www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(3): 970-978

www.thepharmajournal.com
Received: 26-01-2022
Accepted: 28-02-2022

Vivek Kumar Tiwari
(1) Vegetable Science Division, Defence Institute of High Altitude Research (DIHAR)-DRDO, C/O 56 APO, Leh-Ladakh, India
(2) Horticulture Department, College of Agriculture, Lovely Professional University, Jalandhar, Punjab, India

Vivek Chandra Verma
Vegetable Science Division, Defence Institute of High Altitude Research (DIHAR)-DRDO, C/O 56 APO, Leh-Ladakh, India

Khushboo
Horticulture Department, College of Agriculture, Lovely Professional University, Jalandhar, Punjab, India.

Avantika
Vegetable Science Division, Defence Institute of High Altitude Research (DIHAR)-DRDO, C/O 56 APO, Leh-Ladakh, India

Kaushal Kumar
Vegetable Science Division, Defence Institute of High Altitude Research (DIHAR)-DRDO, C/O 56 APO, Leh-Ladakh, India

Thupstan Tsewang
Vegetable Science Division, Defence Institute of High Altitude Research (DIHAR)-DRDO, C/O 56 APO, Leh-Ladakh, India

Anshu Verma
Vegetable Science Division, Defence Institute of High Altitude Research (DIHAR)-DRDO, C/O 56 APO, Leh-Ladakh, India

Tsewang Norbu
Vegetable Science Division, Defence Institute of High Altitude Research (DIHAR)-DRDO, C/O 56 APO, Leh-Ladakh, India

Somen Acharya
Vegetable Science Division, Defence Institute of High Altitude Research (DIHAR)-DRDO, C/O 56 APO, Leh-Ladakh, India

Corresponding Author
Somen Acharya
Vegetable Science Division, Defence Institute of High Altitude Research (DIHAR)-DRDO, C/O 56 APO, Leh-Ladakh, India

Edible coating for postharvest management of fruits and vegetables

Vivek Kumar Tiwari, Vivek Chandra Verma, Khushboo, Avantika, Kaushal Kumar, Thupstan Tsewang, Anshu Verma, Tsewang Norbu and Somen Acharya

Abstract
Postharvest practices of vegetables and fruits through green technology show salient health benefits. Edible coating is widely accepted post-harvest approach for increasing the shelf life of perishable crops. Application of edible coatings augments shelf life, market value and quality of harvested vegetables and fruits. It does not have any residual effect hence making the horticultural commodities easily consumable without any adverse effect on human body. It responds positively on physical (Moisture retention, glossiness, appearance, firmness), physiological (Respiration rate, ethylene evolution rate) and biochemical attributes (Cell wall degrading enzymes) of commodities grown by agricultural practices. Factors affecting shelf life of fruits and vegetables and how edible coatings help to enhance shelf life, quality and market value of harvested vegetables and fruits are discussed in details in the present review article.

Keywords: Edible coating, fruits and vegetables, post-harvest management, shelf life, consumer demand

Introduction
The maximum post-harvest loss of fruits and vegetables are due to its perishable nature. The necessary action to minimize the post-harvest losses are related to delay in biochemical changes such as ethylene formation, softening, change in pigmentation, respiration rate, acidity and decrease in weight. The minimization of post-harvest losses depends upon various postharvest practises such as selection of products, cleaning, washing, grading, disinfecting, drying, packing and storing. Post-harvest practises also include maintenance of temperature, relative humidity and application of coating for enhancing shelf life of the products. Researchers focussed on developing edible coatings and also improving their properties like mechanical strength, softness, water resistance and transparency. Biopolymers are biodegradable and environment friendly compounds and they can reduce the amount of chemical hazards and home wastes. Water soluble gums are used as coating materials, packaging films, texture modifiers, thickeners, stabilizers and emulsifiers (Nasiri *et al.*, 2017) [31]. Edible coatings are effective in postharvest management practices as they maintain quality of fruits and vegetables (Figure 1). Physical changes during storage can be prevented by using edible coating of lipids, polysaccharides and proteins. The main function of edible coating is to provide barrier between respiration and transpiration. It acts as a variety of functional ingredients such as antimicrobial and antioxidant agents thus enhancing quality and improving shelf life of fresh and minimally processed fruits and vegetables. Edible coatings add layer on outer surface of fruits and vegetables that coats the stomata resulting in reduced transpiration rate hence leading to the reduction in weight loss. It has been proved in a wide range of fruits such as apple, papaya, carrot, guava, plum, mango, apricot, banana, orange, mushroom, tomato and vegetables like radish, potato, tomato and turnip etc. (Prasad *et al.*, 2018) [38]. It also protects a layer from deterioration by inhibiting dehydration, preventing respiration, improving texture quality, helping to retain volatile flavour compounds and decreasing microbial contamination. Edible coatings are classified as hydrophobic (lipid or wax based coating), hydrophilic (polysaccharide-based coating) and hydrocolloids (Warriner *et al.*, 2009) [56]. Edible coatings are natural biomolecules used for better appearance and preservation of fruits and vegetables. In recent times, the consumer demands for edible coatings are very high due to its edibility, non-toxic nature and cost effectiveness as compared to other synthetic coating.

The development of substitutes to synthetic polymers such as edible biodegradable coatings and films from gums has been intensified due to removal and environmental harms with plastic waste (Prasad, 2015) [39]. The market demand of fresh and minimal processed fruits and vegetables has been increasing rapidly over the year, in which the role of edible coating is commendable. Present time, a lot of research is being done on edible coating and the materials of edible coating in food processing technology to reduce waste and limit loss and is environmentally friendly, healthy, functional for storage and market distribution.

Factors affecting shelf life: Shelf life of horticultural product may be defined as the time period from harvest to consumption until product remains safe and maintains its recommended harvest quality throughout the storage period. The food quality is commonly defined as all those characteristics of a food that lead a consumer to be satisfied with the product (Echeverria *et al*., 2008) [7].

