Acta Scientific Agriculture (ISSN: 2581-365X)

Volume 2 Issue 5 May 2018

Review Article

Edible Coating Technology for Extending Market Life of Horticultural Produce

K Prasad[1]*, Abhay Kumar Guarav[2], Preethi P[3] and Pallavi Neha[4]

[1]Division of Food Science and Postharvest Technology, ICAR-IARI, New Delhi, India

[2]Division of Floriculture and Landscaping, ICAR-IARI, New Delhi, India

[3]ICAR-Directorate of Cashew Research, Puttur, Karnataka, India

[4]Division of Postharvest Technology and Agricultural Engineering, ICAR- IIHR, Bengaluru, India

***Corresponding Author:** K Prasad, Division of Food Science and Postharvest Technology, ICAR-IARI, New Delhi, India.

Received: December 20, 2017; **Published**: April 27, 2018

Abstract

Postharvest quality management of horticultural produce through eco-friendly treatments is an emerging field. One of such promising and emerging postharvest treatment for extending the market life of lively respiring horticultural produce is 'Edible coating'. Edible coatings when applied on harvested horticultural commodities such as fruits, vegetables, edible products of flowers, plantation and mushrooms, extend their shelf life, marketability and postharvest quality. The edible coating does not leave any post application residues and thus makes the product readily consumable. It positively affects physical (moisture retention, glossiness, appearance, firmness), physiological (respiration rate, ethylene evolution rate), and biochemical attributes (cell wall degrading enzymes) attributes of horticultural commodities. Recent advances have now enabled growers to intelligently apply edible coating both solely and in combination with other postharvest treatments and natural preservatives for retention of postharvest quality with the minimized postharvest loss. This review presents a compiled information extracted from various scientific reports (> 50 scientific articles (2002 - 2017)) to put light on various aspects of edible coating technology. The objective of this review is to describe detailed information on the mechanism, formulation and application of edible coating technology on horticultural commodities such as fruits, vegetables and edible products of flowers, plantation and mushroom along with highlighting future perspectives of this technology. Although the results of this technology are promising, at the same time we need to extend the horizon to explore potential uses of this technology on the commercial scale in various corners of the world.

Keywords: Edible Coating; Horticultural Produce; Eco-Friendly Technology

Introduction

Horticultural crops such as fruits, vegetables, edible products of flowers, plantation crops and mushroom are well known for its high commercial value, meanwhile, maintenance of its postharvest quality is now becoming mandatory for successful trade [1]. Postharvest quality retention by the application of postharvest treatments proved to be promising in fruits [2]. There are several postharvest treatments which are used for postharvest quality retention, but most of them are chemical based and thus pose health and eco concerns. This lead to the discouragement of several chemical postharvest treatments by scientific communities time to time, this also resulted in strict regulations and monitoring laws for the consignments by the quality control organisations [3]. Healthy and eco-friendly postharvest treatments/technologies are very demanding now-a-days [4].

One of such promising postharvest treatment used for extending the market life of lively respiring horticultural produce is 'Edible coating technology'. Edible coatings indicate the application of commercial food grade waxes or films to protect the loss of natural glossiness during the postharvest period. The best part of the edible coating is that these are edible, healthy and biodegradable in nature, unlike other chemical postharvest treatments which leave a residue [5].

Material and Method

The use of certified food grade edible coating on fruits is safe and is approved for application on fresh fruits, vegetables and similar horticultural produce [6].

Through this review, an attempt has been made to highlight, update and compile the scientific literature available on emerging technology of edible coating in context to horticultural crops. This review refers and present findings of various scientific reports and articles (> 50 scientific reports between 2002 - 2017) quoting the advances occurred in this technology during earlier as well as in recent times. The detailed information is presented on this topic under various heads and subheads hereunder.

Edible Coating Technology: In Context of Horticultural Crops

Definition

Edible coatings are thin layers of edible material when applied over the surface of the horticultural commodities not only extend their shelf life but also marketability [7]. They protect produce by acting as a replacement for natural protective waxy coatings known as 'bloom' and provides a barrier against moisture, oxygen, and solute movement [5,8]. Edible coating positively influences physical (moisture retention, glossiness, appearance, firmness) [9], physiological (respiration rate, ethylene evolution rate) [10], biochemical attributes (cell wall degrading enzymes) [9], and pathological factors (disease decay incidence) [11] for retaining postharvest quality. Edible coatings can be applied solely and in combination with other natural preservatives and postharvest treatments [11,12].

Sl. No	Trade/ commercial Name	Composition
1	FreshSeal™	Polyvinyl alcohol, starch, and surfactant
2	Fry shield	Calcium pectinate
3	Nature seal	Calcium pectinate
4	Nutri-save	*N, O-Carboxymethyl chitosan*
5	Opta Glaze	Wheat gluten
6	Seal gum, Spray gum	Calcium pectinate
7	Semperfresh™	Sucrose esters
8	Z Coat	Corn Protein
9	Prolong	Mixture of sucrose fatty acid esters, sodium CMC, and mono and diglycerides
10	Tal Prolong	Mixture of sucrose fatty acid esters, sodium CMC, and mono and diglycerides
11	Nature-seal™	Cellulose-based edible coating
12	Zein	Corn zein protein
13	Brilloshine	Sucrose esters and wax
14	Nu-coatFlo, Ban-seel	Sucrose esters of fatty acids and sodium salt of CMC
15	Citrashine	Sucrose ester and wax
16	Sta-Fresh Series	Shellac/carnauba/Resin
17	Natural Shine™ Series	Vegetable wax, carnauba and shellac
18	PrimaFresh® Series	Vegetable wax, carnauba and shellac
19	Shield-Brite® Series	Carnauba and shellac
20	Peach, Nectarine and Plum	Vegetable oil and Mineral oil
21	PrimaFresh® Series	Vegetable wax, carnauba and shellac
22	Shield-Brite® Series	Carnauba and shellac
23	Syncera series	Carnauba wax, shellac resin and polyethylene

Table 1: Commercially available coatings for horticultural produce.

