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Applications of Polymers in Horticulture Food Packaging

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ABSTRACT

Horticulture produce includes fruits and vegetables, flowers, herbs, etc. but not cereals because it includes only crops with lesser shelf life, perishable nature and active metabolism. The post-harvest fruits and vegetables require special measures to ease the conveyance with preservation of nutritional value. By the introduction of packaging for transportation of perishable horticulture products from farms to consumers, reduces the wastage to one- fourth and save billions. Most of the packaging materials used are polymers because of its light weight, high strength, transparency and potential to be converted into any form. Due to the substantial availability and economical advantage of polymeric packaging material, they have reduced the cost of packaging. They are also highly recyclable and hence reduces the waste generation and prevent atmospheric pollution. Polymeric packaging has widely replaced traditional packaging materials such as wooden and corrugated paper boards. This has also led to a reduction in deforestation which again makes it an effort in the direction of a better world. With the advancement in research andtechnology in the fields of agriculture and packaging, many technologies have been developed such as MAP (modified atmosphere packaging), EMAP (equilibrium modified atmosphere packaging), CA(controlled atmosphere), micro-perforated films, particle films, biodegradable and edible packaging systems.

INTRODUCTION

Polymers have made an enormous impact on packaging industry, mainly on the food packaging. Most of the food products come from the horticultural crops. Horticultural products are basically all the products arising from horticultural industries, continues respiring even after harvesting and hence their preservation is a must.

HORTICULTURE CROPS INVOLVES

- Fruits
- Vegetables
- Seeds, foliage's and roots
- Flowers
- Trees, herbs and shrubs
- Perennial bushes and nuts

It isn't easy to deny the revolution that plastic had in agriculture as well as in other packaging and containerindustries.

Every moment, the population on the planet if drastically increasing. With this growing population, the demand and necessity for food is also rising. This increasing demand of natural products having lower shelf life with the retainment of highest possible freshness and nutritional content and the globalised trade of horticultural products have created a major challenge and hence an opportunity to the packaging sector. The research and investigation in the field of agriculture and horticulture has spread the awareness about the importance on nutritive content in F&V, due to which their production has also increased. This has further stress on the packaging of these goods to minimise the loss and wastage during transport and also to prevent the goods from environmental degradation. [3]

Packaging plays a critical role in the postharvest handling and distribution of fresh and processed food and other biomaterials. Packaging has many other important functions, such as protecting the packaged goods from hazards including contamination in the distribution environment, facilitating transportation and storing of products, and carrying printed information and graphics. Packaging is one of the most

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important steps in the long and complicated journey of fresh horticultural produce from grower to consumer. [7]

Packaging has proved its ability as a vital part of the horticulture industry which is essential for the safe handling and transport of the products such as fruits and vegetables.

The most important phenomenon taking place in horticultural products is water loss, which leads to the deterioration of the produce which includes physical changes like loss of crunchiness, undesirable colour change, wrinkling of the skin, loss of firmness, wilting and loss of crispiness. The associated chemical changes are faster degradation rates, loss of nutritional content, etc. This also affects the commercial nature of the horticultural products [5,9]

Cooling must be incorporated before packaging and after harvesting to extend the shelf life of the fresh horticulture produce. The Forced-air Cooling system helps in lowering the deterioration and water loss rates. There should be a uniform cooling throughout for best results. [8]

One of the most significant contributor to the finances and economy of a country is the horticulture industry, fresh fruits and vegetables contains vitamins, minerals and other important biologically active compounds essential for an individual's health. As these products have an active port-harvest metabolism, their quality continues to degrade due to microbial spoilage, temperature and humidity, etc.To prevent these kinds of loses, there is a requirement of an effective collaboration of the growers and farmers, storage operators, packagers, processors, transporters, retailors and finally the consumers. [6,11]

Post-harvest loses in the horticulture industry are inevitable but can be minimised as much as possible. The waste during storing and transporting can be as high as 13-38% before even reaching our tables, and a further 20%(appx.) is lost due to lack of appropriate refrigeration. One of the important improvement was made using effective packaging to reduce the loss to a minimal amount. A variety of packages are used for transporting and marketing. By the introduction of improved containers and packaging, even a 2% wastage reduction saves 100-200 crores of rupees. [4,3]

There are many ongoing post-harvest treatment processes used to minimise the loss of quality, nutrition and also reduces the risk of contamination by microbes and pathogens. Packaging plays a very important role in maintaining these factors like temperature, humidity and gaseous composition and also protects against various mechanical damages as well as physical injuries. [6,12]

Temperature plays a major role in deciding the shelf life of a horticultural product. For example, strawberries have a life of 7-8 days at 0°C, but lasts only for a day at 20-25°C. hence, they need to be transported in refrigerated trailers and stored in cold containers. RH is another factor which needs to be checked. Most of the fresh horticulture produce has their maximum shelf life at 90-95%, except onions, garlic, squashes and also ginger which has the maximum life around 70%. There is no control of RH in highway trailers, airplanes have RH from 15-20%, marine transport has water spray system to maintain RH, but the temperature must be above 0°C, so that it does not freeze over it. Wax-lined packages are used in which the RH is maintained for a relatively longer duration. [12]

