



Recent Advances in Packaging and Edible Coating for Shelf Life Enhancement in Fruit Crops

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Authors' contributions

This work was carried out in collaboration among all authors. Author TA designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors SS and AS managed the analyses of the study and edited the written manuscript. Author PPSG guided to write the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

In today's competitive world, packaging and edible coating play a significant part in producing usefulness user affable products for marketing. Due to several drawbacks of conventional packaging materials (wooden boxes, gunny bags, pallet, pallet bins, Wire-Bound Crates etc.) new technologies of polymeric films (LDPE, HDPE, Shrink film, Cling film) are adopted. By use of polymeric film (non perforated) modified atmosphere is obtain within the package, which subsequently helps to enhance shelf life of fruits. Application of thin layers of edible coating onto fruit surface helps to modify inner environment of fruit which causes similar effect to the modified atmospheric storage. This technological strategies are helpful to retard water loss, reduces skin damage caused by friction, changes in gaseous composition, moisture content, volatile aromas, and transport of solutes from the fruits overly enhance cosmetic appearance, decreasing ripening process and rise shelf life of fruits.

Keywords: Packaging; edible coating; fruit; shelf life.

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1. INTRODUCTION

Fruits are extremely perishable in nature as they contain 80–90% of water by weight [1]. Significant losses in quality and amount of fresh fruits happen among utilization and consumption. After the harvesting of fruits, the rate of gaseous exchange increase, resulting in to a loss of metabolic activity and eventually leading to gradual maturation and senescence of fruits. The internal and external factors are responsible for the transfer of gases. The growth stage, species and cultivar are internal factors, while the atmospheric composition (O₂, CO₂, and ethylene), temperature, and other stress factors are external factors [2]. In addition, defilement of the fruit begins from the skin, further expanding the fruit spoilage, inward searing, off-flavor advancement, and surface breakdown resulting in to decline in quality of fruit and chance to consumer due to disease causing microorganisms like *Salmonella sp.*, *E. coli* [3,4, 5]. For increasing the postharvest life of food products is critically dependent upon three factors: (i) reduction in desiccation, (ii) reduction in the physiological process of maturation and senescence, and (iii) reduction in the onset and rate of microbial growth [6]. Several postharvest techniques used for fruit preservation includes packaging, edible coating etc. which improves the fruit quality as well as prevent losses.

Different packaging techniques and edible coatings on fresh fruits are alternative to modified atmosphere storage through modification of the internal atmosphere of the individual fruit. Packaging not only protects and preserves fruits but also ensures safe transportation during storage and handling. Increasing exports and stringent export market demands have influenced the packaging trend. The shelf-life of fruits is increasing by use of edible coatings which contribute to extend slow down moisture losses, solute migration, gas exchange, respiration & oxidative reaction rates and also reduces or suppresses physiological disorders [7,8]. The active ingredients such as anti-browning agents, colorants, favours, nutrients, spices, and antimicrobial compounds are present in edible coatings which have a high potential to extend shelf-life and reduce the chance of pathogens which conduct fruit spoilage [9]. Moreover, these edible coatings are composed of biodegradable raw material, thereby reducing the risk of synthetic packaging waste.

2. PACKAGING

Packaging is the science and technology for preservation of fruit quality and allows safe transportation. It helps to extend the marketing period by providing an additional layer of protection to keep the items safe for consumption and also provides a barrier against pathogen infestations, thus helping distributors and retailers reduce food waste. Packaging prevents food from spoilage under normal conditions and therefore allows it to be consumed safely over a longer period of time. Therefore, through the use of technologies that include postharvest preservation and packaging, the quality parameters of produce that include the human sensory responses to taste, smell, texture, and appearance (color) plays a key role in maintaining or extending the physiological degradation of fresh fruits over days, weeks, and months.

2.1 Development of Transport Pack for Consumer

To hold a suitable numbers of consumer packs for the transportation, outer boxes have been developed. These transport boxes are developed from corrugated fibre board as per the international practice, taking into consideration the following factors.

- Nature of the produce
- Net weight of contents
- Stacking during transportation
- Mode of transportation
- Modularity with Euro pallets.

2.2 Palletisation - Transport Pack for Consumer Packs

The consumer packs of selected fresh fruits are packed in outer transport packs and exported by air. The loads are generally palletised. The two standard dimensions of Euro pallets for fresh produce are:

The suggested transport pack dimensions are modular to the Euro pallets [10].

- a) 1200 mm x 1000 mm
- b) 1200 mm x 800 mm

In addition to above IATA pallet sizes were also considered. These are:

- a) IATA A 3070 mm x 2130 mm
- b) IATA B 3070 mm x 2340 mm

3. TYPES OF PACKAGING

3.1 Conventional Packs

In order to obtain optimal shelf-life, it is essential to minimize the physical damage to fresh produce. The most common form of packaging is the use of the fiberboard carton; however, for most of the produce, additional internal packaging like tissue paper wraps, trays, cups or pads, are required to reduce damage caused from abrasion. For delicate fruits, smaller packs with relatively few layers of fruits are used to reduce the compression damage. Moulded trays are also used which physically separates the individual pieces of produce or individual fruits may be wrapped separately in tissue or waxed paper. This improves the physical protection and reduces the spread of disease causing organisms within a pack [11].