Basic approaches for using edible coatings

Edible coatings maintain the quality by forming a protective film over the produce acting as a barrier to different gases like O_2 and CO_2, and water vapour. It created a modified atmosphere around the horticultural commodity and thereby retains postharvest quality [13,14].

The coating is applied through various methods includes dipping, spraying, or brushing on the food surface in order to create a modified atmosphere. Edible coatings can be applied by the simple technique of dipping products in coating materials and then allowing excess coating to drain as it dries and solidifies. Thus, edible coatings and films do not replace traditional packaging materials but provide an additional support to fruits and vegetables for their preservation [15].

Effect of edible coatings on horticultural crops

Edible coatings bring their response by affecting the physical, physiological and biochemical attributes of horticultural commodities such as fruits (Table 2), vegetables (Table 3) and postharvest edible products of plantation, mushroom and flower crops (Table 4).

Physical factors

External appearance and glossiness

External appearance is the face of the horticulture commodity [55]. Rough physical handling of fruits at postharvest stage causes destroy of natural wax coating and bruising injury occurs during the packing and transport operations [8]. The edible coating provides a physical barrier between the fruit surface and the external surrounding of harvested produces, which ultimately lead to retention of postharvest quality of horticultural commodities [7].

Fruit	Coating Material	Increased shelf life by	Reference
Mango	Emulsion- carnauba wax and acrylic resin	Reduced mass loss and retention of firmness	Fonseca., *et al.* 2004 [16]
Banana	Chitosan	Inhibited pathogenic growth of *Colletotrichum musae*	Maqbool., *et al.* 2010 [17]
	Chitosan	Reduced weight loss	Malmiri., *et al.* 2011 [18]
Papaya	*Aloe vera* gel	Retained firmness. Delayed peel color development. Reduced weight loss	Marpudi., *et al.* 2011 [19]
Avocado	Carnauba	Reduced water loss, shrinkage, chlorophyll breakdown and chilling injury	Feygenberg., *et al.* 2005 [20]
Grape	*Aloe vera* gel	Delayed softening process and color development. Lowered ethylene production and Reduced weight loss	Valverde., *et al.* 2005 [21]
Sapota	Carnuba wax+1- MCP	Enriched desired salmon color of pulp	Ergun., *et al.* 2005 [22]
Pomegranate	Putrescine + carnauba wax	Delayed maturation process	Barman., *et al.* 2011 [23]
Blueberries	Semperfresh	Lowered weight loss	Duan., *et al.* 2011 [24]
Apple	*Aloe vera* gel	Retention of firmness	Ergun and Satici 2012 [25]
	Arabic gum	Delayed fruit ripening and decay	El-Anany., *et al.* 2009 [26]
	Aloe vera gel	lower loss of weight	Ergun and Satici, 2012 [25]
Pear	Shellac, Semperfresh	Decreased weight loss	Zhou., *et al.* 2008 [27]
	Shellac, Semperfresh, CMC	Lowered respiration rate	Zhou., *et al.* 2008 [27]
Plum	Alginate	Decreased weight loss	Valero., *et al.* 2013 [8]
	Alginate	Inhibits ethylene production	Valero., *et al.* 2013 [8]
	Alginate	Slowed softening process	Valero., *et al.* 2013 [8]
Nectarines	Carnauba wax	Reduced brown rot incidence	Goncalves., *et al.* 2010 [28]
Fresh-cut persimmon	Pectin coating + Potassium sorbate, sodium benzoate or nisin(NI) and $CaCl_2$ and Citric acid	Inhibited browning, moulds, yeasts and psychrophilic aerobic bacterial growth	Sanchez., *et al.* 2016 [11]
Cherry	Semperfresh	Retained firmness, Reduced the weight loss	Yaman., *et al.* 2002 [29]
	Aloe vera gel	Lowered respiration rate	Martinez-Romero., *et al.* 2006 [30]
Strawberries	*Aloe vera* gel	Maintained higher firmness	Martınez-Romero., *et al.* 2006 [30]
	Chitosan coating	Reduced decay incidence	Wang and Gao., *et al.* 2013 [31]
	Beeswax	Lowered respiration rate	Velickova., *et al.* 2013 [32]
	Aloe vera gel	Reduced fruit weight loss	Vahdat., *et al.* 2009 [33]
	Chitosan + acetic acid + beeswax coatings	Prolonged storage life, reduced fungal infection and weight loss.	Velickova., *et al.* 2013 [32]

Table 2: Application of edible coatings in fruit crops.

Vegetable	Coating Material	Increased shelf life by	Reference
Tomato	Aloe juice + cinnamaldehyde	Increased storage life, internal quality, skin colour and firmness. Decreased respiration rate and moisture loss	Athmaselvi., *et al.* 2013 [34]
	Carnauba	Storage life increased. Inclined total phenol, flavonoid content and radical scavenging activity	Jorge., *et al.* 2014 [35]
Cucumber	Pectin + sorbitol + bee wax	Reducing moisture loss, changes in firmness, color, chlorophyll, and other quality parameters. Prolong storage life.	Moalemiyan and Ramaswamy, 2012 [36]
Cucumber	Carboxymethyl cellulose and corn starch	Maintained marketable quality. Reduced decay incidence, susceptibility to mechanical damage and surface microbial load	Oluwaseun., *et al.* 2013 [37]
	Chitosan + *Aloe vera* gel	Extended shelf life, Delays senescence and onset of post-harvest rot. Slowed changes of pH, titrable acidity, TSS and ascorbic acid	Adetunji., *et al.* 2014 [38]
	Gum Arabic	Maintained fruit sensory quality with increased shelf life	Al-Juhaimi., *et al.* 2012 [39]