Low relative humidity (RH) results in excessive loss of weight and firmness, while very high RH favors water vapor condensation on mushroom surface, which accelerates microbial growth and discoloration. Thus, their postharvest life is shortened as consequence of these processes. Appropriate packaging is one of the essential methods for protecting and maintaining the quality and prolonging the shelf life of produce from growers to consumers. [17]

Physical injury is a major cause of wastage and deterioration of horticultural products. It can be caused by many factors like vibration, compression and impact. Proper packaging has its role here also. Also, the placement of the produce as well as the containers, stacking of the containers as well as the quantity of product should be taken care of. If the packaging material does not possess a good strength, then on stacking them over each-other, it will get damaged. Over-filling of the boxes can also be a cause because in such cases the load is supported by the produce except the container. In case of corrugated fibreboard boxes, if moisture is absorbed, strength will get decreased and hence they are sometimes wax-coated. Due to this, at high RH, recyclable plastic containers are used instead of corrugated fibreboard boxes. Vibrational damages can be prevented by gluing the containers with each-other, but there must be a little space in between the two boxes for uniform temperature inside all the boxes. [12]

The famous old saying "a bad apple can spoil the whole barrel" has been cited to the phenomenon of increasing the rate of decomposition with time. Horticultural products like fruits and vegetables may be classified into two categories. First is of those fruits and veg-eatables which releases ethylene and the other is of those which are sensitive to ethylene.

Ethylene is that plant hormone which is responsible for ripening and all other ripening related changes. Ethylene is a colourless and odourless gas. Unripe or raw horticultural products secreates lesser ethylene compared to the corresponding riped products. The damaged/ injured horticulture products have a very high rate of ethylene release and hence the products gets overriped (decomposed easily).[13,14,15]

The chin ease previously used the technique of placing the unriped F&V inside closed rooms where incense sticks are burning. Burning of incense sticks emits ethylene gas, which increases the concentration of ethylene. Fruits gets easily riped by this technique. This is the reason that raw fruits and vegetables are sent to the markets so that over-riping doesn't occur. Over-riped products are very much prone to the decomposition, microbial spoilage and transport damage. [14,16]

This paper gives detailed information about the horticulture and its packaging, storage and transport. This paper explains and categorises all the products included in the horticultural industries. The paper focuses on the need and requirement of packaging of horticulture packaging including discussions about the advantages as well as the drawbacks. A detailed discussion on the properties and applications of the synthetic as well as biodegradable products generally used in horticulture packaging. The paper also covers certain challenges to the horticulture packaging like controlling the ethylene gas release, protecting against microbial spoilage and to control the water loss. A special focus has been given to the edible coating because of its wide and sustainable acceptance and scope. Finally, the paper deals with the advanced technology for horticultural packaging like MAP, EMAP, CAP, micro-perforated, particle film systems, etc. this paper covers almost all the information which would be much beneficial at the primary stage of researches in the field of horticultural packaging.

REQUIREMENT OF HORTICULTURE PACKAGING

A product of the horticulture industry has a long journey of thousands of miles, but with a short life only of a few days. So to ease this process of transportation of these products from the source to the kitchens, packaging plays it role. Packaging has an important function to protect the content against physical, physiological and pathological deterioration during marketing and handling.

Horticultural products have a shorter shelf life due to their active metabolism even after harvesting. Due to the process of transpiration and respiration, fresh fruits and vegetables, keeps losing water. This leads to a faster deterioration of the horticultural products and also a loss in nutritional content and weight. Loss of weight has a direct impact on economy and leads to a loss of millions and billions of dollars globally. Water loss has a colossal impact on the properties of the fruits. It reduces the quality, appearance, shrivelling, gloss reduction, limpness, wilting, freshness and shelf life of the produce. It has a negative impact on the bacterial resistance, that means the more is the water loss, more will be the growth of bacteria and spoilage microorganisms.[53]

The transfer of fresh fruits and vegetables from the farming sites should be as such that it reaches the hands of the consumer with retainment of maximum nutritional content. This may includes a veriety of steps, many criterias to be satisfied and also many factors to be taken care of. There are a number of factors which reduces the shelf life as well as the nutritional value of the horticultural produce like temperature, relative humidity, gaseous composition, microbial growth, etc.[12]

Packaging provides containment and protects food products during distribution and storage from external and internal unfavorable conditions, such as water vapor, microorganism, gases, orders, dust, and mechanical shock and vibrations. [48]

Atmospheric gases can contaminate the horticultural produce and may lead to biochemical (for e.g.,bacterial metabolism) and physical (for e.g., texture and colour) changes. Hence a good packaging system must not allow excess of a particular gas to penetrate. For example, in a Controlled Atmosphere packaging, the concentration of Carbon Dioxide is increased and that of oxygen is decreased which reduces the ethylene production in the packed product.[44,46]

A good packaging system is thus required to maintain the desired conditions of temperature, RH, gaseous composition, etc. to obtain the maximum nutrition as well as shelf life. The factors which are considered most importantly for horticultural packaging are:

- Cooling rate
- Box ventilation
- Product quality
- Shelf life
- Mechanical strength
- Energy consumption (only if a ventilation system is involved)

There are various levels of packaging for packaging of horticulture products. The basic level of packaging predominantly uses fibreboards (ventilated or non-ventilated), boxes of plastics and woods, plastic clamshells stacked in pellets, etc. internal packaging is one of the other scale of packaging, using trays, polymer bags, pellet covers, punnets, thermal and mass transfer limiting pellet covers. [4]

Till now, it has become evident that the major function of horticulture food packaging is to increase the shelf life of the produce by maintaining the temperature, relative humidity and gaseous composition. It also serves another purpose of protecting against mechanical damage to the produce during handling, storage and transport.