3.2 Features and Specifications

3.2.1 Plastic pouch

The flexible heat sealable pouches are provided with a number of holes which allows the air to circulate in and around the pack and help in prolonging the shelf-life of the fresh produce.

3.2.2 Plastic punnets with lids

Punnets are clean bright containers which offer product visibility. Holes provide ventilation and circulation of air thereby retaining the freshness of the produce. The containers are light weight, stackable and recyclable.

3.2.3 EPS tray

These trays are clean, neat in appearance and light in weight. They give a cushioning effect to the products packed inside. The trays can be easily moulded in any size and shape. The materials used can be easily cleaned, re-used and is also recyclable.

3.2.4 Stretch film/cling film

The stretch film is a transparent film with the property of clinging to the packed product when stretch wrapped. It can be used without application of heat. The film is semi-permiable and allows exchange of gases for respiration of the produce.

3.2.5 Jute bag

The mesh of the fabric helps in providing ventilation to the product. Jute bags can be made

in to any shape and size by machine or hand stitching. The nature of the fabric allows usage of hooks without much damage to the material and hence it is preferred by the exporters. However, the disadvantages of jute are that it can easily get infested and decayed and is not very hygienic in nature.

3.2.6 Leno /raschel/ net bags

All the three types of bags provide good aeration and strength. The bags are resistant to moisture, fungal and insect damage. These bags are soft and pliable and provide visibility to the product packed inside. These bags do not impart odour to the product packed inside and are recyclable and reusable. By allowing the air to circulate in and around the pack and by keeping flies and insects away, these bags prolong freshness and shelf-life of the fruits and vegetables. They also eliminate pack condensation thereby preventing spoilage and wastage.

3.2.7 Moulded pulp tray

It is made up from recycled substance and is non-polluting. The abrasion and bruising is avoided during transport so produce is placed in individual cavities. The tray also supply a cushioning effect to the produce.

3.3 Modified Atmosphere Packaging (MAP)

To control of water loss, protection from skin abrasion and decreased contamination of the produce during handling polymeric films have been used to package fresh products. They also supply a barrier to the spread of spoil from one unit to another [12]. These films will also affect the movement of respiratory gases depending on the relative permeability of the film. This can lead to the development of lowered O₂ and raised CO₂ levels within the package, this can decrease the respiration of the produce and potentially increase shelf-life.

Within the pack in two ways modified atmosphere (MA) can be created. Active moderation require the pulling of a slight vacuum within the pack and then replacing the atmosphere with the desired gas mixture. Absorbers (active packaging) of CO₂, O₂ or ethylene may be included within the pack to control the concentration of these gases. In passive modification systems, the atmosphere is attained through the respiration of the commodity

within the pack. The final equilibrium atmosphere will depend on the characteristics of the commodity and the packaging film [12]. The control of temperature is highly important with MAP, as this will effect the gas permeability belongings of the fibre as well as the respiration rate of the product. One of the main drawbacks to MAP is the potential for O₂ levels to fall too low and cause the production of undesirable off-odours caused by fermentation of the tissues. The MA packaging technique consists of the enclosure of respiring produce in polymeric films in which the gaseous environment is actively or passively altered to slow respiration, reduce moisture loss and decay and/or extend the shelf life of the products. Many of the films used in MAP, singly do not offer all the properties required for a modified atmosphere pack. To provide packaging films with a wide range of physical properties, many of these individual are combined through processes like lamination and co-extrusion. There are several groupings in MAP films. Polyethylene is most commonly used to provide a hermetic seal and also as a medium of control for characteristics like anti-fogging abilities, peelability and ability to seal through a degree of contamination. For highly respiring produce low-density polythene (PE-LD), poly vinyl chloride (PVC), ethylene/vinyl acetate (EVAC), oriented polypropylene (OPP) and cellulose acetate are not sufficiently permeable. Such highly respiring produce is most suitably packed in highly permeable microperforated films. The permeabilities of two commercial ceramic-filled PELD films were measured and compared with those of a plain PE-LD film. Furthermore, films can be laminated to achieve needed properties. Among this class are high (6–18%) EVAC content, PE-LD, oriented polypropylene laminates, styrene butadiene block copolymer films and ultralow-density ethylene octene copolymer films and polyolefin plastomer octene copolymer films. Films using micro perforations can attain very high rates of gas transmission [13].

Also a procedure to maintain desired levels of O₂ and CO₂ inside packages that are exposed to different surrounding temperatures was designed and tested and modeled. Useful models have been developed that would allow fresh produce processors to choose packaging materials most suited to the enclosed product. A common mathematical model involves the use of what is known as a Michaelis–Menten type respiratory model to describe the influence of temperature,

O₂ (and potentially CO₂) on respiration. This approach has been used for blueberries [15], strawberries [16], raspberries [17] and apple slices [18]. Respiratory models are then coupled with an equation describing the temperature sensitivity of film permeability to gases (known as the Arrhenius equation) to predict package O₂ partial pressure as a function of temperature, product mass, surface area and lm thickness [15, 18].

