatoes were stored at 10°C and 90% RH for 48 days and in controlled atmospheric unit at 10°C, 90% RH for 65 days. In normal storage the produces were stored at atmospheric condition , while in CA the gas composition of the atmosphere surrounding the produce is controlled. At 10°C the EC coated tomatoes remained fresh for 48 days, under CA storage the shelf life increased to 65 days. The uncoated tomatoes lost its firmness and color in 15 days of storage at 10°C 90% RH.

Rice starch-ι-carrageenan coating on banana

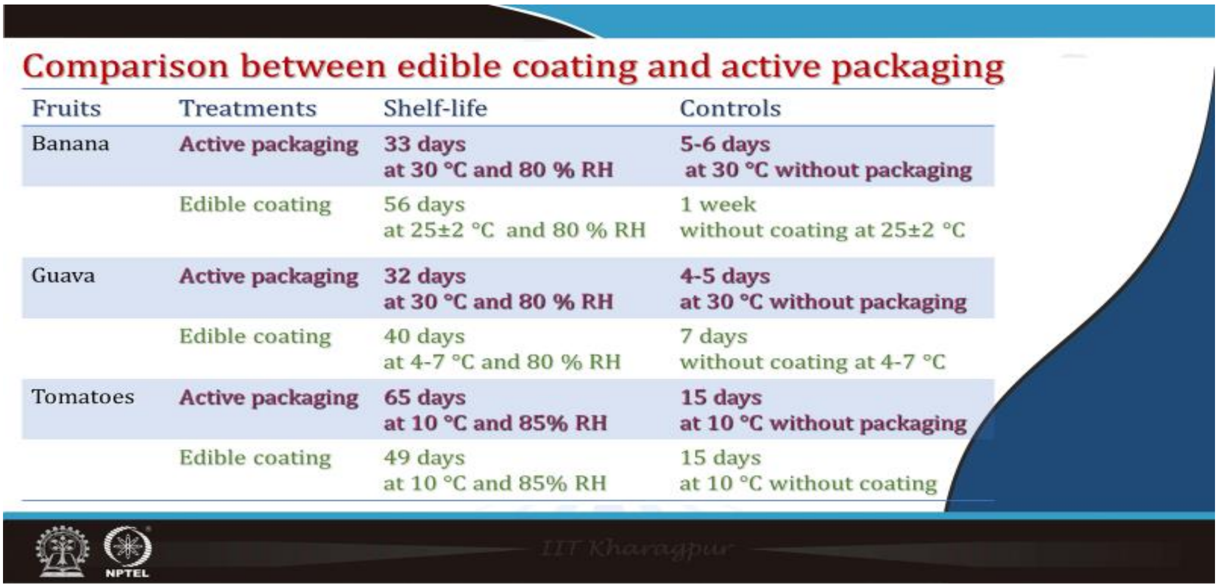


Bananas were coated with rice starch- ι-carrageenan and their respiration rate, ethylene rate and ripening stages were observed. The influence of the coating on the fruit surface characteristics through SEM analysis is illustrated in figure (b and c). Starch coating uniformly covered the pericarp surface without cleavage among epidermal cells, however, some cracks and/or cleavage was observed between the cells in non-coated fruits. Starch coating provided more uniform coverage onto the fruit surface without any cracks thus slowing down the ripening. The results presented in this study demonstrated the efficiency of coating in controlling gas transfer rates including atmospheric oxygen and ethylene production that control respiration and maturation in the fruit. Banana pieces were coated with iodine to visualize the breakdown of starch to sugars during the ripening process. The figure shows delay in the loss of stain in coated bananas showing that the ripening process is delayed.



Edible composite coating based on corn starch and plasticized gelatin (with glycerol or sorbitol) was applied onto the red crimson grapes to extend its shelf-life. Coated grapes had improved appearance after storage for 21 days under refrigerated conditions, and also had a lower weight loss compared with the control group. The flow chart shows the formation of edible film using mung dal beans and pomegranate peel. Different concentration (0, 2.5, 12.5 and 25%) of the pomegranate peel were produced and made into films. It was observed that the mechanical properties, reducing power, anti-radical activity, antibacterial attributes of mung bean protein films considerably improved by adding pomegranate peel.