CHALLENGES WITH HORTICULTURE PACKAGING

There are many associated factors responsible for the decay of horticultural products. Various post-harvest methodologies had been incorporated to reduce the decay and increase the shelf life, of which packaging is an integral part. There are many challenges associated with packaging because of the presence of multiple affecting factors.[4]

Horticulture products are perishable commodities which deteriorates at a very high rate.The transport to the markets and further to the consumer is a time taking process are accompanied with variations in climatic conditions and packaging technology. The packaging these products must present it from all the factors responsible for its fast deterioration.

Due to the post-harvest metabolism of horticulture, their deterioration can only be slowed but can not be eliminated.

There are many factors associated with the decay of fruit and vegetables, that need to be eliminated liminated or reduced to a minimum. Some of the major challenges possessed by the horticulture products to the packaging industries are

Insect pest damage – insects and microbes are a big community responsible for the spoilage of fresh fruits and vegetables. These pressure is inevitable and difficult to control. Earlier, natural anti- microbial agents were being used like neem. People used to place neem leafs with food, clothes etc to protect microbial growth.

The use of antimicrobial packaging is a promising technology which introduces antimicrobial nature in the film covering the product. It kills the pathogens and microbes which effects the food and thereby increases the shelf life.[57] Some potential anti-microbial agents are Grapefruit seed extract, starch, chitosan, cinnamaldehyde, linalool, terpinol, pedicin, lacticin, gelatin, etc.[58]

Ethylene: The Ripening Hormone- fruit and vegetable consist of ethylene, which act as ripening hormone. Rate of emission of ethylene of fruits depends upon the age of the plant.

The older the plant is, more will be the ethylene emission. Not all fruits emit ethylene like apple, banana, tomatoes, peach and mangoes are high producers of ethylene.

The production of ethylene further rises after some damage or injury and leads to the contamination of the whole package containing tons of product.

Oxygen favours the ethylene release and hence the packaging industries have developed may technologies to reduces the concentration of oxygen in the atmosphere. One such technology is CAP where the concentration of oxygen is reduced significantly with increased concentration of CO2.[13,15]

Freeze damage- In some regions on the globe, where the temperature goes below 0°C. water freezes on the fruit surface to become ice. The nucleation around the surface of fruits slowly extends this inside the fruits and hence damages the fruits permanently. Packaging industry deals only after harvesting and hence isolated polymeric boxes which does not allow the heat to pass through it.[42]

UV damage-packaging incorporates certain UV absorbing materials like carbon black and several other natural agents.

They protect the products from hazardous solar radiations. Polymers in Packaging, their properties and applications

The types of packaging used for fresh horticultural produce handling include wood crates, corrugated shipping boxes, polymeric films pouches, bags, baskets, crates, trays, paper sheets, pouches, etc.[44] Recently plastics have replaced most of the convensionally used packaging materials for the horticulture industry, and will continue to do so in the future also like paper and wood. Current application of plastics in the horticulture is as follows :

- Plant and seed containers
- Tanks and pits
- Troughs, pans and buckets
- Packaging for fertilisers and chemicals
- Packaging for food stuffs.

Albaar, Budiastra and Hariyadi compared the wooden trays with the plastic trays for the packaging and transport of carrots. They found that the plastic trays have a lower water loss than that of wooden trays.[49] Also the percentage of carrot broken down during transport is found least in case of plastic trays.

The properties essential for packaging materials are decided by the physical and chemical characteristics of the product, as well as by the external conditions in which the product is stored/ transported. As plastics have a wide range of properties which can be tailored according to the product requirement, they are the most attractive materials for packaging applications. Polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), polyvinyl chloride (PVC), and polystyrene (PS) are the most common packaging plastics, accounting for more than 90% of the total volume of plastics used in packaging.Due to increasing environmental concerns, focus on research in bio-based sustainable plastic packaging materials has increased significantly in the past few years.ost of the synthetic plastics currently used for packaging are non-degradable and hence not friendly to environment. Bioplastics are biodegradable which resolves the problem of land filling. After disintegration and composting, bioplastics can be used as fertilizer and soil conditioner. The most promising bio-based polymers for future packaging applications are cellulose, chitosan, polylactic acid (PLA), and polyhydroxyalkanoates (PHA).[56,18,19]

Several properties are important in determining the suitability of polymers for packaging applications. Such properties depend on the type and structure of the polymer. The polymer properties most relevant for packaging applications can be broadly classified into morphology, barrier properties, mechanical properties, thermal properties, and optical properties. These properties strongly influence several key features of the finished packaging material such as strength, transparency, and the ability to seal off oxygen and water vapor.[18]

PROPERTIES AND APPLICATIONS OF CERTAIN COMMONLY USED POLYMERS IN PACKAGING IS GIVEN BELOW

POLYETHYLENE (PE) is currently the most common packaging plastic in use. It is produced from the polymerization of ethylene which in turn is obtained as a petrochemical product by thermal cracking of ethane and propane. Depending on the polymerization process conditions, different types of PE can be obtained.