3.4 Antimicrobial Packaging

The potential alternative to enhance the safety of fresh-cut produce is the use of edible coatings as carriers of antimicrobial compounds. Antimicrobial edible coatings may provide increased inhibitory effects against spoilage and pathogenic bacteria by maintaining effective concentrations of the active compounds on the food surfaces. There are several categories of antimicrobials that can be potentially incorporated into edible coatings, including organic acids (acetic, benzoic, lactic, propionic, sorbic), fatty acid esters (glyceryl monolaurate), polypeptides (lysozyme, peroxidase, lactoferrin, nisin), plant essential oils (cinnamon, oregano, lemongrass), nitrites and sulphites, among others [20]. Although several types of antimicrobials incorporated into edible coatings have been used for extending shelf-life of fresh commodities, their use in fresh-cut fruits is yet limited. Currently, organic acids and plant essential oils are the main antimicrobial agents incorporated into edible coatings for fresh-cut fruits. Despite the good results achieved so far with the incorporation of essential oils into edible coatings, the major drawback is their strong flavour which could change the original taste of foods. To confer antimicrobial activity, antimicrobial agents may be coated, incorporated, immobilized, or surface modified onto package materials [21].

Antimicrobial films can be classified into two types: those that contain an antimicrobial agent which migrates to the surface of the food and, those which are effective against surface growth of microorganisms without migration. It should be considered as a hurdle technology that in addition with other non-thermal processes such as pulsed light, high pressure and irradiation could reduce the risk of pathogen contamination and extend the shelf-life of perishable food products [22].

Table 1. Gas permeability and Water transmission rate of different polymeric films:[14]

Film	Permeability (C/m ² day atm) for 25 µm film at 25 C			WTR (g/m ² /day/atm) at 38°C, 90% RH
	O ₂	N ₂	CO ₂	
Ethylene- vinyl alcohol (EVAL)	3-5	-	-	16-18
PVdC-PVC copolymer (Saran)	9-15	-	20-30	-
Low-density polythene (PE-LD)	7800	2800	42000	18
High-density polyethylene (PE-HD)	2600	650	7600	7-10
Polypropylene cast (PPcast)	3700	680	10000	10-12
Polypropylene, oriented (OPP)	2000	400	8000	6-7
Polypropylene, oriented, PVdC coated (OPP/PVdC)	10-20	8-13	35-50	4-5
Rigid poly(vinyl chloride) PVC	150-350	60-150	450-1000	30-40
Plasticized poly(vinyl chloride) (PVC-P)	500-30000	300-10000	1500-46000	15-40
Ethylene-vinyl acetate(EVAC)	12500	4900	50000	40-60
Polystyrene, oriented (OPS)	5000	800	18000	100-125
Polyurethane (PUR)	800-1500	600-1200	7000-25000	400-600
PVdC-PVC copolymer (Saran)	8-25	2-2.6	50-150	1.5-5.0
Polyamide (Nylon-6), (PA)	40	14	150-190	84-3100

Table 2. Recommended gas mixtures for different fruit crops [19]

Fruits	O ₂ (%)	CO ₂ (%)	N ₂ (%)
Apple	1–2	1–3	95–98
Apricot	2–3	2–3	94–96
Avocado	2–5	3–10	85–95
Banana	2–5	2–5	90–96
Grape	2–5	1–3	92–97
Grapefruit	3–10	5–10	80–92
Kiwifruit	1–2	3–5	93–96
Lemon	5–10	0–10	80–95
Mango	3–7	5–8	85–92
Orange	5–10	0–5	85–95
Papaya	2–5	5–8	87–93
Peach	1–2	3–5	93–96
Pear	2–3	0–1	96–98
Pineapple	2–5	5–10	85–93
Strawberry	5–10	15–20	70–80

3.5 Active Packaging

Active packaging employs a packaging material that interacts with the internal gas environment to extend the shelf-life of a food. Such new technologies continuously modify the gas environment (and may interact with the surface of the food) by removing gases from or adding gases to the headspace inside a package.

3.5.1 Ethylene scavenging

A chemical reagent, incorporated into the packaging film, traps the ethylene produced by ripening fruit or vegetables. The reaction is irreversible and only small quantities of the scavenger are required to remove ethylene at the concentrations at which it is produced.

3.5.2 Oxygen scavenging

The presence of oxygen in food packages accelerates the spoilage of many foods. Oxygen can cause off-flavour development, colour change, nutrient loss and microbial attack. One of the most promising applications of oxygen scavenging systems in food packages is to control mould growth.

3.5.3 Carbon dioxide

High carbon dioxide levels are desirable in some food packages because they inhibit surface growth of microorganisms. However with the introduction of modified atmosphere packaging there is a need to generate varying concentrations of carbon dioxide to suit specific food requirements. Since carbon dioxide is more

permeable through plastic films than is oxygen, carbon dioxide will need to be actively produced in some applications to maintain the desired atmosphere in the package.