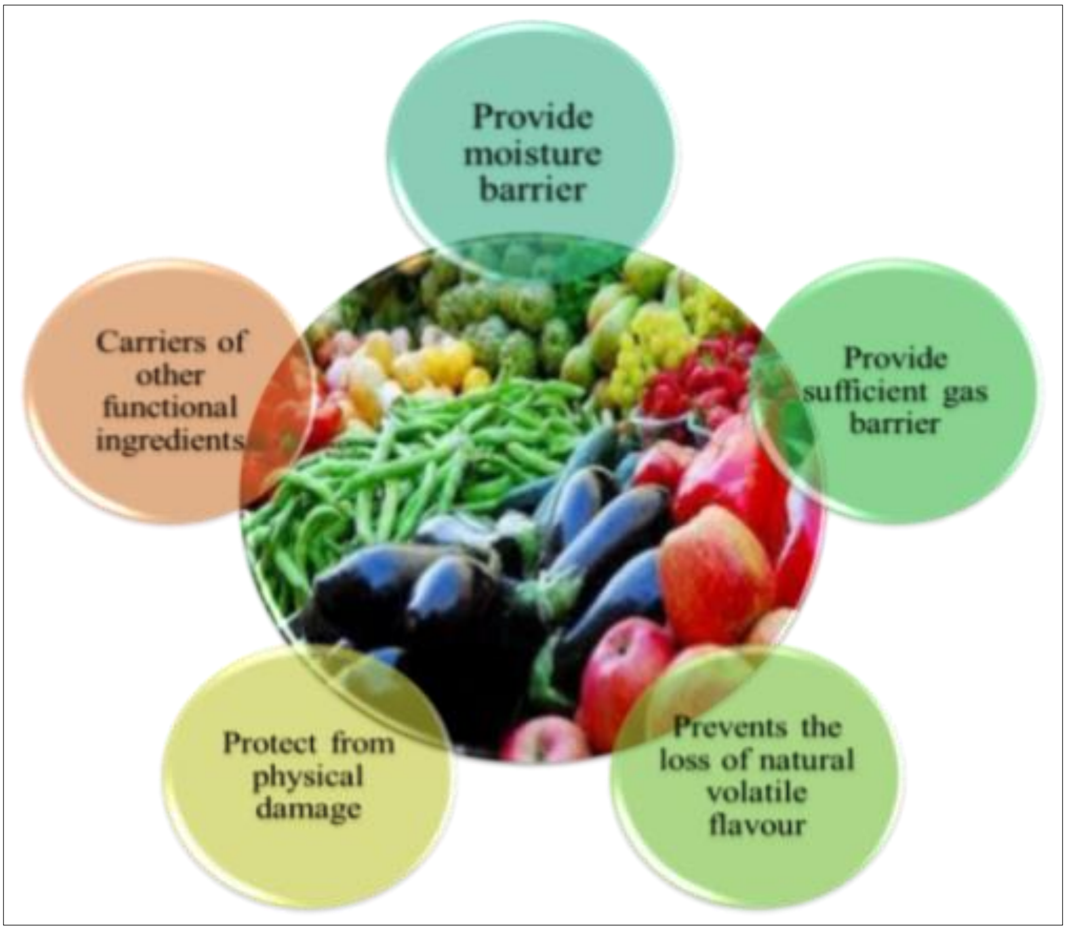

Fig 1: Potential benefits of edible coating

Shelf-life is affected by natural factors such as rate of respiration, biological structure, ethylene biosynthesis, sensitivity, transpiration, compositional changes, developmental stages and physiological breakdown (Martinez-Romero *et al*., 2006) [27] which are described in details as follows:

Respiration rate: Plant tissues survive and continue to respire even after harvesting. It is a metabolic process in which carbohydrates are broken down in the presence of oxygen and release energy. Respiration is a catabolic process which involves carbohydrates, fats, proteins and organic acids in the plant tissue to form various intermediate compounds (Fonseca *et al*., 2002) [12]. The rate of deterioration of harvested fruit and vegetable is proportional to the respiratory rate (Fallik and Aharoni, 2004) [11]. In general, the storage life of horticultural produce varies inversely with the rate of respiration. This is because respiration supply compounds that regulate the rate of metabolic processes directly related to quality parameters, e.g. firmness, sugar content, aroma, flavours, etc. Respiration is widely assumed to be slowed down by decreasing available oxygen as a consequence of decrease in overall metabolic activity (Kanellis *et al*., 1989) [21]. Reduced oxygen level will decrease respiration rates (Isenberg, 1979) [18], biosynthesis of ethylene and reduce sensitivity to ethylene (Kader *et al*., 1989) [20]. The reduction of respiration rate in response to low levels of oxygen is due to a decrease in the activities of other oxidases such as polyphenol oxidase, ascorbic acid and glycolic acid whose congeniality is much lower (Jayas and Jeyamkondan, 2002) [19].

Temperature: The physiological temperature range of the crops varies between 0 to 30 ˚C. The van' thoff rule states that the biological reaction increases 2 to 3fold as the temperature rises by every 10 °C. The increase in temperature also increases the respiration of the horticultural produce which increases the metabolic activities of fresh vegetable and fruits leading to decreases the shelf life. Low temperature has been used to extend the shelf life of temperate fruits and vegetables and has the additional benefit of protecting non-appearance quality attributes: texture, nutrition, aroma and flavour (Paull,

1999) [33].The shelf life of commodities can be enhanced by increasing or lowering the temperature. Enzyme denatured at high temperature, due to reduced respiratory rate. Enzymatic activity slows down at low temperature that is known to increase the shelf life. Fresh fruits and vegetables probably receive the greatest temperature abuse during transportation. Temperature abuse is a function of time and temperature during holding and the relative perishability of a particular commodity. For examples, apples and cabbages are often displayed at improper temperature but they do not lose quality rapidly when compared to strawberries or broccoli. Mean temperatures of display cases used for fruits and vegetable are 7.6 and 8.4 °C in winter and summer, respectively (Leblanc *et al*., 1954) [24]. The optimum temperature and relative humidity for storage of some fruits and vegetables are listed in Table1.