PROPERTIES

Polyethylene is easy to process, tough, and flexible, has good chemical resistance and good barrier properties for moisture and water vapor.It is free from odor and toxicity, has excellent electrical insulation properties, and is easily heat sealable.

The PE shows poor barrier properties toward gases, oils, and fats. The PE is flammable and possesses lower thermal stability compared to other plastics used in packaging. It is a semi-crystalline polymer having varying degree of crystallinity.

Higher Crystallinity In Pe Leads To Improved Stiffness, Hardness, Tensile Strength, Opacity, Barrier Properties, And Heat And Chemical Resistance

- Properties of different types of PE vary with density, molecular weight, degree and type of branching, and degree of crystallization. Thus, different types of PE such as HDPE, MDPE, LDPE, LLDPE, VLDPE, and ULDPE are suited to different types of applications.

- The LDPE is a highly branched polymer, and consequently has low crystallinity. The LDPE is mostly used in manufacturing sheets and fi lms.
- The HDPE has higher crystallinity and melting temperature than LDPE because HDPE chains are relatively unbranched.[20,21]
- Applications
- PE is most commonly used packaging plastic worldwide.

Various general and industrial packaging applications of PE include bags for garments and grocery, trash bags, packaging for bakery, meat, poultry and dairy products, frozen food packaging, pharmaceutical and cosmetic products packaging, and packaging for pesticides, insecticides and fertilizers. [22]

POLYPROPYLENE (PP) is another common plastic used extensively in packaging applications. Its homopolymer is produced by catalytic addition polymerization of propylene. In the case of PP copolymer, a co-monomer such as ethylene is also used. An organo- metallic catalyst is used, which attaches to propylene, works as a functional group and reacts with the unsaturated bond of propylene to form a long chain polymer.[21,23]

PROPERTIES

- Polypropylene is a low cost plastic, having a density between LDPE and HDPE, but possessing higher thermal resistance due to the presence of a methyl group in the main chain.
- It has high chemical resistance, but has poor oxidative resistance due the presence of methyl group. Addition of antioxidants is therefore required for stability in applications involving oxidative environments.
- PP is nontoxic, easily processable, and has good dielectric and insulation properties, excellent clarity, and good mechanical properties.
- PP is very lightweight and has high-dimensional stability, making it suitable for replacement of metallic parts in automobiles.
- Ethylene propylene elastomers, produced by copoly- merizing propylene with ethylene, shows improved resistance to heat and oxidation, as well as favorable tensile and tear properties.[24,25]

APPLICATIONS

- Polypropylene is a versatile plastic with applications ranging from packaging to automobile and textile industry. It possesses properties similar to those of PE and hence, competes with PE in several product applications.
- It is generally used in packaging applications as an alternative to PE. Due to its higher stability, PE is generally preferred over PP in applications where the product is to be used in an oxidative environment.
- Textile industry is another major area of application for PP where it is primarily used to produce synthetic fibers.[23]
- Polyvinyl chloride (PVC) is a commercially important thermoplastic. It has a huge demand in the production of flexible goods, and has replaced metal, glass, wood, leather, and rubber in several applications. The PVC is synthesized by polymerization of vinyl chloride, which is produced by chemical reaction between chlorine and ethylene. Chlorine is obtained by electrolysis of sodium chloride solution, and ethylene is obtained as a petrochemical product.[21-27]

PROPERTIES

- It possesses good combustion resistance due to the presence of chlorine in polymer chain. When burnt, PVC generates hydrogen chloride gas that retards combustion reactions by limiting oxygen supply to the PVC surface.
- PVC, in its pure form, has low thermal stability and cannot be processed. Several additives are used in the synthesis of PVC due to which PVC displays a vast range of physical and chemical properties, and has most number of compounded products.
- Different additives used in PVC synthesis are plasticizers, impact modifiers, stabilizers, lubricants, fire retardants, blowing agents, fillers, and viscosity modifiers.
- Most of the physical properties of PVC are dependent on molecular weight. For example, its tensile strength, abrasion resistance, creep resistance, chemical resistance, and oil resistance increase with increasing molecular weight. Thus, properties of PVC can be tailored according to requirement by adding different additives, and by controlling the molecular weight of the polymer.[21.27]

APPLICATIONS

- Due to its versatile chemical and physical properties PVC is used for a wide range of applications.
- Applications include piping, building construction, clothing, wire insulation, molded automobile bodies, and toys.
- Addition of plasticizer to PVC improves its flexibility, toughness, and impact resistance, making it suitable for a variety of packaging applications.[20,21]
- Polystyrene (PS) is an addition polymer, which may be produced by bulk, emulsion or suspension polymerization of styrene. Styrene is obtained from ethylbenzene by catalytic dehydrogenation. It is a vinyl polymer in which hydrogen is replaced by phenyl group. Its copolymers can be produced using different monomers such as butadiene, acrylonitrile, ethyleneoxide, and divinylbenzene.[18]

PROPERITES

Properties of PS are highly dependent upon molecular weight and can be controlled by incorporation of different additives.