Muskmelon	Sodium Alginate + gellan	Prevented desiccation and maintained fruit firmness, quality attributes and antioxidant properties.	Oms-Oliu., *et al*. 2008 [40]
Fresh-cut cantaloupes	Alginate + Repititive Pulsed treatment	Increased shelf life, fruit firmness. moisture retention. Lower microbial growth retained antioxidant enzymes and biochemical quality	Koh., *et al*. 2017 [9]
Sweet pepper	Chitosan + cinnamon oil	Improved texture, colour retention, cell membrane stability, storage life and ROS scaveng activity, low decay and electrolyte leakage	Xing., *et al*. 2013 [13]
	Gum Arabic	Prolonged shelf life and visual appearance, reduced shriveling and wilt while retaining biochemicals	Ochoa-Reyes., *et al*. 2015 [7]
Bitter gourd	Carnuba wax	Prolonged shelf life and colour retention. Reduced moisture loss and disease index	Bhattacharjee and Dhua, 2017 [41]
Sliced carrot	yam starch + coatings based on yam starch + glycerol + chitosan	Reduced microbial load, mesophilic aerobes, mold, yeast and psychrotrophic	Durango., *et al*. 2006 [42]
Peeled carrot	*A. vera* with carboxymethyl cellulose	Reduced gaseous exchange, water vapor transit and microbial load. Mantained TSS, sugar and carotenoids. Increased storage life.	Panwar., *et al*. 2016 [10]
Lotus root	Chitosan + ascorbic acid and 1% citric acid formulation + MAP	CO_2 / O_2 rates affected, Inhibited PPO and MDA content, lowest surface browning and increased acceptability	Xing., *et al*. 2010 [43]
Cut eggplant cv. Telma	1% Cysteine + Soyprotein + MAP	Increased storage life and whiteness index. Reduced PPO activity	Ghidelli., *et al*. 2014 [44]

Table 3: Application of edible coatings in vegetable crops

Plantation crop	Coating Material	Increased shelf life by	Reference
Fresh Arecanut berries for chewed products	Chitosan coating and SO_2 fumigation	Inhibited physiological senescence, pathogen attack. Increased shelf life, maintained safety and commercial quality	Zhang., *et al*. 2016 [12]
	Various herbal extracts, from ginger, garlic and leaves of *Macaranga*, *Canthium*, *Hainania*, *Vatica*, and chitosan	Increased shelf life and overall acceptability of product	Shi., *et al*. 2013 [45]
Cashew nut kernels	Starch-Cashew tree gum coatings	Reduced change in kernels texture. Improved stability, and reduce lipid oxidation	Pinto., *et al*. 2015 [14] Cortez-Vega,., *et al*. 2014 [46] Slavutsky., *et al*. 2014
Canning of flower. Crystallized/candy edible flowers	Egg white	Flower petal pre-dipped, used for dessert such as toppings for for cakes, pies, sorbet, ice cream, truffles, cupcakes, beverages and fruits salads.as well as for decoration.	Sue Bradley, The Telegraph, 2015 [47]
Edible flower : 12 flower product	Sugar canning, preserved in distillates	Preserved and used as garnishes and mostly consumed fresh, besides being consumed dried, in cocktails (in ice cubes), by canned in sugar and preserved in distillates, attempted for *Antirrhinum*, *Centaurea cyanus*, *Chrysanthemum*, *Dianthus*, *Fuchsia*, *Impatiens*, *Rosa*, *Tropaeolum s*, *Viola*, *Begonia*, *Tagetes*, *Calendula*	Rop., *et al*. 2012 [48] Neugebauerova and Vabkova, 2009 [49]
Mushroom	Vegetable oils, cellulose gums, emulsifiers, surfactants, and fatty acids.	Enzymatic browning reduced, the anti-browning property of coating materials improved with the incorporation of antioxidants and chelator (EDTA).	Nisperos-Carriedo., *et al*. 1991 [50]
	Stearic acid, ascorbic acid and citric acid, in the methyl cellulose based coating	Decreased oxygen permeability, slowed browning reaction and PPO activity. Reduced vitamin- C loss.	Ayranci and Tunc 2003 [51]
Fresh-cut Button mushroom (*Agaricus bisporus*).	Chitosan coating	Extend the shelf life and maintain acceptable quality besides, controlling decay extent to some extent.	Eissa HA 2007 [52]
	Aloe vera, and gum tragacanth-based edible coating	Delayed rapid weight loss, color changes, and accelerated softening. Good quality even at higher temperatures of storage.	Mohebbi., *et al*. 2012 [53]
Shiitake (*Lentinus edodes*) mushroom	Chitosan, glucose and chitosan–glucose complex (CGC)	Maintained mushroom quality, extended postharvest life, maintained tissue firmness, lowered respiration rate, reduced microorganism counts. Reduced change in ascorbic acid and soluble solids concentration.	Jiang., *et al*. 2012 [54]

Table 4: Edible coatings used in postharvest processed products of plantation, flower crops and mushroom.

*Note- In floriculture crops, there is limited work on the edible coating, recent advances reflect edible coating technology for preservation of edible products of floricultural crops will be emerging in near future.

Fruit firmness and softening

Edible coating maintains the firmness by avoiding excessive respiration and transpiration those involved directly in depleting storage reserves. Edible coating directly affects fruit firmness by delaying ripening process and decreasing the activity of cell wall degrading enzymes [56]. It is well known that calcium directly affects fruit firmness, the incorporation of calcium in the edible coating was also proved to be effective [57].

Loss of weight of fruits

The weight of horticultural commodity determines the returns of farmers. This loss in weight of particular commodity is due to the transpiration process which is determined by the gradient of water vapour pressure between the fruit and the atmosphere. Edible coatings act as an extra barrier between the fruit surface and atmosphere, the process transpiration which occurs across it [9,58,59].

Physiological impact

Edible coatings have their direct as well as the indirect effect on the physiology of harvested commodities. Physiological factors such as alteration in the physical state via fruit respiration and ethylene production rate are few best examples of their role in altering fruit physiology.