Table 1: Optimum storage temperature for the storage of fresh fruits & vegetables

Commodity	Storage temperature	Relative Humidity (%)	Approximate storage life
Cabbage, early	0 °C	98-100	3-6 weeks
Cabbage late	0 °C	98-100	5-6 months
Cabbage, Chinese	0 °C	95-100	2-3 months
Cauliflower	0 °C	95-98	3-4 weeks
Broccoli	0 °C	95-100	10-14 days
Carrots, bunched	0 °C	95-100	2 weeks
Carrots, mature	0 °C	98-100	7-9 months
Carrots, immature	0 °C	98-100	4-6 weeks
Beets, bunched	0 °C	98-100	10-14 days
Beets, topped	0 °C	98-100	4-6 months
Asparagus	0-1.67 °C	95-100	2-3 weeks
Cucumbers	10-12.8 °C	95	10-14 days
Garlic	0 °C	65-70	6-7 months
Greens, leafy	0 °C	65-70	6-7 months
Lettuce	0 °C	98-100	2-3 weeks
Mushrooms	0 °C	95	3-4 days
Okra	7.2-10 °C	90-95	7-10 days
Onions, green	0 °C	95-100	3-4 weeks
Onion, dry	0 °C	65-70	1-8 months
Onion sets	0 °C	65-70	6-8 months
Peas, green	0 °C	95-98	1-2 weeks
Potatoes, early crop	4.4 °C	90-95	4-5 months
Potatoes late crop	3.3-4.4 °C	90-95	5-10 months
Pumpkins	10-12.8 °C	50-70	2-3 months
Radishes, Spring	0 °C	95-100	3-4 weeks
Radishes, Winter	0 °C	95-100	2-4 months
Spinach	0 °C	95-100	10-14 days
Turnips	0 °C	95	4-5 months
Turnip greens	0 °C	95-100	10-14 days
Tomatoes mature green	12-21 °C	90-95	1-3 weeks
Tomatoes firm ripe	12-21 °C	90-95	4-7 days
Apples	-1.0-4.4 °C	90-95	1-12 months
Apricots	-0.5-0 °C	90-95	1-3 weeks
Bananas, green	17-21 °C	85-95	1-4 weeks

Source: Hardenburg *et al*., 1954 [15]

Temperature is an important factor in terms of appearance, shelf life, texture and nutritional attributes during storage of fruits and vegetables. Heat treatments are used for insect disinfectants and disease control. After the heat treatments sometimes, injuries occur due to storage of fresh commodities at low temperature (Paull and Armstrong, 1994) [34]. This is only due to temperature variation which leads to thawing and ultimately disruption of membrane integrity. Heat sensitivity may be modified by differences in season and types of cultivars. Storage temperature also influences the vitamins and other nutrients in many fruits and vegetables. Loss of vitamin c is generally occurred at higher storage temperature (Weichmann, 1987) [57]. Kale, collards, turnip greens, spinach, grape, cabbage, and snap beans exposed to conditions favorable for water loss have more rapid loss of vitamin C (Ezell and Wilcox, 1959) [10]. Flavor is determined largely by the sugar to acid ratio. Changes in these two components can vary independently and so alter flavor. Storage temperature can influence the flavor by alteration in sugar and acid in various fruits (Reyes and Paull, 1995) [41]. Storage at higher temperature also leads to the loss of volatile compounds which is responsible for aroma (Paull, 1999) [33].

Ethylene production and sensitivity: Ethylene (C_2H_4) is natural phytohormones synthesized in plants from methionine. The major role of ethylene is to promote ripening of fruits. It is simple organic molecule present in the form of gas and regulates the physiological processes of plants and commodity after harvest (Abeles, 1992) [1]. Various factors influence ethylene production are physical injuries, disease incidence, water stress, increased temperatures (up to 30 °C) and maturity stage (Saltveit, 1996) [48]. Ethylene production rates decreases when fruit and vegetables stored at low temperature. It is due to reduction in oxygen levels, and improved co_2 levels around the commodity (Saltveit, 1999) [47].

Physiological breakdown: Exposure of a commodity to chilling temperature results in the disruption of tissues or cells and the quality of the product deteriorates mostly in some tropical and subtropical region (Kays, 1991) [22]. Storing a crop below its freezing point causes injury (Salunkhe *et al*., 1995) [49]. The chilling injuries caused internal browning, pitting, uneven ripening, off flavor development and enhanced incidence of decay. Some physiological disorders originate from abiotic factors such as heat or chilling injuries in the field which appear as bleaching, surface burning or scalding or nutritional imbalances. The lowO_2level, high $CO_2$and excessive C_2H_4 concentrations, may escalate the rapidity of physiological disorders related to storage conditions (Saltveit, 1996) [47].

Enzymatic browning: Enzymatic browning occurs in some fruits and vegetables during processing and storage due to the presence polyphenol oxidase. The enzymatic browning outcome is loss of functional, nutritional and organoleptic abilities like softening, darkening and off-flavour changes (Zawistowski *et al*., 1991) [59]. Enzymatic browning leads to unfavourable changes in the sensory properties, along with reduced market value. Therefore, it has been considered as a main problem to economic losses of fruits like apples, pears, bananas, grapes, etc. And vegetables like lettuce, potatoes, mushrooms, etc. The substrates (mainly polyphenols) that take part in enzymatic browning are present in plastids, whereas the enzymes are located in the cytoplasm. During processing of fruits and vegetables, when the tissue gets injured, plastids are ruptured, and polyphenols oxidase comes in interaction with the substrates (Mayer and Harel, 1979) [28]. It has been observed that a large number of fruits and vegetables undergo enzymatic browning during harvesting or storage due to physiological / mechanical injury and microbial infection.

Postharvest pathology of fruit and vegetables: The chemical composition of vegetables comprises more available water, less carbohydrate (sugars) and pH near to neutral (Manay and Shadaksharaswamy, 2006) [26]. The high-water content and pH near to neutral provide microenvironment for bacterial growth in vegetables. The typical bacterium which causes spoilage or deterioration in vegetables is *Erwina sp*. Bacterial spoilage of fruits is very rare due to the pH of the fruits. Fruits are extensively spoiled by moulds and yeasts (fungi). Rediers *et al*., 2009 [40] reported that during the post-harvest management spoilage of fruits and vegetables are mainly due to fungi and bacteria (Table 2). Bacteria and fungi enter through wounds or natural openings like stomata, lenticels and hydathodes. However, few species belonging from fungi are able to spoil food through direct penetration (Irtwange, 2006) [17].