The properties which make it an attractive material for various applications are stiffness, good chemical resistance, absence of odor and toxicity, low water absorption, high transparency, and good electrical insulation property.

Foamed or expanded PS, which is obtained by heating polystyrene (PS) and blending with volatile liquid, has good thermal insulation properties.

Although, pure PS is brittle in nature, the brittleness can be reduced by blending it with copolymers.

Blended PS is known as high impact polystyrene (HIPS). [18,21,29]

Applications

The PS is primarily used in packaging of food and nonfood items.

Food packaging applications include packaging of meat and fish, egg cartons, fast food packaging, dairy products packaging, fruit packaging, and disposable food containers.

Nonfood packaging applications consist of packages for electronic instruments, audio cassettes and compact discs, cosmetics, pharmaceuticals, stationery, various machinery tools and accessories, and shipping packages for delicate equipments.[28]

Polyethylene terephthalate (PET) is a linear thermoplastic polymer, which was ini- tially commercialized for packaging carbonated soft drinks due to its excellent gas barrier properties that allows it to retain CO2. Raw materials used for production of PET are ethylene glycol and terephthalic acid. Production of PET is a two-step process: in the first step trans-esterification or esterification takes place, depending on whether terephthalic acid or dimethyl terephthalate is used, and in the second step polycondensation of resulting oligomers produces PET.[30]

PROPERTIES

The PET can exist in either amorphous or crystalline form, which increases its range of applicability to a wide variety of packaging applications.

It is a linear chain thermoplastic polymer due to which it can be easily converted from amorphous phase to crystalline phase by annealing or stretching above glass transition temperature.

Amorphous PET has high transparency, but is vulnerable to heat degradation.

Crystalline PET has good strength, rigidity, dimensional stability, water resistance, and thermal resistance.

Crystalline PET also possesses good chemical resistance, but not at the same level as PE or PP.

The PET has a high glass transition temperature and melting point, and can be easily recycled.

The PET possesses excellent gas barrier properties making it an ideal choice in several packaging applications.[31]

APPLICATIONS

Bottles produced from thick PET sheets are primarily used for packaging carbonated drinks, fruit juice, alcoholic drinks, mineral water, perfumes, and so on.

The PET films are used for food and pharmaceutical packaging.[18]

Starch is a natural polysaccharide that can be derived from inexpensive and renewable resources. Starch films and coatings are primarily used for food packaging. Natural and modified starch films are also used to change the physical properties of food products such as soups and meat products by modifying the texture, viscosity, adhesion, moisture retention, and gel formation.

Starch molecules are composed of two macromolecules namely amylose and amylopectin. The relative amount of amylose and amylopectin depends on the plant source and is a key factor in determining the properties of starch. [18,32].

PROPERTIES

- Starch is a biodegradable material.
- Amylose has excellent film-formability, and forms odourless, tasteless, and colorless films.
- Generally starch contains 20–25% amylose and 75–80% amylopectin.

APPLICATION

Starch films and coatings are primarily used for food packaging.

Used in making paperboard and corrugated boxes.

Starch can be transformed also into a foamed material usingwater steam, replacing the polystyrene foamas packagingmaterial.

It can be pressed into trays or disposable dishes anddissolves in water leaving a non-toxic solution.[61]

Cellulose is the most abundant natural polymer, and is a key structural component of plant cell walls. The main source of cellulose production is wood, which contains 40–50% cellulose by weight. It is a linear polysaccharide having a hydroglucose as the fundamental repeat unit.

PROPERTIES

Cellulose is found in all plant material and is thus a very inexpensive natural resource.[62]

Cellulose is crystalline, infusible and insoluble in water, and most organic solvents, which makes it unsuitable for film production. Therefore, cellulose is converted to cellophane by dissolving insodium hydroxide and carbon disulphide mixture and extruding into a bath of sulfuric acid.

Cellophane has good mechanical strength, superior oil barrier property, and good gas barrier properties at low relative humidity.

It is moisture sensitive. To improve moisture barrier properties,Cellophane is generally coated with nitrocellulose wax or PVDC.

Other than cellophane, cellulose can be converted to various derivatives such as cellulose acetate, ethyl cellulose, hydroxyl-ethyl cellulose, and hydroxyl-propyl cellulose, which are commercially available.

Films cast from cellulose derivatives are tough, flexible, totally transparent, and highly sensitive to presence of water, but resistant to fats and oils.[18,32, 33,34]

APPLICATION

It is incorporated in various ratios with other synthetic and natural polymers in various ratios to obtain variable properties.

Cellulose nanofibres and nanocellulose particles are widely incorporated to bring biodegradability, strength, etc to the package.

Chitin is second most abundant natural biopolymer occurring primarily as a component in the exoskeletons of insects and crustaceans. Chitin also occurs naturally in fungal cell walls and can be produced by cultivation of fungi. Chitin can be recovered from crustacean wastes by simple demineralization and deproteinization processing steps . Chitosan, a derivative of chitin, is obtained by deacetylation of chitin.