3.5.4 Sulphur dioxide

Serious loss of table grapes can occur unless precautions are taken against mould growth. It is necessary to refrigerate grapes in combination with fumigation using low levels of sulphur dioxide. Fumigation can be conducted in the fruit cool stores as well as in the cartons. Carton fumigation consists of a combination of quick release and slow release systems which emit small amounts of sulphur dioxide. When the temperature of the cartoned grapes rises due to inadequate temperature control, the slow release system fails releasing all its sulphur dioxide quickly. This can lead to illegal residues in the grapes and unsightly bleaching of the fruit [23].

3.6 Smart or Intelligent Packaging

Smart packaging uses features of high added value that enhance the functionality of the product, notably mechanical, electronic and responsive ink features, for example electronic and mechanical dispensers in which drugs are supplied and the prepared meal that automatically tells the microwave how it should be cooked. Smart packaging can be categorized into two types, those which incorporate integrated circuits (IC's) and does which do not incorporate IC's otherwise known as chipless smart packaging. Packaging that incorporate diagnostic indicators are also included in smart packaging. These can be used for such functions

as monitoring vibration, acidity, tilt, shock, humidity, light, heat, time chemicals, virus or bacteria as they develop or as they are contacted. Fresh-cut produce continues to be one of the fastest growing segments of food retailing and while conventional film packaging is suitable for lettuce and prepared salads, it cannot cope with the high respiration rates of pre-cut vegetables and fruit, leading to early product deterioration. Novel breathable polymer films are already in commercial use for fresh-cut vegetables and fruit. Packaging films are acrylic side chain crystallized polymers tailored to change phase reversibly at various temperatures from 0-68°C are available. As the sidechain components melt, gas permeation increases dramatically, and by further tailoring the package and materials of construction, it is possible to fine tune the carbon dioxide to oxygen permeation ratios for particular products. The final package is 'smart' as it automatically regulates oxygen ingress and carbon dioxide egress by transpiration according to the prevailing temperature. In this way, an optimum atmosphere is maintained around the product during storage and distribution, extending freshness and allowing shipping of higher quality products to the consumer. Intelligent packaging can also change colour to let the customer know how fresh the food is and show if the food has been spoiled because of a change in temperature during storage or a leak in the packaging. Time temperature integrators (TTI's) are devices that show an irreversible change in a physical characteristic, usually color or shape, in response to temperature history. The TTI's are expected to mimic the change of a certain quality parameter of the food product undergoing the same exposure to temperature. The TTI's presently on the market have working mechanisms based on different principles: biological, chemical and physical. For the first type, the change in biological activity, such as microorganisms, spores or enzymes is the basic working principle. The others are based on a purely chemical or physical response towards time and temperature, such as an acid-base reaction, melting, polymerization, etc [24].

Fresh-Check®LifeLines integrator is supplied as self-adhesive labels, which may be applied to packages of perishable products to assure consumers at point-of-purchase and at home that the product is still fresh. It is commonly referred to as having a bull's eye configuration [25].

Vitsab® Indicator is a full history integrator based on an enzymatic reaction. The device consists of

a bubble-like dot containing two compartments: one for the enzyme solution, lipase plus a pH indicating dye compound and the other for the substrate, consisting primarily of triglycerides. The dot is activated at the beginning of the monitoring period by application of pressure on the plastic bubble, which breaks the seal between compartments [26]. The ingredients are mixed and as the reaction proceeds a pH change results in a color change. The dot, initially green in color, becomes progressively yellow as product approaches the end of shelf-life. ripeSense™ is the world's first intelligent ripeness indicator label. ripeSense™ evolved from the simple idea of making a fruit label that is capable of more than just branding product and this has led to the next revolution in fresh produce marketing. The 3M Monitor Mark uses a coloured ester and phthalate mix with the desired melting point that is coloured with a blue dye. Above its melting point it diffuses along a wick, and the progress along this wick gives an indication of how long the indicator has been liquid [27].

3.7 Biodegradable Packaging

Currently, there are several types of bio-based polymers on the market: some coming from petrochemical monomer, like certain types of polyester, polyester amides and polyvinyl alcohol, produced by different manufacturer, used principally as films or moulding. Four other bio-based polymers are starch materials, cellulose materials, polylactic acid (Polyester, PLA), polyhydroxy acid (polyester, PHA). Until now, the PHA polymer is a very expensive polymer because it is commercially available in very limited quantities. PLA is becoming a growing alternative as a green food packaging materials because it was found that in many situations it performs better than synthetic ones, like oriented polystyrene (OPS) and PET materials [28]. There is an increasing demand for identifying biodegradable packaging materials and finding innovative methods to make plastic degradable. Biodegradation is the process by which carbon-containing chemical compounds are decomposed in the presence of enzymes secreted by living organisms. The use of bioplastic is to replicate the life cycle of biomass by conserving the fossil fuels, carbon dioxide and water production. There are three requirements for the fast degradation process viz. temperature, humidity and type of microbes. In the short term, biobased materials will most likely be applied to foods requiring short-term chill storage, such as

fruits and vegetables, since biobased materials present opportunities for producing films with variable CO₂/O₂ selectivity and moisture permeability. However, to succeed, biobased packaging of foods must be in compliance with the quality and safety requirements of the food product and meet legal standards. Additionally, the biobased materials should preferably preserve the quality of the product better and longer to justify any extra material cost [29].