Biomolecules based edible coating: For enhancing shelf life and storability of fresh produce, food industry is seeking new strategies. Edible coating is a technique which in recent times widely used to increase shelf life of fresh and minimally processed fruits and vegetables. It helps to maintain freshness, taste and aroma, prevents microbial contamination, also maintain the quality of products by regulating the exchange of gases (O_2, CO_2) and moisture. Many polysaccharides such as tapioca, corn, starch, cellulose and cellulose derivatives including MC (Methyl cellulose), HPMC (Hydroxyl propyl Methyl cellulose), CMC (Carboxymethyl cellulose), pullulan and carrageenan have been used for the making edible coatings and films (Figure 2).

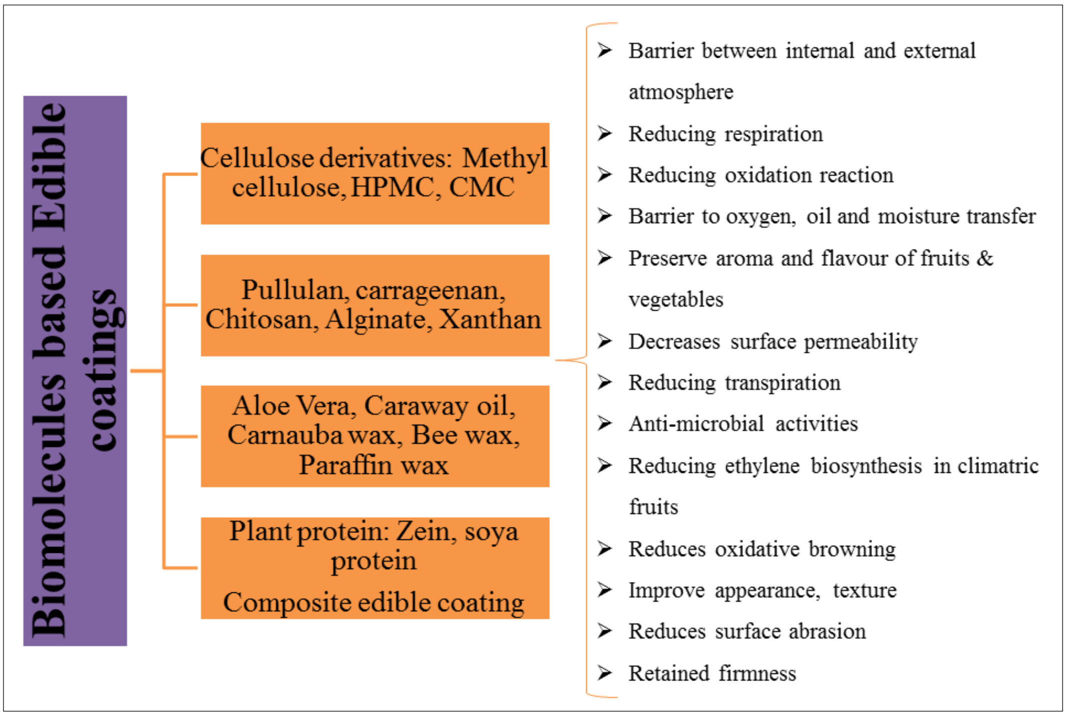

Fig 2: Different types of edible coating and its role in post-harvest management

These coatings materials can be act as a barrier between internal and external atmosphere, thereby reducing respiration of fruits and vegetables (Drake *et al*., 1987) [6]. Starch, the reserve polysaccharide of most plants, is one of the most abundant natural polysaccharides used as food hydrocolloid (Narayan, 1994) [30]. Amylose has a film-forming ability, rendering strong, isotropic, odourless, tasteless and colourless films. Starch films have low oxygen permeability comparable to synthetic oxygen-barrier film such as ethylene vinyl alcohol copolymer (Evoh) at ambient temperature of 20 ºC and relative humidity 50% to 60%. Starch is used for coating fruits and vegetables of perishable nature characterized by high respiration rates thus starch coating suppressing respiration and retarding the oxidation of the coated products (Forssell *et al*., 2002) [13].Cellulose is the structural material of plant cell walls (Nisperos-Carriedo, 1994) [32]. For producing cellulose films, cellulose is first dissolved in mixture of sodium hydroxide and carbon disulphide. After that treated with sulfuric acid to produce cellophane (Petersen *et al*., 1999) [36]. Cellulose-derived films are tough, flexible, totally transparent, water soluble and are resistant to fats and oils. Cellulose derivative-based coatings were applied to some fruits and vegetables for providing barriers to oxygen, oil or moisture transfer.

CMC coatings have capabilities to retain the original firmness and crispness of apples, berries, peaches, celery, lettuce and carrots when used in a dry coating process CMC coating plays an important role in preserving important flavour components of some fresh fruits &vegetables and reducing oxygen uptake without increasing carbon dioxide level in the internal environment of coated apples and pears by simulating a controlled atmosphere environment (Santerre *et al*., 1989) [50].

Edible coatings like chitosan, alginate, xanthan, aloe-vera and caraway oil provide glossy appearance and increases shelf life of fruits and vegetables (Ganiari *et al*., 2017) [14]. These edible coatings decrease surface permeability to CO_2, O_2 and water vapour by acting as physical barriers on the fruits and vegetables surface that leads to decrease in respiration rate and transpiration.

Chitosan (2-amino-2-deoxy-*β*- d-glucan) has been one of the most promising coating materials for fresh commodities because of its excellent film-forming property, broad antimicrobial activity and compatibility with other substances such as vitamins and minerals (Ribeiro *et al*., 2007). Chitosan-based coatings have shown effectiveness in delaying ripening and decreasing respiration rates of fruits & vegetables (Vargas *et al*., 2006). In bell peppers, cucumbers and tomatoes chitosan-based coating reduces weight loss, colour wilting and fungal infection (El-Ghauth *et al*., 1992) [8].