PROPERTIES

Due to its rigid and crystalline structure and strong intra and intermolecular hydrogen bonding, chitosan is insoluble in water and alkaline medium.

It is biodegradable, biocompatible, and non-toxic.

Clear, tough, flexible films having good oxygen barrier properties can be cast from chitosan without the use of any additives .

In addition, chitosan shows antimicrobial activity against bacteria, yeasts, and mold, making it an attractive material for food packaging films.

The major drawbacks of chitosan films are low stability and poor water vapor barrier property.[35,18,36,34]

APPLICATIONS

The use of edible films and coatings to extend shelf life and improve the quality of fresh, frozen and fabricated foods.[59]

Proteins are biopolymers comprised of long chains of amino acids. The barrier prop- erties of proteins are determined by the polar characteristics of protein films. Casein and gluten are two major protein based materials, which exhibit properties favorable for Food packaging.Gluten, commonly found in wheat and corn, is an excellent film forming agent. However, the films formed by gluten are brittle in nature and require addition of plasticizers for mechanical stability.Corn zein, soy protein, whey protein, peanut protein, collagen and gelatin are some of the other protein materials which have been studied and utilized for packaging application.

PROPERTIES

Protein films have high permeability to polar substances such as water and low permeability to nonpolar substances such as oxygen, oils and several aroma compounds.

Their moisture sensitivity can be reduced by blending protein with other bio-based or synthetic materials.

Flexibility and extensibility of protein films can be improved by the use of plasticizer.

Due to its excellent mechanical and barrier properties casein has been used in food packaging applications.

Wheat gluten films show humidity dependent water vapor and gas permeability, so gas and water vapor composition can be optimized by controlling the humidity level in packages.

Corn zein possesses good oxygen barrier property and excellent WVP (about 800 times higher than that of a typical shrink-wrap film).

It is commercially used in coating preparation for shelled nuts, candy and pharmaceutical tablets.[18, 32, 37, 38]

POLY(LACTIC ACID) is a bio-derived polymer having the potential to replace polyethylene (PE), polystyrene (PS), polypropylene (PP), and polyvinyl chloride (PVC). Poly(lactic acid) (PLA), an aliphatic polyester, has outstanding advantages over other polymers, and may thus be part of the solution. As early as the 1970's, PLA products have been approved by the US Food and Drug Administration (FDA) for direct contact with biological fluids. PLA is derived from renewable and degradable resources such as corn and rice, which can help alleviate the energy crisis as well as reduce the dependence on fossil fuels of our society.[41] Polylactic acid (PLA) is at present one of the most promising biodegradable polymers (biopolymers). PLA was introduced as a packaging material and started being produced at a commercial level about ten years ago. It has attracted attention mostly because of its sustainable nature. It is synthesized from processed corn or other naturally produced carbohydrates, thus it is a bio-based material, and it biodegrades after use under industrial composting conditions. PLA can be used for the development of transparent thin films suitable for food packaging. [43][5]

PROPERTIES

It is biodegradable, renewable, and made from agricultural raw materials.[39]

Four of the most attractive advantages are renewability, biocompatibility, processibility, and energy saving.

PLA can be processed with a large numberof techniques and is commercially available (large-scale production) in a wide range of grades.

It is relatively cheap and has some remarkable properties, which make it suitable for different applications. [40]

PLA has a relatively low glass transition temperature (typically between 111 and 145 °F). This makes it fairly unsuitable for high temperature applications.

APPLICATIONS

Some of the most common uses include plastic films, bottles, and biodegradable medical devices (e.g. screws, pins, rods, and plates that are expected to biodegrade within 6-12 months).

PLA constricts under heat and is thereby suitable for use as a shrink wrap material.

Additionally, the ease with which Polylactic Acid melts allows for some interesting applications in 3D printing (namely "lost PLA casting"). [60,61]

S.N0	POLYMER	PROPERTIES	APPLICATIONS
1	POLYETHYLENE(PE)	· easy to process	· commonly used in flexible packaging
		· tough and flexible	· used in manufacturing of jars.
		· good barrier for moisture and water vapour	· Used in laminates
		· free from odour and toxicity	
		· good chemical resistance	
2	POLYPROPYLENE(PP)	· High chemical resistance	· It is used in manufacturing of sacks used for storage of vegetables
		· Poor oxidative resistance	
		· Lightweight and good dimensional stability	
3	POLYVINYL CHLORIDE(PVC)	· Low thermal stability	· Used in variety of packaging products
		· Flame retardant property	
		· Versatile chemical property	
4	POLYSTYRENE(PS)	· Stiffenss	· Packaging of meat and fish, egg cartons, fruit packaging tray
		· Good chemical resistnce	· Disposable food containers for green vegetables and fruit
		· Low water absorption	
		· High transperancy	
		· Foamed or expanded PS has good thermal insulation properties	
		· PS is brittle in nature	
5	POLYETHYLENE TEREPHTHALATE(PET)	· Exist in either amorphous or crystalline	· PET bottles are used for packaging of carbonated drinks, fruit juice, alcoholic drinks, mineral water
		· High transperancy	· PET films are used for food
		· Good strength, rigidity, dimensional stability	
		· Water resistance and thermal resisitance	
		· High Tg and Tm	
		· Possesses excellent gas	