3.8 Application of Nanocomposites

Nanocomposite materials are composed of nanoscale structure that enhances the macroscopic properties of food products. The common nanocomposites used in the food packaging industry are (i) Polymer clay nanoclay (ii) Silica nanocomposites of nanosilver. The effects of nanoclay in polymers are increased stiffness, strength, nucleating agent in foams, smaller cell size, higher cell density, and flame retardant. Nanosilver is composed of de-ionized water with silver in suspension and has excellent antibacterial properties. Silver nanoparticles interact well with other particles as they have large surface area relative to volume which increases their antibacterial efficiency as a result of which they are extensively used in the food packaging industry [30]. One of the potential applications of nanotechnology in food packaging is polymer/clay nanocomposites; they have recently emerged due to their potential for improving properties of packaging materials such as increased mechanical, barrier and chemical properties with a small amount (less than 5% by weight) of nanoclays reinforcement [31]. In particular, these nanocomposites have excellent barrier properties because the presence of clay layers delays the diffusing molecule pathway due to tortuosity [32].

4. EDIBLE COATING

The idea of using edible coatings has also been obtained from skin of fruits. These are thin layer of edible materials which restrict loss of water, oxygen and other soluble material of food [33]. For the fresh fruits and vegetables industry edible coatings can offer the following advantages: a) increasing preservation of colour, acids, sugar and flavour components; b) regulate the quality of products during shipping and storage; c) decreasing the incident of storage disorders; and d) increasing customer appeal. The active ingredients such as anti-browning agents, colorants, flavours, nutrients, spices and antimicrobial compounds are available in edible

coatings and also a high potential to extend shelf life of produce and decreasing the chance of pathogen growth on food surfaces [34,35].

4.1 Materials Used for Edible Coating

Generally, proteins, lipids and carbohydrates are types of coatings, alone or in combined form [36]. They perform as carrier to oxygen and moisture during process of handling and storage and not only enhance its safety due to their natural biocide activity or the incorporation of antimicrobial compounds but also retard food deterioration. The coating materials are differentiated in various types which are discussed here under.

4.2 Lipid Based Coatings

Lipids include a group of hydrophobic compounds, which are neutral esters of glycerol and fatty acids. The waxes, comes under this which are esters of long-chain fatty acids and monohydric alcohols [37]. For moisture losses lipid coatings are good barriers. Lipid coatings not only preventing water loss, but also used to decrease respiration, extending shelf-life and increases appearance by giving a shiny appearance to fruits. Coatings that comprise lipid solids up to 75% can be used to increase coating presentation without decreasing moisture-barrier properties. The Lipid based edible coatings effect on fruits and vegetables is discussed in Table 1. Lipid coating materials of different types are discussed below.

Oils: Paraffin oil, mineral oil, castor oil, acetylated monoglycerides, and vegetable oils, (peanut, corn, and soy) are sources of edible oils and used individually or in mixture with other elements to coat food products.

Waxes: On fruit surfaces wax coatings are naturally found, which help them to resist moisture losses, mainly in the dry humid season [38]. Fresh and dry fruits and nuts are conserved by use of coatings have been practiced since ancient time. To coat food products, paraffin, carnauba, beeswax and candelilla wax (an oily exudate of the candelilla plant grown in USA/Mexico) have been used, individually or in mixture with other elements. To develop edible wax from bio-based materials culminating in products like semperfresh and jonfresh, kafirin from sorghum, and bemul-wax from cassava starch several attempts had been made. The bio-wax (bemul-wax), developed from liquefied cassava starch and bees wax has been reported to be comparable to the Indian's commercial wax

“waxol” for extension of shelf-life of mandarin oranges [39]. Brazilian palm tree leaves (*Copernicia ceirifera*) is used to exudates Carnauba wax has a very high melting point and is used as an additive to increase toughness and luster to other waxes [37]. Beeswax or “white wax” is produced by honeybees, and candelilla wax is exudates of the candelilla plant (*Euphorbia antisiphilitica*).

Government of India approved edible coating (Food Safety and Standards Authority of India under ministry of health and family welfare permits for fresh fruits coating)

- Bee wax (white and yellow)
- Carnauba wax
- Shellac wax

Regulation- 2.4.5 (44) of Food Safety and Standards (Packaging and Labelling).

4.3 Fatty Acids and Monoglycerides

Fatty acids and monoglycerides are used in coatings mainly as emulsifiers and dispersing agents. Fatty acids are generally extracted from vegetable oils, while monoglycerides are prepared by transesterification of glycerol and triglycerol.

Resins: Resins are a group of acidic substances, produced and secreted as a wound response by specialized plant cells of tree and shrubs. Synthetic resins are petroleum based products. The insect *Laccifer lacca* produced shellac resins which is found in India. Shellac is made up of aleuritic & shellac acids [57], and are compatible with waxes and gives high glossy appearance when coated on product. Shellac and other resins have respectively less absorptive to gases and moderate absorptive to water vapour.