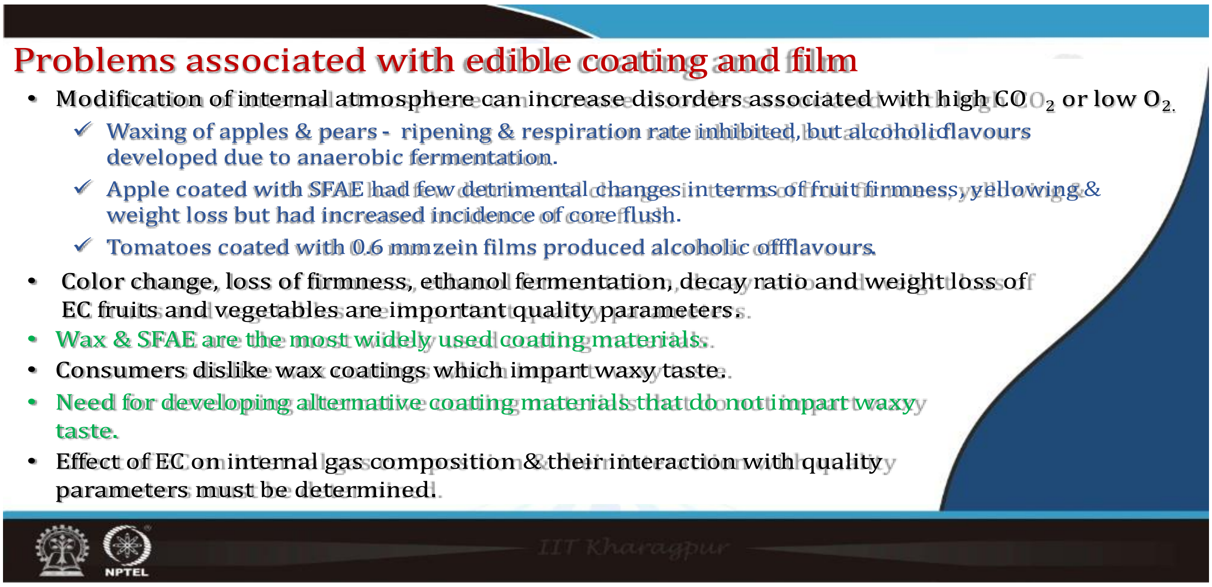
Comparison between edible coating and active packaging


Comparison between edible coating and active packaging

Fruits	Treatments	Shelf-life	Controls
Banana	Active packaging	33 days at 30 °C and 80 % RH	5-6 days at 30 °C without packaging
	Edible coating	56 days at 25±2 °C and 80 % RH	1 week without coating at 25±2 °C
Guava	Active packaging	32 days at 30 °C and 80 % RH	4-5 days at 30 °C without packaging
	Edible coating	40 days at 4-7 °C and 80 % RH	7 days without coating at 4-7 °C
Tomatoes	Active packaging	65 days at 10 °C and 85% RH	15 days at 10 °C without packaging
	Edible coating	49 days at 10 °C and 85% RH	15 days at 10 °C without coating

The comparison between the shelf life of active packaging and edible coating on banana, guava and tomatoes are shown in the table provided. In case of banana, the active packaging increased the shelf life to 33 days at 30°C and 80% RH compared to control with lasted for 5 to 6 days, while EC increased the shelf life to 56 days at at 25±2 °C and 80 % RH compared to control which lasted for 1 week without coating at 25±2 °C. In guava the active packaging extended the shelf life to 32 days at 30 °C and 80 % RH compared to 4-5 days at 30 °C without packaging. Edible coating extended the shelf life to 40 days at 4-7 °C and 80 % RH as compared to 7 days without coating at 4-7 °C. For tomatoes the shelf life was extended to 65 days at 10 °C and 85% RH by active packaging while without packaging the tomatoes only lasted for 15 days. Edible coating gave 49 days at 10 °C and 85% RH compared to 15 days at 10 °C without coating

