Post Harvest Operations and Processing of Fruits, Vegetables Spices and Plantation Crop Product

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Lecture 52

Smart Packaging

In this lecture smart packaging will be discussed. The concept that will cover include smart packaging, active packaging systems, like active scavenging and adsorbents, active emitters, antimicrobial agents or intelligent packaging like sensors, time-temperature indicators, microbial indicator, O_2-CO_2 indicators. Finally, some case studies will be taken up.

Smart packaging

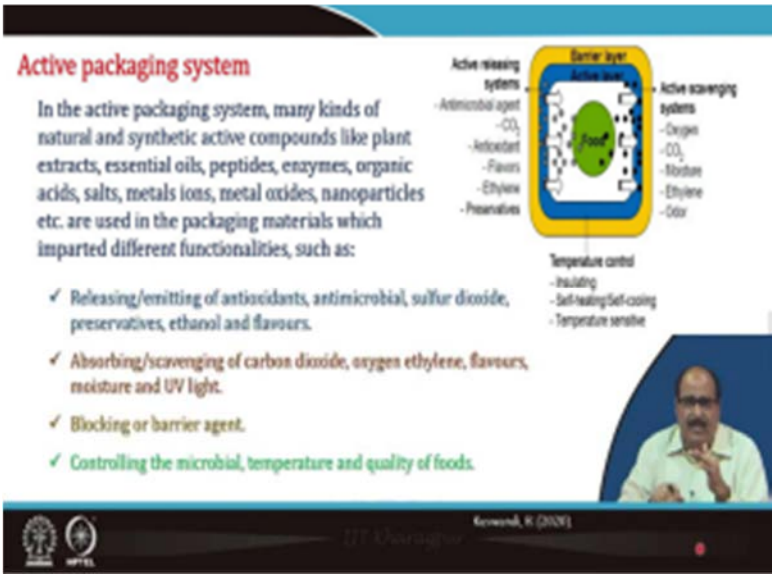
Smart packaging is an advanced packaging technology offering additional functions apart from the traditional packaging. The smart packaging offers benefits such as, it prevents the microbial growth and oxidation of food. It indicates the on-time quality of the food. A smart packaging senses and gives information related to the internal or external conditions change. It also indicates seal integrity and acts against counterfeiting. It communicates additional food information to the user and respond to food condition changes or package environment. Smart package system, acts upon the interactions between the food and the food package. The packaging material characteristics regulate the environment inside the food package. Depending upon their interaction with the food inside, the shelf-life of the food extends.

Smart packaging classifications

The smart packaging systems can be classified into two categories. One is the active packaging that extends the shelf-life based upon the interaction between the food characteristics, environment inside the package, and the packaging characteristics. Another one is the intelligent packaging system that communicates with the consumer. It tells us the food inside is not good or good, its quality is fresh or not. It provides the information about the material inside the package.