4.4 Protein Based Coatings

Wheat gluten, corn zein, soya protein, milk proteins and animal derived proteins like keratin, collagen and gelatine sources of proteins used in edible coatings of plant derived. Primarily protein films are hydrophobic and also not poor barriers to moisture. However, dry protein films such as zein, wheat gluten, and soya present relatively low permeability to O₂. Protein-based films have noteworthy gas hindrance and mechanical properties contrasted and those from lipids and polysaccharides.

Whey protein: Whey is a by product of cheddar fabricating that contains roughly 7% dry matter. The dry matter comprises 13% proteins, 75% lactose, 3% organic acids, about, and 8% minerals, less than 1% fat. In the agro food industries these whey proteins are used as preservative, such as the athletic drinks. From whey proteins, Suitable consumable films and coatings have been successfully obtain; their capacity to serve different functions, viz. transporter of antimicrobials, cell reinforcements, or different nutraceuticals without essentially compromising the beneficial cheif barrier and mechanical properties as packaging films. These developed whey protein formulations have excellent barrier properties almost comparable to the ethylene vinyl alcohol copolymers (EVOH) barrier layer conventionally used in food packaging composites, with an oxygen barrier (OTR) of < 2 [cm³(STP)/ (m²d bar)] when normalized to a thickness of 100 μm [58].

Wheat Gluten: The gluten complex is a blend of gliadin and glutenin polypeptiodes with some lipid and starch segments. Despite the fact that it is solvent in aqueous alcohol, but alkaline or acidic conditions are required for the development of homogeneous film forming solutions. These films have high aqueous permeability but are good barriers to O₂ and CO₂.

Corn Zein: Zein is prolamine obtained from corn gluten and is soluble in alcohol. Because of its faster drying rate, high gloss appearance, and increased stability during storage it has been used as a substitute for shellac [59]. On fresh fruits such as apples, Corn-zein and sucrose fatty acid ester coatings have been applied successfully and oxygen and water vapour barriers are useful for extending their shelf lives [60].

Soy Protein: Soy protein is accessible as concentrate (70% protein) or isolates (90% protein). Film development is increased by warming, which partially denatures the protein and permits the formation of disulfide bonds which brings down the permeability for water vapour.

Surimi: To exhibit the film-forming ability, it has been reported that surimi is obtained from the stabilized myofibrillar fish proteins. However, by many factors including pH, plasticizers the film properties were governed. Recently, from frozen threadfin bream surimi the transparent and flexible edible/biodegradable films were made.

Table 3. Applications of lipid based coatings on fresh fruits and vegetable

Produce	Coatings Types	Effect on Produce	References
Guava	Palm oil	Withstand the filtrate effects	[40]
	Semperfresh	Reduced decay	[41]
	Waxol	Finest fruit quality, better the organoleptic properties, modify shelf life, increased acidity and TSS under the treatment with 6 to 9 %	[42]
	Carnauba wax	It retard ripening and decreased the water loss and retard incidence. Little effect on TSS, total titratable acidity, and ascorbic acid	[43] [44]
	Citrus	Beeswax and Larding (coated fruit with fat)	Delayed water loss, preserve desiccation
Mango	Carnauba Wax	Effective in delayed fruit ripening, retaining fruit firmness, and increase fruit quality attributes including levels of fatty acids and aroma volatiles	[46]
	Carnauba Wax	Decrease weight loss, and shrivel; improve shelf life; increase ground skin colouration	[47]
	Semperfresh and <i>A. Vera</i> gel (1:1 or 100%)	Slightly delayed fruit ripening but reduced fruit aroma volatile development	[46]
Apple	Wax, oil	Modify the shelf life.	[48]
	Paraffin wax + beeswax + soybean oil + CMC	Decreased soluble solids, titratable acidity and ascorbic acid loss; modify storage life up to 34 days.	[49]
	Candelilla Wax	Prolongs and improves the shelf life, excellent antifungal barrier inhibiting the growth of natural phytopathogenic fungal strains and slow weight Loss	[50]
Peach	Wax	Reduced the rate of physico-chemical changes; retained the best quality	[51]
Passion fruit	Carnauba wax	Lower the fresh matter loss percentage and higher the relative water retention; peel percentage decreased and pulp and pulp/peel percentages increased	[52]
Banana	Semperfresh	Extended the green life, delayed ripening	[53]
Pomegranate	Oil + starch	Reduced softening of arils, weight loss and % of browning index, loss of vitamin C, loss of anthocyanin and delayed microbial decay	[54]
Walnuts and Pine nuts	Whey protein isolate + Pea starch (PS) + Carnauba wax	Prevent oxidative and hydrolytic rancidity, improved their smoothness and taste and improved sensory characteristics	[55]
Huanghua Pears	Shellac	Retaining texture (especially for brittleness); also maintained higher POD activity and lower activities of cell wall hydrolases such as PE, PG, and cellulose	[56]