Problems associated with edible coating and film

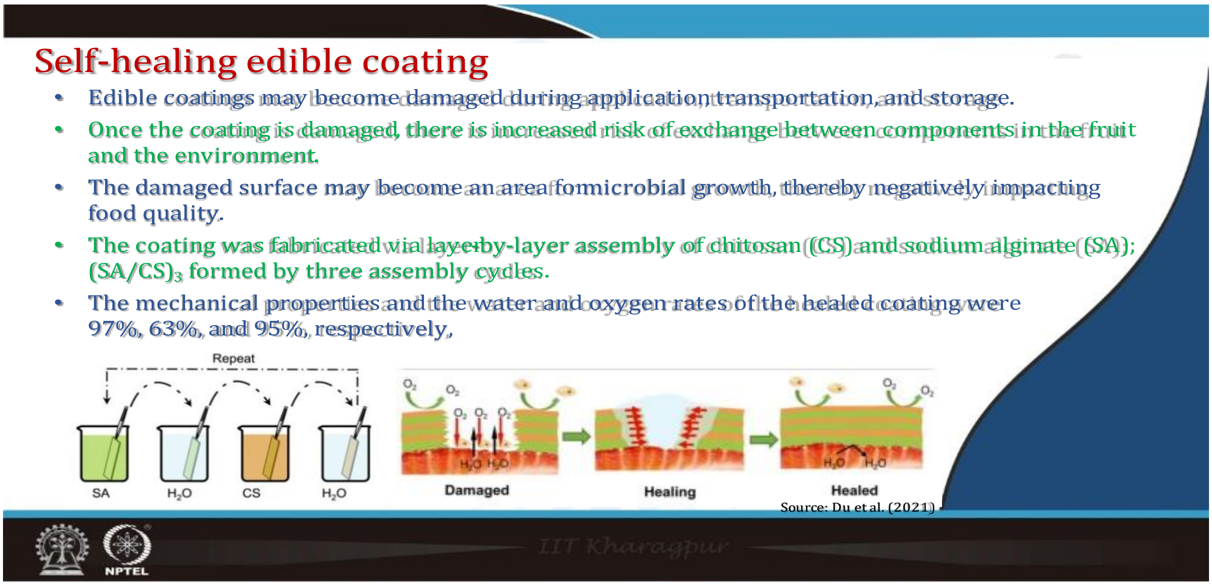


Modification of internal atmosphere can increase disorders associated with high CO_2 or low O_2. Waxing of apples and pears ripening and respiration rate inhibited, but alcoholic flavours developed due to anaerobic fermentation. Apple coated with SFAE had few detrimental changes in terms of fruit firmness, yellowing and weight loss but had increased incidence of core flush. Tomatoes coated with 0.6 mm zein films produced alcoholic off flavours. Color change, loss of firmness, ethanol fermentation, decay ratio and weight loss of EC fruits and vegetables are important quality parameters. Wax & SFAE are the most widely used coating materials. Consumers dislike wax coatings which impart waxy taste. Need for developing alternative coating materials that do not impart waxy taste. Effect of EC on internal gas composition & their interaction with quality parameters must be determined.