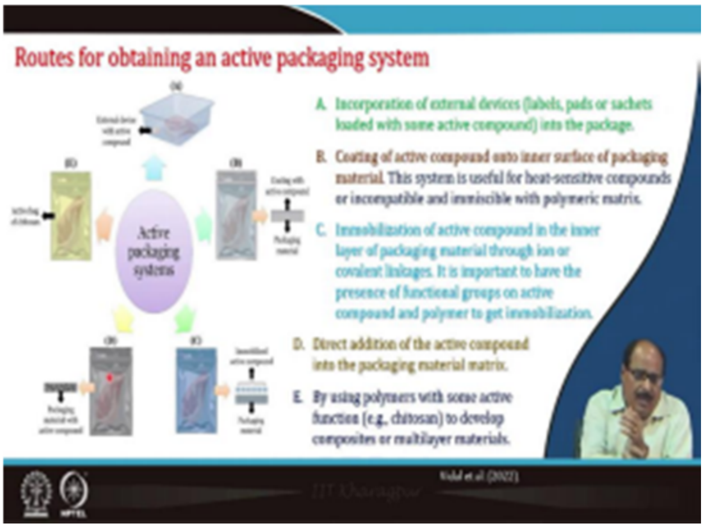
Active packaging

Active packaging is a type of packaging, where certain components are incorporated into the packaging system that release or absorb substances from or into the packaged food or surrounding environment to prolong the shelf-life, the food and sustain the quality, safety, and sensory characteristics of the food. It can be described as a technology devoted to controlling the rate of respiration, the growth of microbial, delayed oxidation, moisture migration with the main purpose to enhance the food quality, shelf-life, freshness, safety. Active packaging basic concept is integrating specific substances in the food packaging, in order to control or extend the quality and enhance the shelf-life of food.



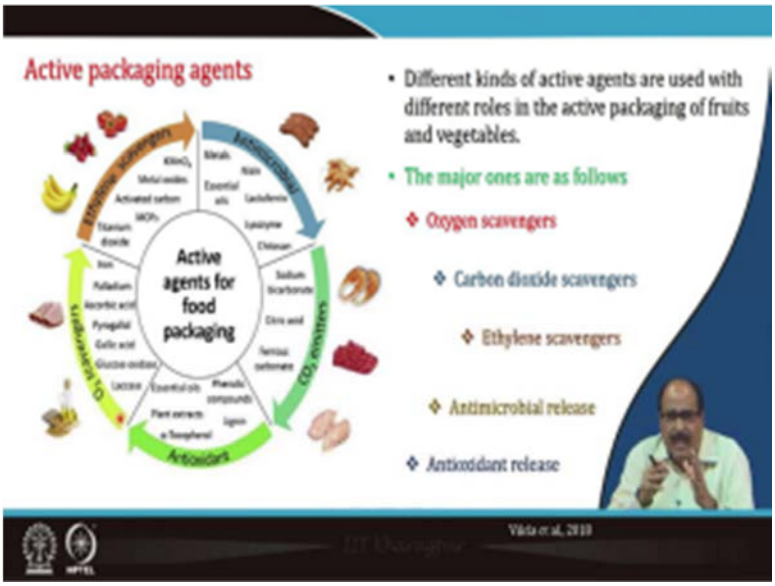
Active packaging system

In the active packaging system, many kinds of natural and synthetic active compounds like plant extracts, essential oils, peptides, enzymes, organic acids, metal ions, metal oxides, nanoparticles etc. are used in the packaging materials which imparted different functionalities, such as releasing or emitting of antioxidants, antimicrobial, sulfur dioxide, preservatives, ethanol, flavors. It may also act as absorbent or scavenger of carbon dioxide, oxygen, ethylene, flavors, moisture, and UV light. It acts as a blocking or barrier agent, or it controls the microbial growth, or temperature and quality of the foods.



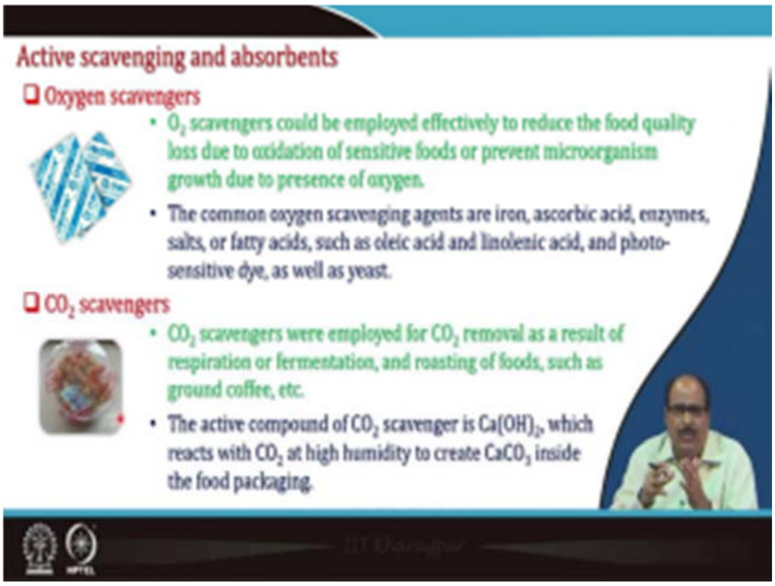
Routes for obtaining an active packaging system