A. Vera is a tropical and subtropical plant that has been used for centuries for its medicinal and therapeutic properties (Eshun and He, 1992) [9]. Recently, there has been increased interest in using *a. Vera* gel as a functional ingredient in drinks, beverages and ice cream (Moore and Mcanalley, 1995) [29]. Apart from that it is widely accepted as edible coating material for fruits and vegetables due to its antimicrobial activities such as reduces populations of bacteria, molds and yeasts (Song *et al*., 2013) [51]. *A. Vera* gel coatings, reduces respiration and ethylene synthesis rates, polyphenol oxidase and peroxidase activity Chauhan *et al*., 2011) [3]. *A. Vera* gel-based edible coatings have shown to prevent loss of moisture and firmness, control respiratory rate and maturation development, delay oxidative browning and reduce microorganism proliferation of table grapes (Valverde *et al*., 2005) [54]. Alginates are extracted from brown seaweeds. Alginate coatings are good oxygen barriers and retard lipid oxidation in fruits and vegetables. They show good ability to reduce weight loss and natural microflora counts in minimally processed carrots (Amanatidou *et al*., 2000) [2].

Table 2: Common postharvest diseases and causal organism of fruits and vegetables

Fruit	Disease	Causal organism	Vegetable	Disease	Causal organism
Apple, Pear	Blue mould	*Penicillium spp.*	Cucurbits	Bacterial soft rots	*Erwinia spp., Bacillus polymyxa*
	Grey mould	*Botrytis cinerea*		Grey mould	*Botrytis cinerea*
	Bitter rot	*Colletotrichum gloeosporioides*		Fusarium rot	*Fusarium spp.*
	Alternaria rot	*Alternaria spp.*		Charcoal rot	*Macrophomina phaseolina*
Peach, Plum, Apricot	Brown rot	*Monilia spp.*	Tomato	Bacterial soft rots	*Erwinia spp., Bacillus polymyxa*
	Grey mould	*Botrytis cinerea*		Grey mould	*Botrytis cinerea*
	Blue mould	*Penicillium spp.*		Fusarium rot	*Fusarium spp.*
	Alternaria rot	*Alternaria alternata*		Watery soft rot	*Sclerotinia spp.*
Grapes	Grey mould	*Botrytis cinerea*	Legumes	Grey mould	*Botrytis cinerea*
	Blue mould	*Penicillium spp.*		White mould and Watery soft rot	*Sclerotinia spp.*
Citrus	Blue mould	*Penicillium italicum*	Brassicas	Bacterial soft rots	*Erwinia spp., Xanthomonas campestris*
	Green mould	*Penicillium digitatum*		Grey mould	*Botrytis cinerea*
	Black centre rot	*Alternaria citri*		Alternaria rot	*Alternaria spp.*
Avocado	Anthracnose	*Colletotrichum gloeosporioides*	Leafy vegetables	Bacterial soft rot	*Erwinia spp.*
	Bacterial soft rot	*Erwinia carotovora*		Grey mould	*Botrytis cinerea*
Banana	Anthracnose	*Colletotrichum musae*		Watery soft rot	*Sclerotinia spp.*
	Ceratocystis fruit rot	*Thielaviopsis paradoxa*	Onions	Bacterial soft rot	*Erwinia spp., Pseudomonas spp.,*
Mango	Anthracnose	*Colletotrichum gloeosporioides*		Black mould	*Aspergillus niger*
	Grey mould	*Botrytis cinerea*		Fusarium basal rot	*Fusarium oxysporum*
	Blue mould	*Penicillium expansum*		Smudge	*Colletotrichum circinans*
Papaya	Phomopsis rot	*Phomopsis caricae-papayae*	Carrot	Bacterial soft rot	*Erwinia spp., Pseudomonas spp.,*
	Anthracnose	*Colletotrichum spp.*		Grey mould	*Botrytis cinerea*
Pineapple	Yeasty rot	*Saccharomyces spp.*		Sclerotium rot	*Sclerotium rolfsii*
	Fruitlet core rot	*Penicillium funiculosum, Fusarium moniliforme var. subglutinans*	Potato	Bacterial soft rot	*Erwinia spp., Pseudomonas spp.,*
				Dry rot	*Fusarium spp.*
				Skin spot	*Polyscytalum pustulans*

Coates & Johnson, 1997[4]

Calcium alginate coatings reduce shrinkage, oxidative rancidity, moisture migration, oil absorption and sealing-in volatile flavours, improving appearance and colour and reducing the weight loss of fresh mushrooms in comparison with uncoated ones (Hershko and Nussinovitch, 1998) [16]. Glycerol (20% glycerol w/w containing 1% gum) is added as a plasticizer to the edible coating in order to decrease moisture loss in fruits and vegetables (Velero *et al*., 2013) [53].

Traditional edible lipids coating used for fresh produce are neutral lipids, fatty acids, waxes and resins which are known to be effective in providing moisture barrier and improving texture appearance. Wax coatings such as carnauba wax, beeswax and paraffin wax is applied commercially as protective coatings to block moisture transport, reduce surface abrasion for fresh fruits and vegetables during fruit handling. Commercial applications of wax coatings are rather extensive on citrus, mature green tomatoes, apples, cucumbers and other vegetables such as beans, sweet potatoes, peppers, potatoes, radishes, carrots, squash and turnips (Salehi and Kashaninejad, 2015) [46].

Plant proteins such as maize protein, soy protein, wheat gluten exhibit gases and lipid-barrier properties at low relative humidity to fruits and vegetables (Salehi, 2017) [44]. Zein and soy protein are the two major plant based proteins used as coating materials of fruits and vegetables. The ability of zein and its resins to form tough, glossy and hydrophobic grease-proof coatings that resistance to microbial attack have been of commercial interest (Pomes, 1971) [37].

Composite or bilayer edible coatings such as integrating proteins, polysaccharides and/or lipids together for improving functionality of the coating's material. The improved moisture-barrier properties of composite coatings have made them promising candidates for coating fresh and minimally processed fruits and vegetables. Cole, 1969 [5] was reported that a bilayer coating formed with amylose ester of fatty acids and protein, prevents dehydration and oxidative degradation of fruits and vegetables. Composite coatings with soy or zein protein with amylose ester or fatty acids provided an effective moisture barrier on carrot and fresh-cut apple slices (Williams, 1968) [58]. Wheat gluten with lipid (beeswax, stearic acid and palmitic acid) based bilayer coatings significantly retained firmness and reduced weight loss of fresh strawberries (Tanada-Palmu and Gross, 2005) [52]. Chitosan-lauric acid composite coatings prevented fresh-cut apple slices from browning and water loss (Pennisi, 1992) [35]. A casein-lipid emulsion coating formed a tight matrix that binds to the cut apple surfaces and protects apple slices from moisture loss and oxidative browning (Krochta *et al*., 1990) [23].