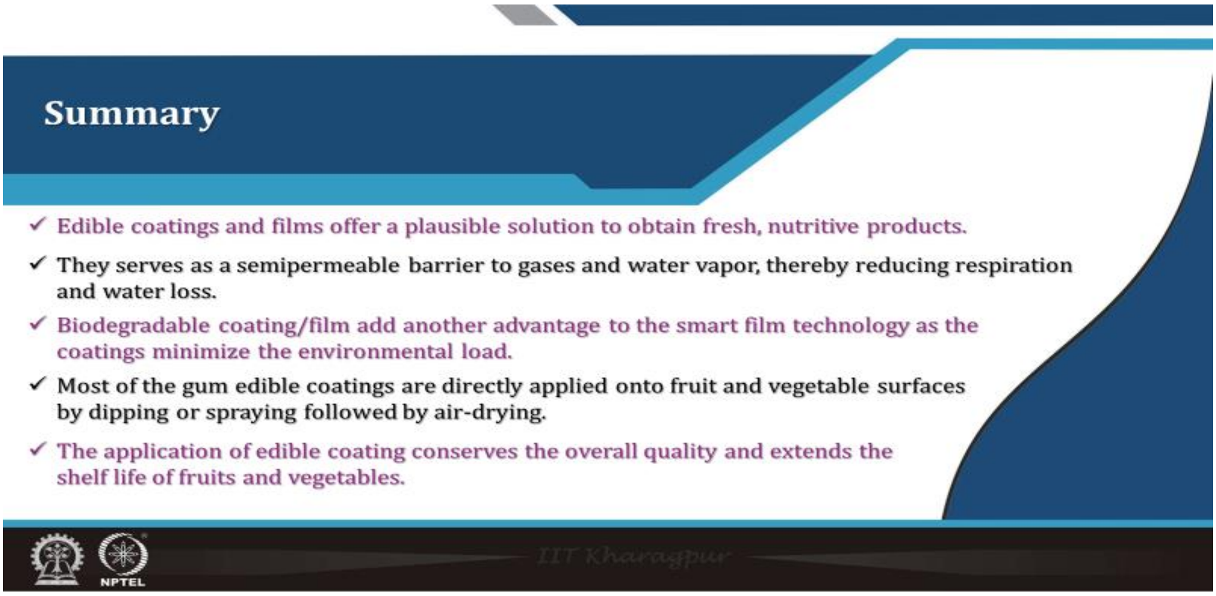
Self-healing edible coating

Edible coatings may become damaged during application, transportation, and storage. Once the coating is damaged, there is increased risk of exchange between components in the fruit and the environment. The damaged surface may become an area for microbial growth, thereby negatively impacting food quality. The coating was fabricated via layer-by-layer assembly of chitosan (CS) and sodium alginate (SA); $(SA/CS)_3$ formed by three assembly cycles. The mechanical properties and the water and oxygen rates of the healed coating were

97%, 63%, and 95%, respectively. The process of layer-by-layer coating of SA, water, CS and water and the repetition process is shown in the figure. When the damage occurs, the gas and moisture transfer through the damaged area. Once the healing proceeds, the surface heals to form a full layer again thus stopping the exchange of gas and moisture between the produce and the atmosphere.