The roots for obtaining the active packaging system are may be incorporation of external devices i.e., the labels, pads or sachets loaded with some active compounds etc. into the package. Here either emitter or absorber are in the calculated amount. The quantity of these absorbents or emitters is calculated based upon the known characteristics i.e., respiratory behavior, transpiration, and the permeability of the packaging materials, permeability to oxygen etc. All this data can be used to calculate the test and extend the self-life. Alternatively, these absorbers or emitters can be coated with the active compound onto inner surface of packaging material like antimicrobial substances etc. They are interior of the packaging material. They are coated, so this comes in contact with the surface of the food material during united package. Then surface microorganisms are inactivated or killed and the shelf-life of the food is extended. This system is useful for heat-sensitive components or incompatible and immiscible with the polymeric matrix. Immobilization of active compound in the inner layer of the packaging material through ion or covalent linkages. It is important to have the presence of functional groups on active compounds and polymer to get immobilization. The direct addition of the active compound into the packaging material matrix and the packaging material is being made like this, so that some antioxidants or some other functional components, can be added or incorporated into the packaging material. This becomes functional packaging. The materials are antioxidant, rich packaging material etc. And this when used for packaging, it extends the desirable properties. By using polymers with some active functions like chitosan to develop the composites or multi-layer materials for use in the pack.



Active packaging agents

Different kinds of active packaging agents are used with the different roles in the active packaging of fruits and vegetables. The major ones include oxygen scavengers, carbon dioxide scavengers or ethylene scavengers. The case may be antimicrobial release or antioxidant release etc.



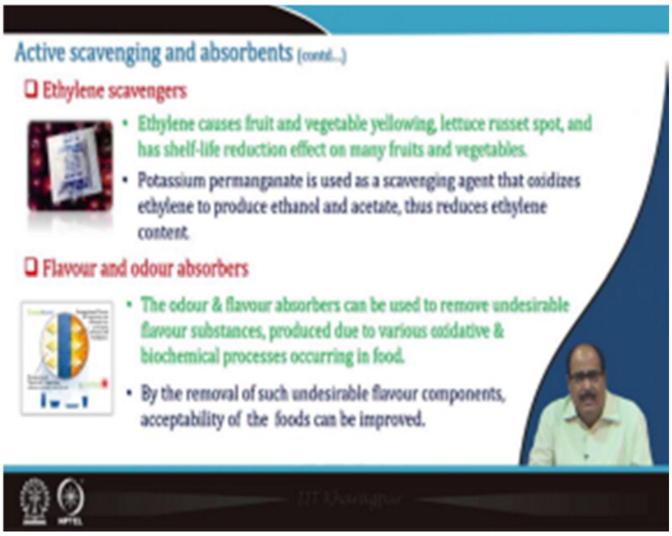
Active scavenging and absorbents

Oxygen scavengers

O_2 scavengers could be employed effectively to reduce the food quality loss due to oxidation of sensitive foods or prevent microorganism growth due to presence of oxygen. The O_2 level inside the packages should be maintained at minimum required level to allow the aerobic respiration at the slow rate as possible. Calculated amount of O_2 scavengers is added for that purpose. Various O_2 scavengers are iron, ascorbic acid, enzymes, salts, fatty acids such as linolenic acid, or photosystem dye etc.

CO_2 scavengers

CO_2 scavengers were employed for CO_2 removal, because when the fruits and vegetables respire, they release carbon dioxide. A particular concentration of carbon dioxide should be maintained inside the package. The scavengers can be added into the active packaging system to absorb the CO_2. Some of the known CO_2 scavengers include $Ca(OH)_2$, which reacts with CO_2 at high humidity to create $CaCO_3$ inside the food packaging etc.