Impact of edible coatings on physiology of fruit and vegetables: Edible coatings prevent loss of firmness and moisture, delay oxidative browning, reduce microorganism proliferation and control respiratory rate (Warriner *et al*., 2009) [56]. The relative humidity and temperature of storage area has been controlled during storage. The application of edible coatings meets the demand of fresh vegetables and fruits (Table 3 and 4). Edible coatings have long been used to retain quality and extend shelf life of some fresh fruits and vegetables, such as citric fruits, apples and cucumbers (Li and Barth, 1998) [25]. Fruits or vegetables are usually coated by dipping in or spraying with a range of edible materials, so that a semipermeable membrane is formed on the surface which suppressing respiration, controlling moisture loss and providing other functions. Edible coatings can be utilized for most foods to meet challenges associated with stable quality, market safety, nutritional value and economic production cost. It restricts the exchange of volatile compounds into its surrounding environment through providing gas barriers, which prevents the loss of natural volatile flavour compounds and colour components from fresh commodities. Edible coating act as carriers of other functional ingredients, such as nutraceuticals, flavour, antimicrobial and antioxidant agents' ingredients for reducing microbial loads, delaying oxidation, discoloration and improving quality (Rooney, 2005) [43].

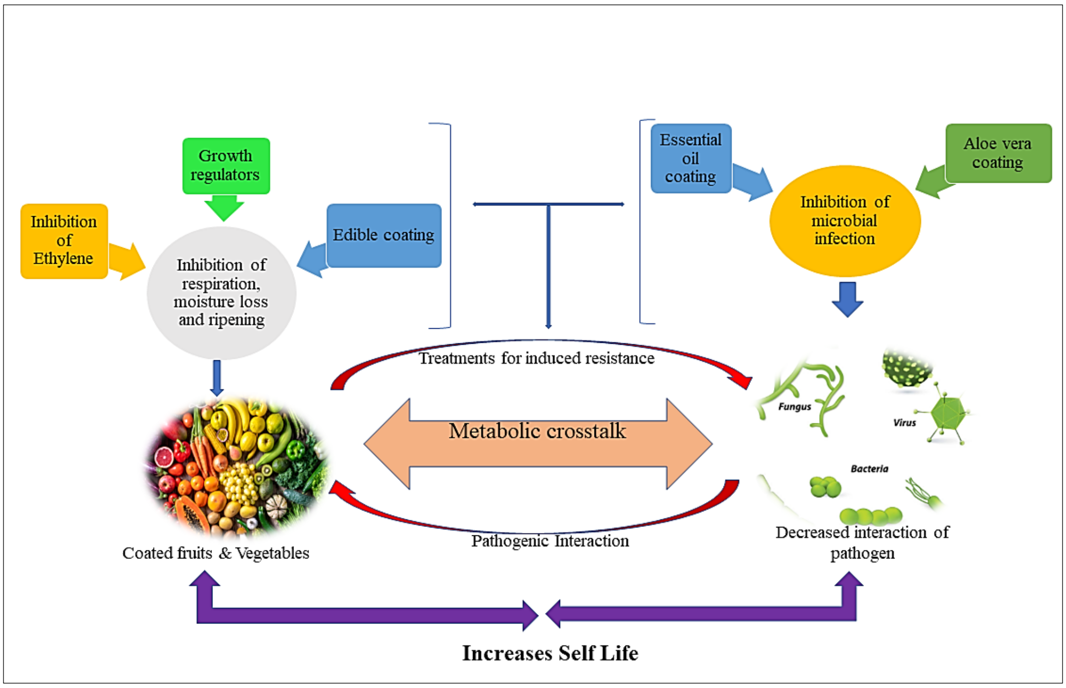

Fig 3: Edible coating improving shelf life of fruits and vegetables

Table 3: Application of edible coatings in vegetable crops (Source: Salehi, 2020) [45]

Vegetables	Edible coating materials	Physiochemical changes
Tomato	Aloe juice/ Cinnamaldehyde	Decrease respiration rate, moisture loss, skin colour and firmness, Increase storage life
	Chitosan	Decreased rate of respiration and ethylene production
Cucumber	Pectin/sorbitol/bee wax	Reduce moisture loss, change firmness
	CMC + corn starch	Reduce mechanical damage and surface microbial load
	Chitosan + Aloe vera gel	Delay post-harvest rotting and slow down changes in pH, titrable acidity, ascorbic acid and TSS
Muskmelon	Gellan + Sodium alginate	Maintain fruit firmness and prevented desiccation
Sliced carrot	Yam starch + glycerol + Chitosan	Reduction in microbial load
Carrot	Alginate	Decrease weight loss and natural microbial total counts
	Casein, casein-monoglyceride, xanthan gum	Casein, casein-monoglyceride: moisture, retention. Xanthan gum: improved color
Melon	β-carotene nano capsules and xanthan	Increased shelf life
Capsicum	Cellulose, chitin/chitosan	Cellulose: O_2 and CO_2 barrier, reduced respiration, colour loss, wilting, fungal infection and the rate of ripening

Table 4: Application of edible coating in fruits (Source: Salehi, 2020) [45]

Fruits	Edible coating material	Physiochemical changes
Fresh-cut Apple	Sodium alginate, Sunflower oil, Whey protein	Reduced browning, Retention of firmness
Apple	Aloe-vera gel	Retention of firmness, Decreased weight loss
Pear	CMC	Decrease weight loss, lower respiration rate, increase shine and extend shelf life
Plum	Alginate	Decreased weight loss, Inhibits ethylene production, delay ripening
Strawberry	Bee wax coatings + chitosan +acetic acid	Reduce fungal infection and weight loss
Banana	Chitosan, modified starch and cellulose	Coatings based on chitosan were much superior in increasing and improving the shelf life and quality of banana.
Apricot	Methylcellulose	Decreasing in the water loss.
Guava	Arabic gum	Edible coatings protect postharvest quality of guavas and reduce its microbial load.
Kiwifruit	Pullulan	Edible coatings can carry biocontrol yeasts against fungi causal agents of postharvest decay.
Mango	Chitosan, modified starch and cellulose	Coatings based on chitosan were much superior in increasing and improving the shelf life and quality of mango.
Orange	Shellac, Gelatin and Persian gum	The results showed that total soluble solids, weight loss, texture firmness, titratable acidity and total antioxidant capacity and respiration rate were influenced by the coatings.
Papaya	Chitosan and pectin	Maintained colour, high β-carotene content, showed lower juice leakage and highest organoleptic acceptability.