Table 4. Applications of protein based coatings on fruit and vegetables

Produce	Coatings types	Effect on produce	References
Cherry	Gelatine film	Small moisture loss	[61]
	Zein	Accelerated ripening and fungal deterioration	[62]
	Soy protein isolate (SPI)	Decrease the acidity	[61]
Kiwifruit	Whey protein concentrate and rice Bran oil	Conserve the taste, color, firmness, and the universal suitability of the fruits, the rise of acidity and weight loss slow down	[63]
Apple	Calcium caseinate and whey protein	Delayed browning	[64]
	Carrageenan + whey Protein Concentrate	To keep the actual colour during storage without changes in sensory properties.	[65]
	Whey protein concentrate + Beeswax	Decreased surface browning	[66]
	Galactomannans and collagen blends	reduced the CO ₂ and the O ₂ production Utilization by approximately 50%	[67]
Mango	Galactomannans + Collagen	Successful in low O ₂ utilization and CO ₂ production	[67]

Table 5. The details of the different herbal products and their effects

Produce	Coatings types	Effect on produce	References
Apple	<i>Aloe vera</i> gel	Retard the dropping of total phenolics and vita. C	[73]
		Retard the weight loss, changes in colour, accelerated softening and ripening, rachis browning, and high incidence of berry spoilage, increases the storage life and decrease the initial microbial counts.	[72]
	Lemongrass + oregano oil + vanillin incorporated in apple puree – alginate edible coating	Decreased native psychrophilic aerobes, moulds and yeast. Ethylene creation in the coated Retard browning more efficiently when was apples remained below 50 $\mu\text{L L}^{-1}$. Lemongrass (1.0-1.5%) and oregano (0.5%) reduced >4 log CFU/g of inoculated <i>Listeria innocua</i>	[74]
	Cinnamon + clove + lemongrass essential oils (Eos) incorporated in alginate-based edible coating	Efficiently keeping the physio-chemical properties for more than 30 days, reduced <i>Escherichia coli</i> O157: H7 strength by about 1.23 log CFU/g at day 0, and modify the microbiological shelf life by at least 19 days. The incorporation of EOs at 0.7% (v/v) or their incorporation of EOs at 0.7% (vol/vol) or their active composite at 0.5% (vol/vol) into the EC enlarge its antimicrobial effect, reduced the <i>E. coli</i> O157:H7 population by more than 4 Log CFU/g, and modify the microbiological. Shelf life more than 30 days.	[75]
Grapes	<i>Aloe vera</i> gel	Restrict loss of water and firmness, control respiratory rate and maturation progress, reduce oxidative browning and decrease microorganism proliferation	[76,77]

Table 6. Applications of carbohydrate based coatings on fresh fruits and vegetables

Produce	Coatings types	Effect on produce	References
Guava	Dextrons	Better properties as gas barrier, increase size, colour, aroma, water content	[78]
	Potato Starch	Did not affect the pH, titratable acidity, and sugars, soluble and total pectin, firmness, and values of chlorophyll a and b	[79]
	Cellulose	Slowed softening, but fruits did not develop as much colour, had a lower soluble solids, and more prone to surface blackening	[80]
Cherry	Carboxy- methylcellulose	Reducing water loss, decrease the acidity	[61]
Banana	Gum arabic and Chitosan	Delayed color development and reduced the rate of respiration and ethylene evolution, maintaining the overall quality	[81]
Pineapple	Chitosan	Extends the shelf-life	[82]
	Sodium alginate and Gellan gum	Control weight loss, preserve flesh firmness, and slow the respiration rate at 10±1°C and 65% RH	[83]
	Alginate	Helped to retain internal liquids	[84]
Apple	Carboxymethyl cellulose (CMC)	Delayed browning more effectively when was applied in an edible coating than in an aqueous solution	[85]
	Lemongrass + oregano oil + vanillin incorporated in apple puree-alginate edible coating	Reduced native psychrophilic aerobes, moulds and yeast. Ethylene production in the coated apples remained below 50 µL L ⁻¹ . Lemongrass (1.0-1.5%) and oregano (0.5%) reduced >4 log CFU/g of inoculated <i>Listeria innocua</i>	[74]
	Cinnamon + clove + lemongrass essential oils (Eos) incorporated in alginate-based edible coating	Effectively maintain characteristics for more than 30 days, decreased the physicochemical the respiration rate, and reduced the <i>Escherichia coli</i> O157: H7 population by about 1.23 log CFU/g at day 0 and extended the microbiological shelf life by at least 19 days. The addition of EOs at 0.7% (vol/vol) or their active compounds at 0.5% (vol/vol) into the EC increased its antimicrobial effect, reduced the <i>E. coli</i> O157: H7 population by more than 4 log CFU/g, and extended the microbiological shelf life > 30 days.	[75]
	HPMC (Hydroxypropyl-methylcellulose)	It slowed down weight losses and controlled the oxygen consumption, had a better microbial safety	[86]
Melon	Alginate	Inhibited the microbial growth and reduced up to 3.1 log CFU/g after 30 days of storage	[75]

Carbohydrate Based Coatings: In food systems, carbohydrates are used as thickeners, stabilizers, gelling agents, and emulsifiers. Polysaccharide films have some resistance to remove of water vapour, but relatively less permeability to gases. During short term storage, such coatings are used to delay water losses. Carbohydrate films can be useful in differentiate of product in packaging and glowing fruit surfaces.