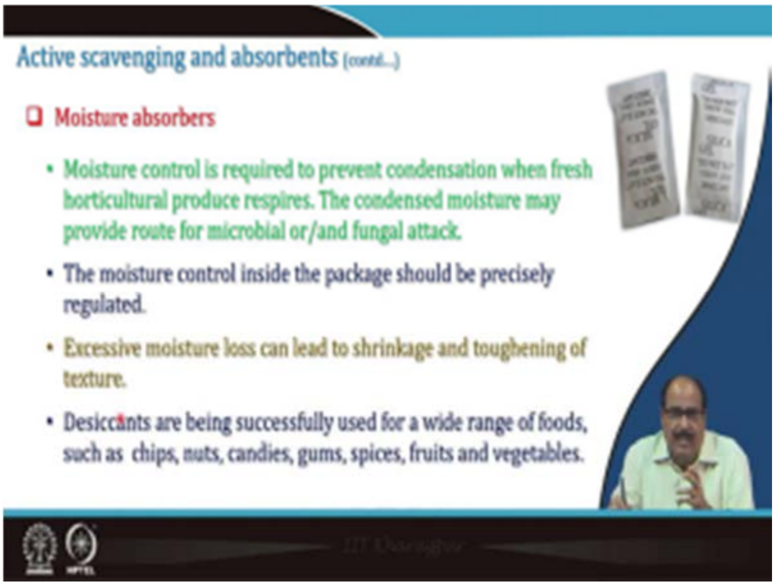


Ethylene scavengers

Ethylene causes the fruit and vegetable yellowing; it is a ripening hormone. It relates lettuce russet spot and has a shelf-life reduction effect of many fruits and vegetables. Potassium paramagnet is used to scavenge ethylene, that oxidizes ethylene to produce ethanol and acetate. Thus, reduces the ethylene content inside the package. By reducing the ethylene content one is reducing the risk of ripening rate and the a shelf-life of the food material is extended. Similarly, in order to enhance the ripening of the fruit, then inside the packet some ethyl ethylene releases can be used.

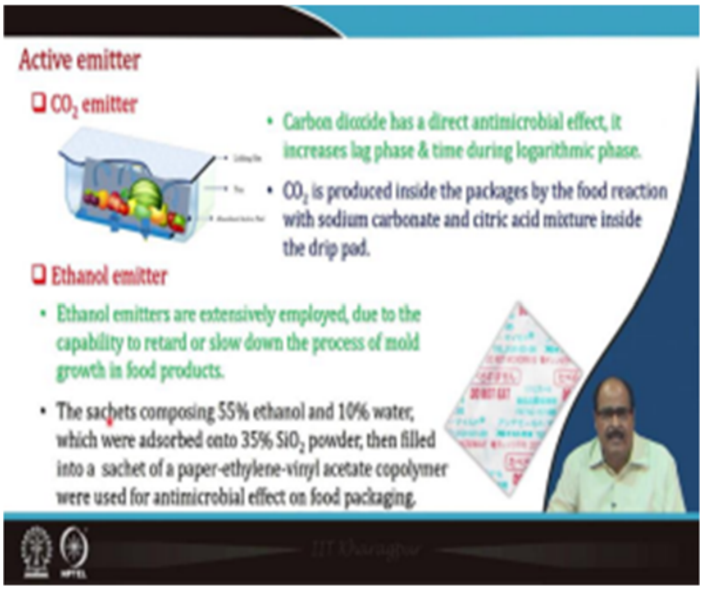
Flavour and odour absorbers

The odour and flavour absorbers can be used to remove undesirable flavour substances, produced due to various oxidative and biochemical processes occurring in the food. By the removal of such undesirable flavour components, acceptability of the fresh fruits can be improved.