Respiration and ethylene production

Fruits and vegetables are alive and respire even after harvest. The edible coating prevents the entry of oxygen inside the fruit and leads to the disruption of ethylene production and declines respiration rate [27]. Thus, ultimately the fruits and vegetables remain firm, fresh, and nutritious for a longer period and their shelf life almost doubles [8]. The natural barrier on fruits and vegetables, the type and amount of coating will influence the extent the formation of the internal modified atmosphere (oxygen and carbon dioxide) will occur [34].

Biochemical parameters

The recent reports revealed that apart from physical and physiological alterations, edible coatings have a direct and indirect role in modifying the biochemical constituents, which are responsible for taste and shelf as well. These include: Total soluble solids, Titratable acidity and ascorbic acid.

Soluble solids and organic acids of fruit are substrates that are consumed by respiration during storage [29]. In horticultural crops, reports suggest that the increase or decrease in biochemical attributes depends on the commodity and type of edible coating used [19]. Biochemical parameters contributing to quality such as acidity, TSS and ascorbic acid are also found to be affected by edible coating [8,10,27,60].

Total phenolic and antioxidants

Total phenolic and antioxidants have an influential role in the shelf life of horticultural commodity, their presence gives the resistance to various postharvest quality deteriorating factors [2,4]. Similar to this, antioxidants also extend the shelf life both from the internal presence and external application [53]. Edible coatings have influence and ability to alter/ increase the antioxidant and similarly total phenolic content in harvested horticultural commodities [61]. Affecting these constituents results in the extended shelf life of horticultural commodities [8,11].

Lipid peroxidation and enzymatic activities

When it comes about the role of edible coatings at enzymatic levels, Edible coating influences the activity of cell wall related enzymes. This is well reported in case of enzymes such as phenylalanine ammonia lyase, polyphenol oxidaseand malondialdehyde [13,44] which have an important role in cell wall degradation and peel browning of horticultural commodities.

Edible coatings also control the process of lipid peroxidation which is responsible for membrane breakdown and free radicals generation which ultimately affects postharvest quality [35,62].

Criteria for ideal edible coating

Postharvest researchers always search for such an option of postharvest treatments which can satisfy the need of growers, traders and farmers simultaneously, without performing below its expected efficacy. Similar is the case with edible coatings.

Although there are several criteria and steps for designating an edible coating as an ideal one, the criteria's may be mainly designated in three contexts.

In the context of physical characteristics: Edible coating should be water-resistant which helps to avoid dissolution of coating material in water. The edible coating should not reduce oxygen concentration or build up excessive carbon dioxide. The ability of ideal coating should reduce the water vapor permeability. Similarly, in the context to cosmetic appeal maintenance, the edible coating should enhance the appearance, maintain structural integrity, improve mechanical handling properties, carry active agents (antioxidants, vitamins, etc.) and retain volatile flavor and aroma compounds [62].

In context to rheological properties: It should easily melt out above 40∘C without decomposition; easily emulsifiable, non-sticky; never affect the quality of fresh fruit or vegetable and have low viscosity and be economical for a large quantity. Similarly, an ideal edible coating material should also provide biochemical and microbial stability to the horticultural commodity by protecting against contamination, pest infestation, and microbial spoilage agents [57].

Feasible application of the edible coating in horticultural commodity: Apart from all the above mentioned criterias, the success of edible coating equally depend on its compatibility to an economical method of application on the horticultural commodity. Method of application of edible coating will determine its adsorption on the surface of the horticultural commodity, which in turn responsible for the efficacy of edible coating [57].

Methods of postharvest application on horticultural produce

Edible coatings are applied in such a form which can lead to its maximum adsorption on the surface of the horticultural commodity [63]. Edible coatings can be applied on horticulture produce by the processes viz. dipping, spraying, brushing, dripping, foaming, fluidized-bed coating, panning and electrostatic coating on various horticultural commodities (Table 2, 3 and 4).

Spraying: Among all the methods spraying is commercially practiced in horticultural produce e.g. mango and apple as an export protocol.

This is the most popular method for coating whole fruits and vegetables, especially with the development of high-pressure spray applicators and air- atomizing systems. Spray applications are also suitable when applying films to a particular side or a dual application must be used for cross-linking, as is practiced with alginate coating.

Dipping: Edible coatings can be applied by dipping products in the coating solution and then allowing excess coating to drain as it dries and solidifies. Uniform coating was mainly achieved by the dipping method. Dipping has been commonly used for coating fruits and vegetables. The first reported dipping application was done by The Florida citrus industry, where the fruits were submerged in a tank of emulsion coating. The fruit was then generally conveyed to a drier under ambient condition.

Dripping: This coating application method is the most economic. In addition, it has the ability to deliver the coating either directly to the commodity surface or to the brushes. However, due to relatively large droplet sizes, good uniform coverage can only be achieved when the commodity has adequate tumbling action over several brushes that are saturated with the coatings. Dripping has been commonly used for coating of horticultural produce.

Foaming: Foam application is used for some emulsion coatings. A foaming agent is added to the coating or compressed air is blown into the applicator tank. The extensive tumbling action is necessary to break the foam for uniform distribution. The agitated foams applied to commodities moving on rollers and cloth flaps or brushes uniformly distribute the emulsion over the surface of the commodity. This type of emulsion contains little water and therefore dries quickly, but inadequate coverage is often a problem.

Composition of edible films and coatings

The speciality of edible coatings is that these are available from natural sources. These sources once after approval by Food and Drug Administration, Food safety authorities, trade and export regulatory authorities gain the confidence of the consumer. These edible coatings may be composed of organic compounds such as hydrocolloids (polysaccharides or proteins), hydrophobic compounds (lipids or waxes) or of a combination of both (composite coatings). Sometimes, compatible and safe additives like antimicrobials, texture enhancers, nutrients, plasticisers, and emulsifiers are also added to improve the efficacy and usefulness of the edible film for certain environment. Any compounds added to the coating have to be examined for safety to eat and generally recognized as safe once approved by FDA, Food safety authorities, trade and export regulatory authorities [5,63].