Cellulose: Cellulose derivatives are polysaccharides made up of linear chains of β (1– 4) glucosidic units with methyl, hydroxypropyl or carboxyl substituents. For edible coatings or films, only four cellulose derivative forms are used: Hydroxypropyl cellulose (E463; HPC), hydroxypropyl methylcellulose (E464; HPMC), Carboxymethyl cellulose (E466; CMC) or Methyl cellulose (E461; MC). However, due to inherent hydrophilic nature of polysaccharides and possess poor mechanical properties, cellulose derivative films are poor water vapour barriers.

Pectin: Pectin is formed in middle lamella of plant cells and is made up of D-galacturonic acid polymers with different degree of methyl esterification and composite group of plant obtained polysaccharides. Due to their hydrophilic nature coatings generally have more water vapour transmission rates. During storage and transport, pectin supply a soft & glossy coat and control the loss of nutrients and volatile materials. In addition, pectin film controlled contamination of product by microorganisms. The main feature of this film is separating of product in its package.

Sucrose ester: Most formulations of sucrose ester have been based on one or more esters, a carrier, sodium carboxymethyl cellulose, or an anti foamant preparation of mono and diglycerides of fatty acids. Sucrose polyester (SPE) coating delayed ripening in banana, pears [68] and apple [69]. An important formulation of earlier SPE products is Semprefresh, which employ in retard ripening of fruits.

Chitin/Chitosan: Because of its high nutritional quality, superb sensory properties, and adequate preservation of food products from their environment, the implementation of edible coatings based on chitosan or caseinates is compulsive. Chitosan is a modified, natural nontoxic biopolymer derived from deacetylation of chitin (poly- β -(1→4)-N-acetyl-D-glucosamine), a major component of the shells of

crustacean such as crab, shrimp, and crawfish [70]. Recently due to its biological activities, including antimicrobial, antitumor, antioxidative, and hypocholesterolemic functions, chitosan has attracted notable curiosity and it has bacteriostatic and bactericidal properties and is a highly recommended polymer for the production of edible film coatings [71].

Starch: Starch, primarily derived from cereal grains like corn (maize), with the largest source of starch and made up of amylose and amylopectin. Different sources of starch e.g. corn, potato, cassava and cereals etc. can be used. Generally the varieties which contain high amylose starches can be utilized for edible film formation. Amylose is responsible for the film forming capacity of starch. High amylose starch films have been made that are flexible, oxygen impermeable, oil resistant, heat sealable, and water soluble.

Alginate: Alginate is isolated from marine brown algae (Phaeophyceae) and is finding an enlarge application in the food industry as texturizing and gelling agents. Alginate is a salt of alginic acid, a polymer of D-mannuronic acid and L-guluronic acid. Alginate has one of a kind colloidal properties and can shape solid gels or insoluble polymers through crossed connecting with Ca^{2+} by post-treatment of CaCl_2 solution. By increasing moisture barrier, restrict microbe contamination, maintaining flavour and texture of the fresh-cut fruits, such biopolymer-based films can keep good quality and prolong shelf-life of foods.

Carrageenan: Carrageenans are water dissolvable polymers with a direct chain of partially sulphated galactans, which present high potentiality as film-forming material extracted from the red-sea weed and ensures against moisture loss. It comprises of a group of sulfonated polysaccharides of D-glucose and 3, 6-anhydro-D-galactose. Recently, carrageenan films were also found to be less opaque than those made of starch.

Herbal coating (Aloe vera.): Aloe vera has been utilized for a considerable length of time for its restorative and remedial properties. Aloe vera contains malic acidacetylated carbohydrates (including β -1, 4 glucomannans) that showed mitigating action. As of late, there has been expanding enthusiasm for the utilization of *A. Vera* gel as a consumable covering material for fruits by its antifungal activity. The edible covering

was able to decrease the starting microbial counts for both mesophilic aerobic and yeast and moulds in cv. Crimson Seedless table grapes [72].

5. CONCLUSION

In today's competitive world, packaging and edible coating play a crucial role in creating value added consumer friendly products for marketing. Due to several drawbacks of conventional packaging new technologies should be adopted. MAP is one of the recent trend very much useful enhance shelf life of fruits. Composite coating and packaging is proved more useful as compared to single use of edible coating or films because of its synergistic effect. Herbal coating, waste material renewable extract coating, antimicrobial coating, nano composite coating, biodegradable packaging, active packaging, smart or intelligent packaging is encouraged as these added high value and enhance the functionality of the product. It is better to choose packaging which is recyclable. The vision of future of packaging and edible coating should operate as a smart system. Combination of nano packaging technology triggers new strategies to bio based edible coating thus reducing packaging waste. Tomorrow's food packages will certainly include radio frequency identification (RFID) tags.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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