Moisture adsorbers

This moisture absorbers are very commonly used inside the packaging materials. Moisture control is required to prevent condensation, when fresh horticultural produces respire. This is very important in the case of equilibrium hemorrhagic packaging (EHP). If the equilibrium humidity inside the package and outside the package is not uniform, then there will be condensation of moisture beneath the packet and it may encourage a microbial growth, fungal attacks, etc. The moisture control inside the package should be precisely regulated. Excessive moisture loss can lead to shrinkage and toughening of the texture. Desiccants are being successfully used for a wide range of foods, such as chips, nuts, candies, gums, spices, fruits, vegetables, etc.



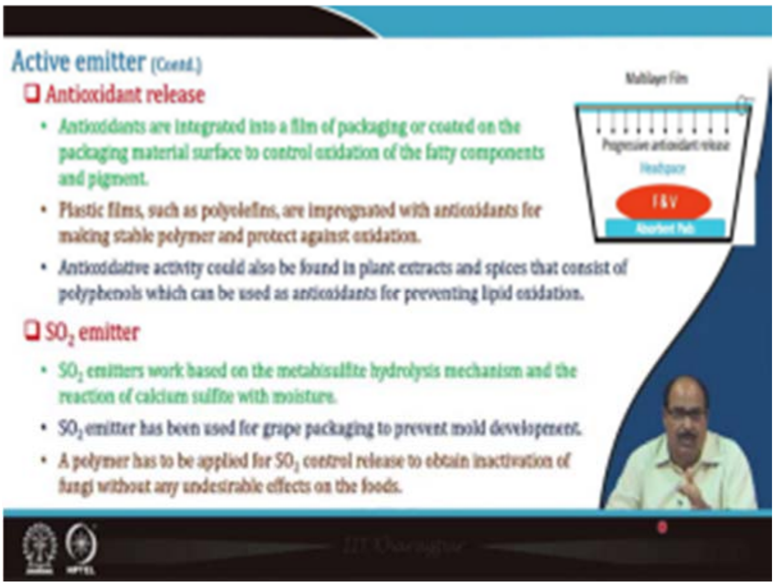
Active emitter

CO_2 emitter

The CO_2 emitter has a direct antimicrobial effect, it increases lag phase and time during logarithmic phase. CO_2 is produced inside the packages by the food reaction with sodium carbonate and citric acid mixtures inside the dip pad.

Ethanol emitter

Ethanol emitters are extensively employed, due to the capability to retard or slow down the process of mold growth in the food products. The sachets composing 55% ethanol and 10% water, which were absorbed into the 35% SiO_2 powder, then filled into a sachet of a paper ethylene vinyl acetyl copolymer were used for antimicrobial effect on food packaging.



Antioxidant release

Antioxidants are integrated into the packaging or coated on the packaging material surface to control oxidation of the fatty components and pigments etc. Plastic films like poly olefins are impregnated with antioxidants for making a stable polymer and protect against oxidation. The antioxidative activity could also be found in plant extracts and spice extract that consist of polyphenols, which can also be impregnated with the packaging material.

SO_2 emitter

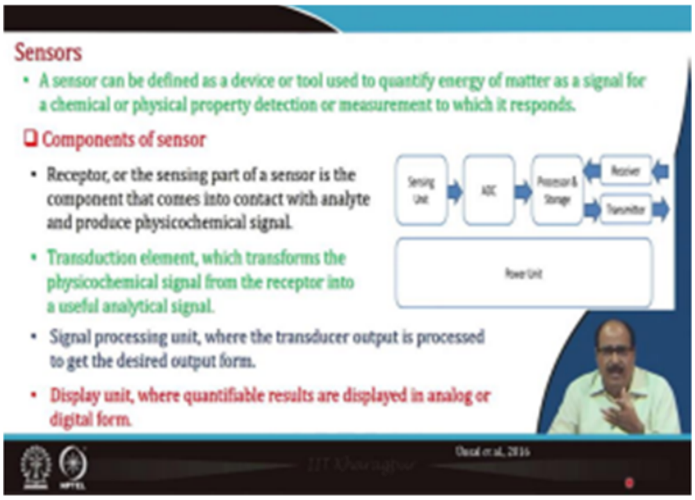
Then SO_2 emitters work based on the metabisulfite hydrolysis mechanism and the reaction of calcium sulphite with moisture. SO_2 emitters have been used for grape packaging to prevent mold developments. A polymer has to be applied for SO_2 control release to obtain inactivation of fungi without the undesirable effect on the foods.