		barrier properties	
		· easily recyclable	
6	STARCH	· Natural polymer	· Used in biodegradable films for food packaging
		· Inexpensive and renewable	
		· Odorless	
		· tasteless	
7	CELLULOSE	· Natural polymer	· Used for films
		· crystalline	
		· Renewable	
		· Produced from plant source	
		· Moisture sensitive	
		· Tough and flexible	
		· Resistant to fats and oils	
8	CHITIN	· Produced from plant and animal source	· Used for packaging films
		· Biodegradable, biocompatible and non-toxic	
		· Transparent, flexible	
		· oxygen barrier properties	
		· shows antimicrobial activity against bacteria, Yeasts	
		· poor water vapor barrier property	
9	PROTEIN	· biopolymers	· Used for packaging films
		· excellent foaming agent	
		· high permeability to polar substance such as water	
10	POLY(LACTIC ACID)	· biodegradable, renewable	· Used for packaging films
		· non toxic	

EDIBLE COATING ON HORTICULTURE PRODUCTS

Edible coating is a thin layer directly applied on the surface of by any technique and could be eaten. The most important function of an edible coating is to improve the quality of products onto which it is applied and its shelf life. The two major characteristics

It acts as a natural barrier against various environmental factors l ike temp, RH, Atmosphereingredients used to make it are derived from foods which are both biodegradable as well as edible, mainly Polysacchiride, Proteins and Lipids.

It could be eaten along with the food and henve waste generation is minimised

The material can be applied on the product by either dipping, spinning or panning. These films are environment friendly as there is no waste generation. These films have many extraneous effect . it prevents maturation and oxidative browning. Also helps in retainment of firmness and moisture. Due to these films, the moisture loss in produce decreases, hence the microbial grs slow, which leads to an increment in shelf life. [54,55,56,37]

Edible coatings or edible films have been used for centuries in the food industry to preserve food products this is not a new preservation technique. For example waxing on fruits and vegetables and cellulose coating in meat casings. Edible coatings have been used since 12th century in China. It was not until 1922 the waxing on fruits was invented and first time was commercially applied on fruits and vegetables. Edible films and coatings form a barrier for chemical, physical and biological changes.

At the time of purchasing fruits and vegetables, consumer judge the freshness and quality of the produce on the basis of its appearance. The most common and challenging problem are to maintain and control fresh quality, growth of spoilage and pathogenic microorganism in fresh cut fruit industry. The solution of this problem is edible coating. Edible coating provides an additional protective coating for fresh fruits and vegetables and can also provide the same effect as modified atmosphere storage in modifying internal gas composition. Recently, various edible coatings were applied successfully for preserving fruits and vegetables such as orange, apples, grapefruit, cherries, cucumber, strawberry, tomato and capsicum were applied successfully. Edible coating of fruits and vegetables is successful or not totally depends on the control of internal gas composition. [55]

PRESENT TECHNOLOGIES FOR PACKAGING OF HORTICULTURE PRODUCTS

In recent days, apart from individual shrink wrapping, CA storage, surface coating etc., there also have been reports of different methods of polymeric film packaging of fresh produces to increase the shelf life. Those methods include MAP, MAP in ventilated films, vacuum packaging, shrink packaging, cling film wrapping etc.[45]

MODIFIED ATMOSPHERE PACKAGING (MAP) is well-proven postharvest technology for preserving natural quality of fresh and minimally processed produce, and extending the storage life under optimum MAP design and storage conditions. Successful MAP design is achieved by the mathematical integration of dynamic produce physiological characteristics, properties of packaging material, coupled with optimum equilibrium atmospheric conditions for the given product.[47]

It is well established that package gas composition in modified atmosphere packaging (MAP) is influenced by respiration rate of the product and the gas permeability of the packaging film. Current MAP design considers the respiration rate of product as the only important parameter for deciding target gas barrier properties required to achieve an equilibrium modified atmospheres. However, besides in-package gas composition it is also important to control the in-package level of relative humidity, in order to avoid condensation and/or mould and bacterial development in MAP systems.[17]

Modified atmosphere packaging (MAP) relies on changing the surrounding gas composition by the interplay between the film permeability to gases (O2 and CO2) and respiration rate (RR) of produce inside the package. Various researchers have reported that MAP system is capable of maintaining the quality of fresh produce if the optimum gas compositions and permeability of the film are designed properly. However, designing MAP systems is a complex task, which involves the need to understand the dynamic interaction and integrated knowledge of product characteristics, packaging material, and atmospheric conditions for the given product. Good MAP design should also enable accurate prediction of these important parameters such as gas concentration, RR and film permeability and prediction is possible with the help of mathematical models. Various studies reported that mathematical models are useful to specify and relate input parameters such as RR, transpiration rate (TR), as well as gas permeability to the film thickness, storage temperature, time, product weight, and heat and mass transfer.[47]

EQUILIBRIUM MODIFIED ATMOSPHERE PACKAGING (EMAP) for dynamically modifying the in-package atmosphere are used for extending the shelf life of high value fresh produce.Equilibrium modified atmosphere packaging (EMAP) is used for prolonging their quality characteristics such as freshness, colour and aroma.[43]

EMAP is ideal for exports, long haul transportation and retail packaging. This is achieved by modifying the permeability of the packaging film, usually through perforation, in order to optimally regulate the equilibrium concentrations of O2 and CO2. When packaging vegetables and fruits in EMAP, the gas atmosphere of package reaches equilibrium, consisting usually of a lowered level of O2 and an increased level of CO2. This kind of package slows down the normal respiration of the product and so prolongs the shelf-life of the product.