Classification of commercial forms of edible coatings are:

Polysaccharides derived edible coatings

The polysaccharides have been extensively studied for its use in edible coating. These polysaccharides are extracted from various plant species. These coatings have greater ability to reduce the water loss, gas barrier property and reduce ripening and senescence. Crystalline property of some polysaccharides causes the cross linkage to form a better coating. The most commonly used polysaccharide materials include cellulose, starch, gums, and chitosan [7,36].

Cellulose based edible films

Cellulose is the natural plant based polysaccharide most abundantly found in the universe. Methylcellulose, hydroxypropylmethylcellulose (HPMC), Hydroxypropyl cellulose (HPC), and carboxymethyl cellulose (CMC) films possess a good film-forming characteristic, are generally odorless and tasteless, flexible and of moderate strength, transparent, resistant to oil and fats, water-soluble, and moderately permeable to moisture and oxygen transmission. The mechanical and physical barrier properties of cellulose edible coating are primarily due to the molecular weight, higher the molecular weight better are the properties [38].

Starch based edible films: Starch is a polymeric carbohydrate consisting of a large number of glucose units joined by glucosidic bonds. Starch is the storage polysaccharide found in cereals, legumes, and tubers vegetables, widely available as raw material and suitable for a variety of industrial uses. The most common starch rich sources include potato, cassava, banana etc. It contains amylose and amylopectin. Starchs are good oxygen barrier, used for coating fruits and vegetables characterized by high respiration rates [42].

Gums based edible films: The gums are polysaccharides based products which are soluble in water. They include exudate gums (gum Arabic), extractive gums (locust bean and guar) and microbial fermentation gums (xanthan and gellan) [7,39].

Pectin based edible films: Pectin is naturally found in plant mainly in fruits and vegetables like Guava, Apple etc. Pectin is a complex anionic polysaccharide composed of β-1, 4-linked d-galacturonic acid residues [11,36].

Chitosan based edible films: Chitosan is derived from chitin; it is an edible polymer, isolated from crustacean animal shells. It is a natural product which is non-toxic and eco-friendly. Chitosan, a high molecular-weight cationic polysaccharide produced by deacetylation of chitin, is applied widely in postharvest treatments because of its excellent film forming and bio chemical properties. Chitosan films are tough, long lasting, flexible and very difficult to tear. Chitosan coating, form an ideal semipermeable film on the fruit surface, modify the fruit internal atmosphere, regulate gas exchange, reduce transpiration losses thus delays the ripening [64].

Proteins derived edible coatings

Proteins are used as a coating material to prevent the moisture loss and to improve the product quality. The extent of protein utilization is very less for coating purpose in comparison to polysaccharides. Protein coatings are in general hydrophilic, poor moisture barrier, hence these are relative humidity and temperature sensitive coating material. The examples of protein coating material include casein, whey protein, collagen, gelatin, keratin, wheat gluten, soy protein, peanut protein, corn-zein and cotton seed protein [44].

Casein derived edible coating: Casein is a milk protein, commonly used in the preparation of emulsion because it is amphipathic in nature and containing hydrophilic and hydrophobic ends. Casein forms transparent, flavorless and flexible films [47].

Soy Protein derived edible coating: Isolated from Soybean. This soy protein coating provides an excellent barrier against oxygen by which they act against oxidation damage on the product. Soy protein coatings generally have poor moisture resistance and water vapor barrier properties [65].

Lipid and waxes derived edible coating

Carnauba wax: Carnauba wax is derived from the palm tree leaves (*Copoernica cerifera*). Carnauba wax is a non-toxic material consisting of alcohols, fatty acids and esters in the composition [41,66]. Carnauba wax has a very high melting point and is used as an additive to other waxes to increase toughness and lusture [20,23].

Bee wax and paraffin wax: Bees' wax is a natural wax produced by honey bees of the genus Apis are widely used as a coating material after purification [32].

Resins: Resin coatings are effective at reducing water loss but are the least permeable to gases resulting in anaerobic respiration and flavor changes thus poor quality. A shellac resin is a secretion by the insect *Laccifer lacca* and is composed of a complex mixture of aliphatic alicyclic hydroxyl acid polymers [27]. This resin is soluble in alcohols and in alkaline solutions. Shellac is not generally regarded as safe substance as it is only permitted as an indirect food additive in food coatings and adhesives [27].

Algae derived edible coating

Alginate based edible films: Alginate is extracted from brown algae, which are sodium salts of alginic acid. Alginate contains excellent barrier to moisture and water vapour [9]. The alginate forms a cross linkage with calcium chloride to form an edible film over the produce surface [9].

Enhancing efficacy of edible coatings

Edible coatings when applied alone do not bring about 100% postharvest quality control. To enhance their efficacy, following approaches have been useful.

Efficacy enhancement through addition of additives

The use of edible coatings as carriers of antimicrobial compounds is another area of research interest for the development of new coating material [11].

Plasticizers and antimicrobials compounds

Glycerol, acetylated Monoglyceride, polyethylene glycol and sucrose are used as a plasticizer material for coating of vegetables and fruits [50].

The incorporation of essential oils and other antimicrobial compounds to provide protection mainly against postharvest diseases spoilage [38,42].

Enzymes such as lysozyme, peroxidase and lactoperoxidase and essential oils such as cinnamon, oregano, lemongrass, clove, rosemary, tea tree, thyme and bergamot have been used to prepare emulsion coating which gives defense against postharvest pathogenic spoilage [13]. Natural antioxidants such as tocopherols, tocotrienols, ascorbic acid, citric acid, carotenoids are also used [13].

Efficacy enhancement through addition of Composites and Bilayer

The Composite and bilayer coatings are considered as the future edible coatings. These coatings may be diverse in nature, consisting of a mixture of polysaccharides, protein, and/or lipids. The major advantage of the composite film includes that they are good carrier materials for various functional components as they are the mixture of several components in one layer. Components are like (a) lipid component; (b) a protein component; (c) a gelled plant gum; (d) an emulsifier; and optionally (e) Buffering agent and/or a plasticizer (Table 2, 3 and 4).