Antimicrobial agents

There are various antimicrobial agents like nisin is a bacteriocin in the plant extract, alicin thiosulfinates, proteins, or gelatin agents like EDTA, enzymes peroxidase, enzymes, fungicide etc. There are various antimicrobial agents and this anti-microbial activity in active packaging can be classified as blocking or barrier functions that prevent microbial growth in food packaging. Antimicrobial food packaging can be classed into four antimicrobial packaging types i.e., the antimicrobial agents are impregnated into a sachet and attached to the package or antimicrobials absorbed or coated into the surface of the polymer. Antimicrobial agents are integrated into the packaging film directly or packaging materials having a matrix that consist of an antimicrobial agent.

Intelligent packaging

Intelligent packaging continuously monitors food quality during distribution, storage, and selling, or even to the end customers. It informs the customer about the quality and other parameters of the food inside. Inside the intelligent packaging, various sensors are used, they work on the principle of detection of biological compounds like enzymes, DNA etc. and chemical compounds like reagent dye, pH indicators etc. There are freshness indicators which work on the principle of detecting biological and chemical compounds like ethylene gas detection, pH detection, or integrity indicators, i.e., the O_2 and CO_2 indicators, leak indicators etc. Time temperature indicators are indicators, which work on diffusion, enzymatic, microbial and photochemical reactions etc. RFID or radio frequency technologies used for tagging the material. RFID tags are used to trace the product during being transported or shipping etc.



Sensors

A sensor can be defined as a device or tool used to quantify energy of matter as a signal for a chemical or physical property detection or measurement to which it responds.

Components of sensor

Various components of a sensor include a receptor or the sensing part of a sensor is the part which comes into contact with the analyte and produces a physicochemical signal. Transducer element, which transforms the physico chemical signal from the receptor into a useful analytical signal. Signal processing unit, where the transducer output is processed to get the output form. The display unit, where quantifiable results are displayed either in analog or digital form.

Types of sensors

Various type of sensors may be either chemical sensors, gas sensors or biosensors are there. They all have the transducers either optical, electrochemical, or electrical devices like metal oxide, semiconductors, etc. or thermometric, magnetic devices etc. These are the various components of the sensors.

Time temperature indicators

Time temperature indicators (TTI) are small and inexpensive devices attached to a packaging material that provides time temperature history of the food product during storage, thus, estimating the remained shelf-life in the non-destructive manner. It can be seen that the time temperature labels are there depending upon the exposure times. Various enzymatic reactions occur and the pH changes. Then the pH indicator will change the color. TTI label may be a microbial load indicator, moisture indicator. It can be designed to have at a particular content, the quality of the color of the sensor will change, TTI level will change. In this way TTI level indicators are formed. They can be classified based on their function like critical temperature indicators, critical temperature time indicators, time temperature indicators. They may be based on the operation principle like mechanical, geometric, chemicals, microbiological etc. or they may be based upon the history of the temperature like partial history indicators or full HD indicators etc. Thus, various types of TTI indicators are used in the intelligent packaging.

Microbial indicators

The information on the food quality is usually based on chemical changes on microbial growth within the food. Microbiological quality is indicated by the reaction of the indicator with microbial metabolites. There is food quality, there will be indirect indicators that the critical temperature indicators, time-temperature indicators, leak indicators etc. When there is a leakage inside the package, the gaseous composition will not be properly maintained. Thus, the shelf-life will be adversely affected. The direct indicators may be like pathogenic bacteria count or biogenic amines, ATP degradation, aroma compounds etc. Various volatile compounds, CO_2 nitrogen etc. also can be determined. Their values inside the package can be directly indicated by the labels. Once the level goes beyond a certain limit, it can be said that the food is good or bad.