Conclusion

The use of edible coating promoting green technology and it has crucial importance during transportation of horticultural crops in different sectors**.** Food safety regulatory bodies have recommended safe limits of edible coatings for horticultural crops and other food products**.** The development of biodegradable coatings and films from gums replace synthetic polymers. It has been widely accepted because it reduces environmental harms due to plastic waste. The edible coatings may replace synthetic packaging has become one of the focuses by scientists. Fresh or blanched fruits and vegetables are protected by natural hydrocolloids/edible coating during transportation. The crucial study of edible coating application on horticultural commodities will help to develop novel coatings materials and explore new formulations which will surely open the gate for future research**.**

References

1. Abeles FB. Fruit ripening, abscission, and postharvest disorders. Ethylene in plant biology. Academic press. 2NDED, 1992, 182-221.
2. Amanatidou A, Slump RA, Gorris LG, Smid EJ. High oxygen and high carbon dioxide modified atmospheres for shelf-life extension of minimally processed carrots. J Food Sci. 2000 Jan;65(1):61-6.
3. Chauhan OP, Raju PS, Singh A, Bawa AS. Shellac and aloe-gel-based surface coatings for maintaining keeping quality of apple slices. Food Chem. 2011 Jun 1;126(3):961-66.
4. Coates L, Johnson G. Postharvest diseases of fruit and vegetables. Plant pathogens and plant diseases. 1997, 533-48.
5. Cole, M.S. U.S. Patent No. 3,479,191. Washington, Dc: U.S. Patent and Trademark Office, 1969.
6. Drake SR, Fellman JK, Nelson JW. Postharvest use of sucrose polyesters for extending the shelf-life of stored 'Golden Delicious' apples. J Food Sci. 1987 Sep;52(5):1283-85.
7. Echeverría G, Graell J, Lara I, López ML. Physicochemical measurements in 'Mondial Gala ®' apples stored at different atmospheres: Influence on consumer acceptability. Postharvest Biol. Technol. 2008 Nov 1;50(2-3):135-44.
8. El Ghaouth A, Ponnampalam R, Castaigne F, Arul J. Chitosan coating to extend the storage life of tomatoes. Hort. Science. 1992 Sep 1;27(9):1016-8.
9. Eshun K, He Q. Aloe vera: A valuable ingredient for the food, pharmaceutical and cosmetic industries—a review. Crit. Rev. Food Sci. Nutr. 2004 Mar 1;44(2):91-6.
10. Ezell BD, Wilcox MS. Vegetable vitamins, loss of vitamin C in fresh vegetables as related to wilting and temperature. J Agric. Food Chem. 1959 Jul;7(7):507-09.