Herbal coatings

Herbal coating of aloe gel, neem, lemon grass, rosemary, tulsi and turmeric: Aloe gel is isolated from *Aloe vera* medicinal plant. *Aloe vera* gel is a polysaccharide matrix rich in active compounds. This gel is tasteless, colorless and odorless transparent in nature [10,34]. This natural product is a safe and environmental friendly alternative to synthetic preservatives such as sulfur dioxide. This coating is tried on raw produce including nectarines, mangoes, apples, strawberries, cherries, papayas, peaches and plums, tomatoes and table grapes [67].

Various herbal extracts from ginger, garlic, *Macaranga hemsleyana, Canthium horridu, Hainania trichosperma, Vatica mangachapoi* have antimicrobial properties. It consists vitamins, antioxidants and essential minerals. Herbal coatings are non-toxic and eco-friendly coating material. Now a days Herbal edible coating getting higher importance in the market [45].

Results

Through the study presented in this review, it can be suggested that, where at once side edible coating technology has many advantages, on the other hand, there is the existence of some challenges which need to be addressed.

Use of edible coating technology in horticultural produce leads to the following advantages mentioned hereunder.

Advantages of edible coatings over other postharvest treatments in context of health

As discussed earlier edible coatings can be consumed with the packaged products, which reduces the use of synthetic packaging material. As there are no materials to discard and if even left will degrade more readily than synthetic, thus contribute to the reduction of environmental pollution [43].

In context of improvement in cosmetic appeal

As discussed earlier in the review, Edible coating technology enhances the organoleptic properties of fruits and vegetables by giving additional shine to the fruit surface besides act as flavoring agent and sweetener. In addition, edible coating reduces fresh weight loss and keep the fruit firm so that its fresh look can be maintained [41].

In the context of improvement in shelf life

The coating reduces the respiration rate as well as senescence by delaying and reducing ethylene production (Partial barrier to gas exchange). It also prevents fruits and vegetables against different storage disorders including chilling injuries mainly in tropical crops. It can be also be used successfully for individual packaging of small products such as pears, beans, nuts, and strawberries for increasing shelf life [9].

In context of being Intermediate technology

Edible coatings serve as an intermediate and linking technology Viz., this can be used as carrier technology for other applications. It acts as a base for different postharvest chemical treatments like the addition of anti-microbial compounds, aroma compounds, and fortification. Encapsulation of different aroma compounds, antioxidants, pigments, ions with edible coats can reduce the browning reactions and enhance the shelf-life of fruits and vegetables. Different nutritional substances such as vitamins and minerals can also be added to enrich the product. They enhance the nutritional composition of fruits and vegetables without affecting its quality [34].

Future challenges in edible coating technology of horticultural produce

Consumer satisfaction is the ultimate goal of any technology. The success of any technology is directly dependent on the level with which consumer is satisfied. This has been observed that edible coatings having thick consistency could restrict the respiratory gas exchange, causing the product to accumulate high levels of ethanol and to develop off- flavour which is not desirable.

Edible coatings which may have good gas barrier properties can sometime cause anaerobic respiration due to which normal ripening process is disturbed in horticultural commodities. Similar the case with coatings by providing an adequate gas exchange fails to be good barriers to water vapour increasing the incidence of microbial spoilage. Allergic reactions might be possible by edible coatings mixed with other coating materials. The vulnerability of antioxidant compounds to high temperature and light, high volatility, limited solubility and unpleasant flavor, limit their application. In near future, these concerns more likely to be solved looking at the existing pace of research in edible coating technology.

Conclusion

From the detailed study presented in this review, it can be said that edible coating technology is a green technology and need of present era. Various food and drug administrations and Food safety regulatory bodies have not only approved but also have prescribed the safe limits of edible coatings. From this review, it can be concluded that In the era where chemical additives eating the health of consumers, edible coatings technology proved to be boon for horticulture postharvest industry of fruit, vegetables, mushrooms, postharvest edible products of flowers and plantation crops etc. Information on various aspects of edible coating with respect to horticultural commodities will help to evolve novel coatings in this field. Knowhow of various aspects of edible coating to retain the postharvest quality of horticultural produce and products will help in exploring new formulations and will open up the gates for increasing efficacy of existing edible coating as well.

Bibliography

1. Anon. Indian Horticulture Database: National Horticulture Board, Ministry of Agriculture, Government of India, Gurgaon, India (2017).
2. Prasad K., *et al.* "Postharvest treatment of antioxidant reduces lenticel browning and improves the cosmetic appeal of mango (*Mangifera indica* L.) fruits without impairing quality". *Journal of Food Science and Technology* 53.7 (2016a): 2995-3001.
3. APEDA Agricultural and Processed Food Products Export Development Authority 2015: Ministry of Commerce, Government of India, New Delhi, India (2015).
4. Prasad K and Sharma RR. "Screening of mango genotypes for the incidence of lenticel browning, a new postharvest problem". *Indian Journal of Agricultural Sciences* 86.9 (2016): 1169-1171.
5. Kumar R and Kapur S. "Morpholine: A Glazing Agent for Fruits and Vegetables Coating/Waxing". *International Journal of Science Technology and Engineering* 2.11 (2016): 694-697.
6. PFA. "Prevention of Food Adulteration Act", 19th edition. International Law Book Co., New Delhi, India (2008).
7. Ochoa-Reyes E., *et al.* "Improvement of shelf life quality of green bell pepper using edible coating formulation". *The Journal of Microbiology, Biotechnology and Food Sciences* 2.6 (2013): 2448-2451.
8. Valero D., *et al.* "Effect of alginate edible coating on preserving fruit quality in four plum cultivars during postharvest storage". *Postharvest Biology and Technology* 77 (2013): 1-6.
9. Koh PC., *et al.* "Application of edible coatings and repetitive pulsed light for shelf life extension of fresh-cut cantaloupe (*Cucumis melo* L. *reticulatus* cv. *Glamour*)". *Postharvest Biology and Technology* 129 (2017): 64-78.
10. Panwar S., *et al.* "Permeability of Aloe vera composite coatings and their effect on quality of peeled carrots". *Current Science* 111.12 (2016): 2031-2035.
11. Sanchez-Gonzalez L., *et al.* "Effect of hydroxypropyl methylcellulose and chitosan coatings with and without bergamot essential oil on quality and safety of cold-stored grapes". *Postharvest Biology and Technology* 60.1 (2016): 57-63.