O_2 and CO_2 indicators

The shelf-life of the fruits and vegetables depends upon the rate of respiration, that can be expressed as O_2 consumed or CO_2 evolved, which further causes changes in the food colour. When the respiration rate is increased, the production of ethylene is increased. These properties can be employed as marker or indicator for the freshness and the quality the food. The indicators must be in direct contact with the gaseous environment immediately surrounding the food in a container. The presence of O_2 may indicate that the package was sealed incorrectly either leaking or damaged. Plastic optical fluorescent films are highly sensitive for the detection of the gases and dissolve CO_2 etc.

Smart packaging systems for fruits and vegetable freshness

It allows continuous monitoring of the quality of packaged fruits and vegetables. Fruit freshness sensors are on package indicators that monitors environment inside or outside the packet. it allows consumers to make informed decision about the quality of the fruits. The sensor is the signal light in the food packaging systems. But one need to calibrate the signal and then this sensor signals in the sensor inputs finally. The signal is released in the output by the color, fading, voltage etc. in various forms and from that one can infer the quality of the food inside.

Case study: Active packaging of fruits & vegetables

Action of self-generating chlorine dioxide (ClO_2) gas for fruits and vegetables packaging systems containing moisture activated ClO_2 gas releasing label. ClO_2 gas lowers the metabolism of fresh produce, which helps in maintaining weight and firmness of the fresh produce during their storage period. ClO_2 gas prevents fruits from softening, associated with its capability to prevent protein synthesis in cell walls. Compared to the control sample, a lower weight loss and a lower firmness value were noticed in tomatoes packaged in ClO_2 gas. It can be seen in the picture the sources of ClO_2. $NaClO_2$ plus acid and moisture and all these three give ClO_2 gas. There is a ClO_2 releasing label. ClO_2 gas comes and this automatic release of ClO_2, that extends the shelf-life. They are put outside in the packaging material. In this way, the quality of the tomato or other fruit is accordingly increased.

Case study: Application of freshness indicators for apples

It can be seen in the picture, the pressures indicators of the apple. The red line indicates the degree of sensory ripeness and the black line shows the ethylene concentration in the package. Thus, a relationship between ethylene concentration and degree of ripeness is shown here. The changes are with the storage time in days. Ethylene emission of apples can be detected through the ripeness indicator. This indicator is based on the reduction effect of ethylene causing color changes in selected metal ions. The used molybdenum (Mo) chromophores change under impact of ethylene in color spectrum from white/light yellow to blue because of partial reduction in Mo(VI) to Mo(V). The color changes from white to blue in the ripeness indicator labels on the apples were clearly visible over the studied time.

Case study: Application of freshness indicators for apples

A novel packaging nanopackaging was synthesized in the study by coating the polyvinyl chloride (PVC) film with nano- ZnO powder. On investigating its effect on the preservation quality of fresh cut 'Fuji' apple nanopackaging significantly reduced the fruit decay rate. Both the polyphenoloxidase and pyrogallol peroxidase activities were decreased in nanopackaging fruits. The initial appearance of apple slices was retained and the browning index was preserved in nanopackaging samples. These results indicated that nano-ZnO active packaging could be a viable alternative to common technologies, for improving the shelf-life properties of 'Fuji' apples as a fresh-cut products.

Summary

Smart packaging is a combination of both active and intelligent packaging systems, that increases the shelf-life of the food. These monitor the shelf life, extend the shelf-life of the food, and they also monitor the quality, and improve the quality as well as inform the condition of the food inside in terms of its particular quality maybe color, flavor, microbiological value, or in terms of shelf-life. It may say that whether it is spoiled or is fresh. Thus, any system can be used to indicate the role of the smart packaging. Active packaging systems consists of absorbers, emitters, barriers and controlling systems. Intelligent packaging continuously monitors and communicates food quality through sensors, freshness indicators, time temperature indicators etc.

So, these are the references used in this lecture with this lecture.