The effect of the EMAP gas atmosphere on slowing down respiration is attributed to low O2 levels and possibly to increased CO2 levels. The effect of the range of the gases levels on respiration depends however very much on the produce/ cultivar and temperature. For example, for tomatoes, the combination of both low O2 levels and increased CO2 levels results in slowing down the normal respiration.

The in-package RH has also to be regulated, since it is responsible either for the excessive weight loss or for enhancing fungal spoilage of the fresh produce. The growing popularity of EMAP for vegetables and fruits can be explained with the behaviour of the modern consumer who demands fresh vegetables and fruits which have a long shelf-life without the use of preservatives. As EMAP enables processors to extend shelf-life without using chemicals it is also ideal for the packaging of organic produce.The most commonly used films for equilibrium modified atmosphere packaging are made of low density polyethylene (LDPE) and of isotactic polypropylene (PP). Both plastics can be formulated into films of adequate strength. In addition, both LDPE and PP are rather inexpensive, but not biodegradable materials.[5]

CONTROLLED ATMOSPHERE PACKAGING (CAP)

In controlled atmosphere packaging (CAP), the gaseous environment over a food product is constantly altered to meet the food shelf life demands. The altered gaseous compo- sition is dynamically maintained throughout storage and distribution. In contrast, modified atmosphere packaging involves only an initial alteration of gaseous composition at the time of packaging with no further alterations thereafter. In CAP, continuous monitoring and control of gas compositions, temperature and moisture content are required within the package. To keep the environment unaltered inside the package, the package should have high barrier properties.[50,18]

ADVANCEMENTS IN THE PACKAGING OF HORTICULTURE PRODUCTS

Micro- perforated packaging films are commonly used in fresh produce packaging to enhance O2 and CO2 gas permeability and achieve equilibrium MAP. But generally such films do not allow the diffusion of sufficient amounts of water vapour into the environment leading to high humidity levels and condensation of water vapour in the package. A possible solution to control humidity is to use of moisture absorbers to remove excess moisture from the packaging headspace. These moisture absorbers have beneficial effect on the shelf life by lowering the surface moisture content, reducing microbial growth and better colour preservation.[17]

Recently a humidity regulating packaging system has been developed. It consists of 3-layer structure: barrier layer, active layer with NaCl and sealing layer. The active layer consisted of polypropylene with different percentage of NaCl and it was foamed and stretched in order to form cavities around salt particles.[17]

PARTICLE FILM TECHNOLOGY

is also being used in the horticultural packaging. These are chemically inert biological films used to minimise the hazardous effect caused by microorganisms, insects, UV radiations, diseases, and helps in improving the finish of the product like colour, texture of the surface, Yield and post-harvest quality. These films have resulted in additional benefits of reducing damage due to insects and pathogens, and also enhanced the Yield. The first particle film was synthesised by EGELARD Corporation, Iselin, New Jursey in 1999 for commertial application and was named SURROUND. The film is further formulated or compounded to be used as coating in both agricultural as well as horticultural industries. [42]

Hypobaric system of food packaging and storage is growing with a good pace. There are a plenty of researches doing with this system, but most of them have unwanted result where major water loss is due to leakage in the container.

According to Burg and Davenport hypobaric system represents a system of relatively lower pressure with respect to the atmosphere generally pressure range for this system is 0.1 – 0.5 bar which gives a relative humidity of around 90-95%. He tested Red roses for 35 days , only 6.78% of water was lost during the interval. [52]

CONCLUSION

Horticulture packaging is a boon to the agriculture. The horticulture products like fresh fruit and vegetables need to pave its way to our daily diet with maximum nutritional value, this requires a good economical packaging system. The packaging protects the products from various effecting factors like change in the temperature, RH, microbial growth, freeze damage, UV rays, water loss and also reduces the physical damage by vibrations, compression and loading. Packaging has proved its economical imporatnce by saving upto 60-80% of the waste previously produced leading to a billions of dollars. A good packaging must bear all the load on itself and protect the content of packaging.

Due to the active post-harvest metabolism of the horticulture products, they have a short shelf life. Hypobaric packaging system increases the shelf life of products by upto 30 times.

Recently , bio-based packaging systems made their way to the food and horticulture packaging because of two main main reasons i.e., bio-based and biodegradable hence environment friendly. They are gradually replacing the synthetic plastic which are developed from the diminishing petroleum source. Edible coating has been successfully used which has futher lead to reduction of waste.

The recent advancement in packaging technology introduced many new technology like particle films, hypobaric systems, etc. within the MAP, CAP, EMAP systems which have increased the shelf life of the horticulture products. The various advanced methods are helping the society to live a better life by getting the maximum nutrition which is important for proper growth and development

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