11. Fallik E, Aharoni Y. Postharvest physiology, pathology and handling of fresh produce. Lecture Notes. International Research and Development course on Postharvest Biology and Technology. The Volcani Center, Israel. 2004, 30p.
12. Fonseca SC, Oliveira FA, Brecht JK. Modelling respiration rate of fresh fruits and vegetables for modified atmosphere packages: a review. J Food Eng. 2002 Apr 1;52(2):99-119.
13. Forssell P, Lahtinen R, Lahelin M, Myllärinen P. Oxygen permeability of amylose and amylopectin films. Carbohydr. Polym. 2002 Feb 1;47(2):125-29.
14. Ganiari S, Choulitoudi E, Oreopoulou V. Edible and active films and coatings as carriers of natural antioxidants for lipid food. Trends Food Sci. Technol. 2017 Oct 1;68:70-82.
15. Hardenburg RE, Wright RC, Rose DH, Watada A, Whiteman TM, Wang CY. The commercial storage of fruits, vegetables, and florist and nursery stocks. USDA-ARS Agriculture Handbook. 1954, 136.
16. Hershko V, Nussinovitch A. Relationships between hydrocolloid coating and mushroom structure. J Agric. Food Chem. 1998 Aug 17;46(8):2988-97.
17. Irtwange SV. Application of biological control agents in pre-and postharvest operations. Int. J Agric. Eng. 2006 Feb;8:1-12.
18. Isenberg FM. Controlled atmosphere storage of vegetables. Hort. Rev. 1979;1:338-94.
19. Jayas DS, Jeyamkondan S. PH—postharvest technology: modified atmosphere storage of grains meats fruits and vegetables. Biosyst. Eng. 2002 Jul 1;82(3):235-51
20. Kader AA, Zagory D, Kerbel EL, Wang CY. Modified atmosphere packaging of fruits and vegetables. Crit. Rev. Food Sci. Nutr. 1989 Jan 1;28(1):1-30.
21. Kanellis AK, Solomos T, Mattoo AK. Hydrolytic enzyme activities and protein pattern of avocado fruit ripened in air and in low oxygen, with and without ethylene. Plant Physiol. 1989 May;90(1):259-66.
22. Kays SJ. Postharvest physiology and handling of perishable plant products. Van Nostrand Reinhold Inc, 1991, 1-532.
23. Krochta JM, Pavlath AE, Goodman N. Edible films from casein-lipid emulsions for lightly-processed fruits and vegetables. Engineering and food. 1990;2:329-40.
24. Leblanc DI, Stark R, Macneil B, Goguen B, Beaulieu C. Perishable food temperatures in retail stores. Science et Technique du Froid (France). 1996;2:1
25. Li P, Barth MM. Impact of edible coatings on nutritional and physiological changes in lightly-processed carrots. Postharvest Biol. Technol. 1998 Sep 1;14(1):51-60.
26. Manay NSO, Shadaksharaswamy M. Food: Facts and Principles. New Age International. 2NDED. 2006
27. Martínez-Romero D, Alburquerque N, Valverde JM, Guillén F, Castillo S, Valero D, Serrano M. Postharvest sweet cherry quality and safety maintenance by Aloe vera treatment: a new edible coating. Postharvest Biol. Technol. 2006 Jan 1;39(1):93-100
28. Mayer AM, Harel E. Polyphenol oxidases in plants. Phytochemistry. 1979 Jan 1;18(2):193-215
29. Moore de, Mcanalley B.H. U.S. Patent No. 5,443,830. Washington, Dc: U.S. Patent and Trademark Office. 1995.
30. Narayan R. Polymeric materials from agricultural feedstocks. Polymers from agricultural co-products. J. Am. Chem. Soc. 1994;2-28.
31. Nasiri M, Barzegar M, Sahari MA, Niakousari M. Tragacanth gum containing Zataria multiflora Boiss. Essential oil as a natural preservative for storage of button mushrooms (*Agaricus bisporus*). Food Hydrocoll. 2017 Nov 1;72:202-09.
32. Nisperos-Carriedo M.O. Edible coatings and films based on polysaccharides. Edible coatings and films to improve food quality. 1994;1:322-23.
33. Paull R. Effect of temperature and relative humidity on fresh commodity quality. Postharvest Biol. Technol. 1999 Mar 1;15(3):263-77.
34. Paull RE, Armstrong JW. Insect pests and fresh horticultural products. Treatments and responses, 1994.
35. Pennisi E. Sealed in edible film. Science news (USA). 1992;141(1):12-13.
36. Petersen K, Nielsen PV, Bertelsen G, Lawther M, Olsen MB, Nilsson NH, Mortensen G. Potential of biobased materials for food packaging. Trends Food Sci. Technol. 1999 Feb 1;10(2):52-68.
37. Pomes AF. Zein in encyclopedia of polymer science and technology. Plastics, Resins, Rubbers, Fibers. 1971;15:125-32.
38. Prasad K, Guarav AK, Preethi P, Neha P. Edible coating technology for extending market life of horticultural produce. Acta Sci. Agric. 2018;2(5):55-64.
39. Prasad N, Batra E. Edible coating (the future of packaging): Cheapest and Alternative Source to Extend the Post-harvest Changes: A Review. Asian J. Biochem. Pharm. Res. 2015;3(5):2231-560.
40. Rediers H, Claes M, Peeters L, Willems KA. Evaluation of the cold chain of fresh-cut endive from farmer to plate. Postharvest Biol. Technol. 2009 Feb 1;51(2):257-62
41. Reyes MU, Paull RE. Effect of storage temperature and ethylene treatment on guava (*Psidium guajava* L.) Fruit ripening. Postharvest Biol. Technol. 1995 Oct 1;6(3-4):357-65.
42. Ribeiro C, Vicente AA, Teixeira JA, Miranda C. Optimization of edible coating composition to retard strawberry fruit senescence. Postharvest Biol. Technol. 2007 Apr 1;44(1):63-70.
43. Rooney ML. Introduction to active food packaging technologies. In innovations in food packaging. Academic Press, 2005, 63-79.
44. Salehi F. Edible coating of fruits and vegetables using natural gums: A review. Int. J Fruit Sci. 2020 Sep 14;20(sup2):S570-89.
45. Salehi F. Rheological and physical properties and quality of the new formulation of apple cake with wild sage seed gum (*Salvia macrosiphon*). J. Food Meas. Charact. 2017;11(4): 2006-2012.
46. Salehi F, Kashaninejad M. Static rheological study of *Ocimum basilicum* seed gum. Int. J Food Eng. 2015;11(1): 97-103.
47. Saltveit ME. Effect of ethylene on quality of fresh fruits and vegetables. Postharvest Boil. Technol. 1999;15(3):279-292.
48. Saltveit ME. Physical and physiological changes in minimally processed fruits and vegetables. In Proceedings-Phytochemical Society of Europe. 1996;41:205-220.
49. Salunkhe DK, Kadam S. Handbook of fruit science and technology: production, composition, storage, and processing. CRC Press. 1995, 1-62.

50. Santerre CR, Leach TF, Cash JN. The influence of the sucrose polyester, semperfresh™, on the storage of Michigan grown "Mcintosh" and "Golden delicious" apples 1. J Food Process. Preserv. 1989 Aug;13(4):293-305.
51. Song HY, Jo WS, Song NB, Min SC, Song KB. Quality change of apple slices coated with Aloe vera gel during storage. J Food Sci. 2013 Jun;78(6):C817-22.
52. Tanada-Palmu PS, Grosso CR. Effect of edible wheat gluten-based films and coatings on refrigerated strawberry (*Fragaria ananassa*) quality. Postharvest Boil. Technol. 2005 May 1;36(2):199-208.
53. Valero D, Díaz-Mula HM, Zapata PJ, Guillén F, Martínez-Romero D, Castillo S, Serrano M. Effects of alginate edible coating on preserving fruit quality in four plum cultivars during postharvest storage. Postharvest Boil. Technol. 2013 Mar 1;77:1-6.
54. Valverde JM, Valero D, Martínez-Romero D,Guillén F, Castillo S, Serrano M. Novel edible coating based on Aloe vera gel to maintain table grape quality and safety.J. Agric. Food Chem. 2005 Oct 5;53(20):7807-13.
55. Vargas M, Albors A, Chiralt A, González-Martínez C. Quality of cold-stored strawberries as affected by chitosan–oleic acid edible coatings. Postharvest Boil. Technol. 2006 Aug 1;41(2):164-71.
56. Warriner K, Huber A, Namvar A, Fan W, Dunfield K. Recent advances in the microbial safety of fresh fruits and vegetables. Adv. Food Nutr. Res. 2009 Jan 1;57:155-208.
57. Weichmann J. Post Harvest Physiology of Vegetables. Marcel Bekker. Inc, New York, P, 1987, 145
58. Williams LG. U.S. Patent No. 3,406,078. Washington, DC: U.S. Patent and Trademark Office, 1968.
59. Zawistowski J, Biliaderis CG, Eskin NM. Polyphenol oxidase. In: Robinson DSR, Eskin NAM (eds) oxidative enzymes in foods. Elsevier Sci. 1991;217-273.