12. Zhang J., *et al.* "Effect of Chitosan Coating Combined with Sulfur Dioxide Fumigation on the Storage Quality of Fresh Areca Nut". *Journal of Food Processing and Preservation* 41.3 (2016): 1-7.

13. Xing Y., *et al.* "Effects of chitosan coating enriched with cinnamon oil on qualitative properties of sweet pepper (Capsicum annuum L.)". *Food Chemistry* 124.4 (2013): 1443-1450.

14. Pinto AM., *et al.* "Starch-cashew tree gum nanocomposite films and their application for coating cashew nuts". *LWT-Food Science and Technology* 62.1 (2015): 549-554.

15. Baldwin EA., *et al.* "Edible Coatings and Films to Improve Food Quality". CRC Press-Taylor and Francis Group, New York (2011).

16. Fonseca MJO., *et al.* "Fungicides and wax in the postharvest preservation of mango 'Haden'". *Acta Horticulture* 645 (2004): 557-563.

17. Maqbool M., *et al.* "Control of postharvest anthracnose of banana using a new edible composite coating". *Crop Protection* 29.10 (2010): 1136-1141.

18. Malmiri J., *et al.* "Development of an edible coating based on chitosan-glycerol to delay 'Berangan' banana (Musa sapientum cv. Berangan) ripening process". *International Food Research Journal* 18.3 (2011): 989-997.

19. Marpudi SL., *et al.* "Enhancement of storage life and quality maintenance of papaya fruit using Aloe vera based antimicrobial coating". *Indian Journal of Biotechnology* 10 (2011): 83-89.

20. Feygenberg O., *et al.* "Postharvest use of organic coating for maintaining bio-organic avocado and mango quality". *Acta Horticulture* 682 (2005): 507-512.

21. Valverde JM., *et al.* "Novel edible coating based on aloe vera gel to maintain table grape quality and safety". *Journal of Agricultural and Food Chemistry* 53.20 (2005): 7807-7813.

22. Ergun M., *et al.* "Ripening and quality responses of mamey sapote fruit to postharvest wax and 1-methylcyclopropene treatments". *Postharvest Biology and Technology* 36.2 (2005): 127-134.

23. Barman K., *et al.* "Putrescine and carnauba wax pretreatments alleviate chilling injury, enhance shelf life and preserve pomegranate fruit quality during cold storage". *Scientia Horticulturae* 130.4 (2011): 795-800.

24. Duan J., *et al.* "Effect of edible coatings on the quality of fresh blueberries (Duke and Elliott) under commercial storage conditions". *Postharvest Biology and Technology* 59.1 (2011): 71-79.

25. Ergun M and Satici F. "Use of Aloe vera gel as biopreservative for 'Granny Smith' and 'Red Chief' apples". *Journal of Animal and Plant Sciences* 22.2 (2012): 363-368.

26. El-Anany AM., *et al.* "Effect of edible coatings on the shelf life and quality of 'Anna' apple (Malus domestica Borkh.) during cold storage". *Journal of Food Science and Technology* 7 (2009): 5-11.

27. Zhou R., *et al.* "Quality and internal characteristics of huanghua pears (Pyrus pyrifolia Nakai, cv. Huanhhua) treated with different kinds of coating during storage". *Postharvest Biology and Technology* 49 (2008): 171-179.

28. Goncalves FP., *et al.* "Postharvest control of brown rot and Rhizopus rot in plums and nectarines using carnauba wax". *Postharvest Biology and Technology* 58.3 (2010): 211-217.

29. Yaman O and Bayoundurlc L. "Effect of an edible coating and cold storage on shelf life and quality of cherries". *Lebensmittel-Wissenschaft and Technologie* 35.2 (2002): 146-150.

30. Martinez-Romero D., *et al.* "Postharvest sweet cherry quality and safety maintenance by Aloe vera treatment: A new edible coating". *Postharvest Biology and Technology* 39.1 (2006): 93-100.

31. Wang SW and Gao H. "Effect of chitosan-based edible coating on antioxidants, antioxidant enzyme system, and postharvest fruit quality of strawberries (Fragaria x aranassa Duch)". *Food Science and Technology* 52.2 (2013): 71-79.

32. Velickova E., *et al.* "Impact of chitosan-beeswax edible coatings on the quality of fresh strawberries (Fragaria ananassa cv Camarosa) under commercial storage conditions". *Food Science and Technology* 52.2 (2013): 80-92.

33. Vahdat S., *et al.* "Effect of Aloe vera gel on maintenance of strawberry fruits quality". *Acta Horticulture* 877 (2009): 875-884.

34. Athmaselvi KA., *et al.* "Development of Aloe vera based edible coating for tomato". *International Agrophysics* 27 (2013): 369-375.

35. Jorge E., *et al.* "Effect of edible coatings on bioactive compounds and antioxidant capacity of tomatoes at different maturity stages". *Journal of Food Science and Technology* 51.10 (2014): 2706-2712.

36. Moalemiyan M and Ramaswamy HS. "Quality retention and shelf-life extension in mediterranean cucumbers coated with a pectin-based film". *Food Research International* 1.3 (2012): 159-168.

37. Oluwaseun AC., *et al.* "Effect of edible coatings of carboxy methyl cellulose and corn starch on cucumber stored at ambient temperature". *Asian Journal of Agriculture and Biology* 1.3 (2013): 133-140.

38. Adetunji CO., *et al.* "Effect of chitosan combined aloe vera gel on cucumber (Cucumis sativa L.) postharvest quality during ambient storage". *International Journal of Emerging Trends in Engineering and Basic Sciences* 5.6 (2014): 391-397.