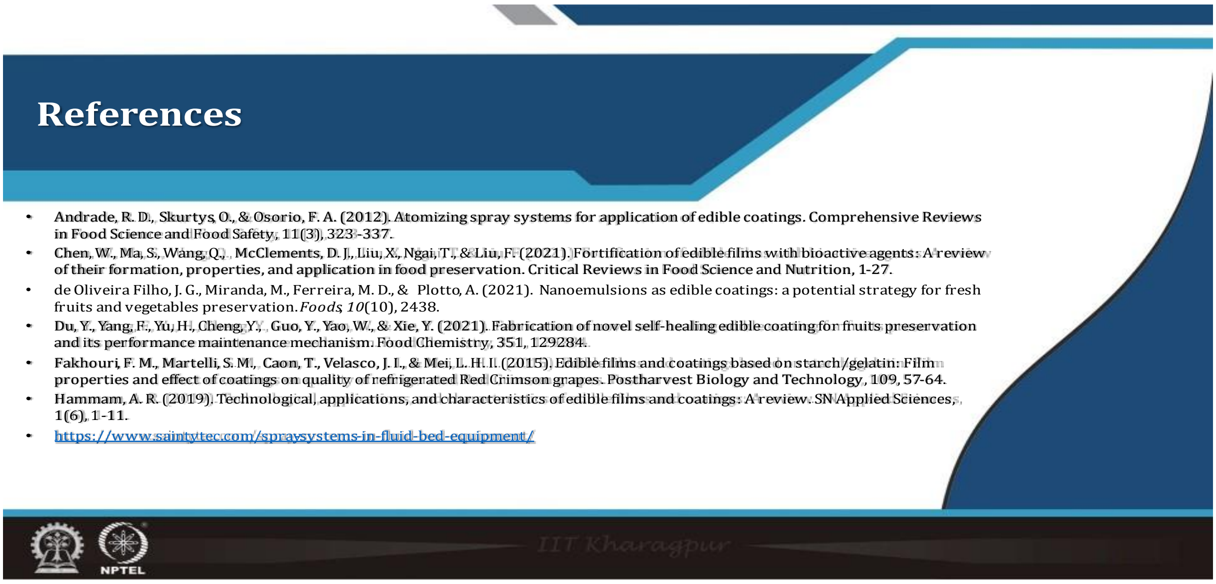


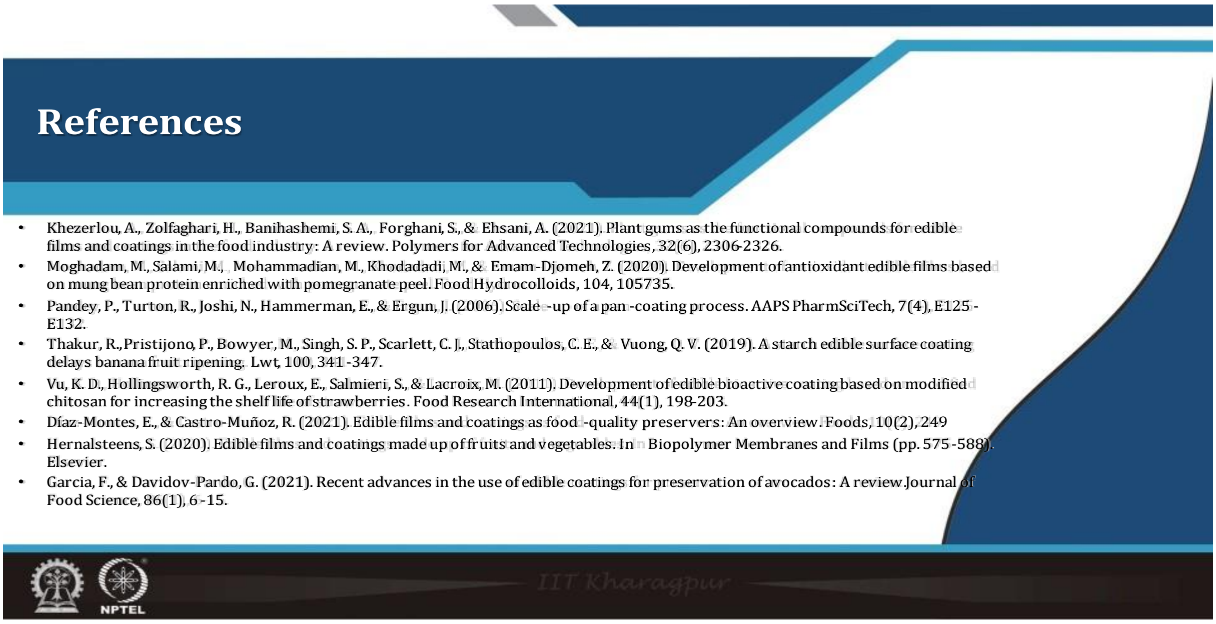
Summary



Edible coatings and films offer a plausible solution to obtain fresh, nutritive products. They serves as a semipermeable barrier to gases and water vapor, thereby reducing respiration and water loss. Biodegradable coating/film add another advantage to the smart film technology as the coatings minimize the environmental load. Most of the gum edible coatings are directly applied onto fruit and vegetable surfaces by dipping or spraying followed by air-drying. The application of edible coating conserves the overall quality and extends the shelf life of fruits and vegetables.

References





Reference for further reading is provided in the slide.