39. Al-juhaimi F., *et al.* "Effect of gum arabic edible coating on weight loss, firmness and sensory characteristics of cucumber (cucumis sativus l.) fruits during storage". *Pakistan Journal of Biotechnology* 44.4 (2012): 1439-1444.

40. Oms-Oliu G., *et al.* "Modeling changes of headspace gas concentrations to describe the respiration of fresh-cut melon under low or superatmospheric oxygen atmospheres". *Journal of Food Engineering* 85.3 (2008): 401-409.

41. Bhattacharjee D and Dhua RS. "Impact of Edible Coatings on the Postharvest Behaviour of Bitter Gourd (*Momordica charantia L.*) Fruits". *International Journal of Current Microbiology and Applied Sciences* 6.3 (2017): 336-347.

42. Durango AM., *et al.* "Microbiological evaluation of an edible antimicrobial coating on minimally processed carrots". *Food Control* 17.5 (2006): 336-341.

43. Xing YX., *et al.* "Effects of chitosan-based coating and modified atmosphere packaging (MAP) on browning and shelf life of fresh-cut lotus root (Nelumbo nucifera Gaerth)". *Innovative Food Science and Emerging Technologies* 11.4 (2010): 684-689.

44. Ghidelli C., *et al.* "Extending the shelf life of fresh-cut eggplant with a soy protein–cysteine based edible coating and modified atmosphere packaging". *Postharvest Biology and Technology* 95 (2014): 81-87.

45. Shi ZF., *et al.* "Preservation of fresh areca nuts with several herbal medicine extracts". *Advanced Materials Research* 647 (2013): 532-537.

46. Cortez-Vega W R., *et al.* "Using edible coatings from Whitemouth croaker (Micropogonias furnieri) protein isolate and organo-clay nanocomposite for improving the conservation properties of fresh cut 'Formosa' papaya". *Innovative Food Science and Emerging Technologies* 22 (2014): 197-202.

47. Sue Bradley. The Telegraph (2015).

48. Rop O., *et al.* "Edible flowers-a new promising source of mineral elements in human nutrition". *Molecules* 17.6 (2012): 6672-6683.

49. Neugebauerova J and Vabkova J. "kvety soucasti food styling". *Zahradnictv* 83 (2009): 22-24.

50. Nisperos-Carriedo MO., *et al.* "Development of an edible coating for extending postharvest life of selected fruits and vegetables". *Journal of the American Society for Horticultural Science* 107 (1991): 57-60.

51. Ayranci E and Tunc S. "A method for the measurement of the oxygen permeability and the development of edible films to reduce the rate of oxidative reactions in fresh foods". *Food Chemistry* 80.3 (2003): 423-431.

52. Eissa H A. "Effect of chitosan coating on shelf life and quality of fresh-cut mushroom". *Journal of Food Quality* 30.5 (2007): 623-645.

53. Mohebbi M., *et al.* "Suitability of Aloe vera and gum tragacanth as edible coatings for extending the shelf life of button mushroom". *Food and Bioprocess Technology* 5.8 (2012): 3193-3202.

54. Jiang T., *et al.* "Changes in microbial and postharvest quality of shiitake mushroom (Lentinus edodes) treated with chitosan-glucose complex coating under cold storage". *Food Chemistry* 131.3 (2012): 780-786.

55. Prasad K., *et al.* "Effect of hot water treatment on the incidence of lenticel browning and quality of mango fruits". *Indian Journal of Horticulture* 73.4 (2016b): 576-581.

56. Dang KT., *et al.* "Edible coatings influence fruit ripening, quality and aroma biosynthesis in mango fruit". *Journal of Agricultural and Food Chemistry* 56.4 (2008): 1361-1370.

57. Dhall RK. "Advances in Edible Coatings for Fresh Fruits and Vegetables: A Review". *Critical Reviews in Food Science and Nutrition* 53.5 (2013): 435-450.

58. Ayranci E and Tunc S. "The effect of edible coatings on water and vitamin C loss of apricots (*Armeniaca vulgaris Lam.*) and green pepers (*Capsicum annum L.*)". *Food Chemistry* 87 (2004): 339-342.

59. Diaz-Mula HD., *et al.* "Alginate coatings preserve fruit quality and bioactive compounds during storage of sweet cherry fruit". *Food and Bioprocess Technology* 5.8 (2012): 2990-2997.

60. Singh DB., *et al.* "Effect of Aloe vera coatings on fruit quality and storability of strawberry (Fragaria x Ananassa)". *Indian Journal of Agricultural Sciences* 81.4 (2011): 407-412.

61. Jimenez A., *et al.* "Changes in oxidative processes and components of the antioxidant system during tomato fruit ripening". *Planta* 214.5 (2002): 751-758.

62. Singh SP and Singh Z. "The postharvest oxidative behaviour of 1-methylcyclopropene treated Japanese plums (Prunus salicina Lindell) during storage under controlled and modified atmospheres". *Postharvest Biology and Technology* 74 (2012): 26-35.

63. Raghav PK., *et al.* "Edible coating of fruits and vegetables: a review". *International Journal of Scientific Research and Modern Education* 1.1 (2016): 188-204.

64. Varasteh F., *et al.* "Pomegranate (Punica granatum L.) Fruit Storability Improvement Using Pre-storage Chitosan Coating Technique". *Journal of Agricultural Science and Technology* 19.2 (2017): 389-400.

65. Alves MM., *et al.* "Effect of ferulic acid on the performance of soy protein isolate-based edible coatings applied to fresh-cut apples". *LWT-Food Science and Technology* 80 (2017): 409-415.

66. Mattos D G., *et al.* "Water relations in post-harvested torch ginger affected by harvest point and carnauba wax". *Postharvest Biology and Technology* 127 (2017): 35-43.

67. Chrysargyris A., *et al.* "Effectiveness of Aloe vera gel coating for maintaining tomato fruit quality". *New Zealand Journal of Crop and Horticultural Science* 44.3 (2016): 203-217.

Volume 2 Issue 5 May 2018