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Manisha Ch. Momin
Department of Post-Harvest Technology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India

Alemmoa R Jamir
Department of Plantation, Spices, Medicinal and Aromatic crops, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India

Nikhil Ankalagi
Department of Post Harvest Technology, H. H. Sri Sri Murlidhara Swamiji College of Horticulture, Malegaon Nahsik, Maharashtra, India

Takhellambam Henny
Department of Floriculture and Landscape Architecture, KRC College of Horticulture, Arabhavi, Belagavi, Karnataka, India

Okram Bijaya Devi
Department of Horticulture, North Eastern Hill University, Chasingre, Tura, Meghalaya, India

Corresponding Author:
Manisha Ch. Momin
Department of Post-Harvest Technology, Bidhan Chandra Krishi Viswavidyalaya,

Edible coatings in fruits and vegetables: A brief review

Manisha Ch. Momin, Alemmoa R Jamir, Nikhil Ankalagi, Takhellambam Henny and Okram Bijaya Devi

Abstract
Nowadays, fruits and vegetables are highly demanded in the market because of its nutritional value. Due to their perishable nature, fruits and vegetables have a short shelf life. About 30% fruits and vegetables are affected or damaged by insects, microorganisms, pre and post harvesting conditions during transport and preservation. Preservation of fruits and vegetables is a big challenge for world. Edible coating is an effective method to solve this problem. It provides protective edible covering to fruits and vegetables. It is beneficial for consumers and environment. Today herbal edible coatings are used as a nutraceutical and beneficial for consumer health. Edible coatings are of different types such as hydrocolloids, lipids and plasticisers. These have good barrier properties to O_2, CO_2, moisture and water vapour.

Keywords: edible coating, fruits, vegetables, coating types, hydrocolloids & shelf life

Introduction
Fruits and vegetables are essential constituents of daily diet and are highly demanded in the recent years from most of the population. They are reservoir of vitamins, essential minerals, antioxidants, bio-flavonoids, dietary fibres and flavour compounds which fall easily victim to abiotic and biotic adversities. Fruits and vegetables are highly perishable and during the post-harvest, there are considerable losses due to microbes, insects, respiration and transpiration (Tiwari, 2014) [57]. The external factors of food loss include atmospheric composition such as O_2, CO_2, ethylene ratios, temperature and the stress factors while the internal factors include the species, cultivar and its growth stage (Kluge *et al*., 2002) [25]**.** In addition, contamination of the fruits and vegetables flesh can occur from the skin increasing the fruits and vegetables spoilage leading to biochemical deterioration such as browning, off flavour and texture break down, decreasing the fruits and vegetables quality and the risk to the consumers due to the presence of pathogenic microorganism (Harris *et al*., 2003)**.**
The important quality factors of fresh produce contributing to the marketability are texture, colour, appearance, flavour, nutritional value and microbial safety. These quality factors are measured by plant variety, ripening stage, maturity stage pre-harvest and post-harvest conditions (Lin *et al.*, 2007) [29]**.** The Post-harvest losses of fruits and vegetables are a serious problem because it rapidly deteriorates them during handling, transport and storage. Edible coating over fruits and vegetables are used to improve their quality and shelf life (Kumar *et al*., 2014) [27].
Edible coatings are used for extension of shelf life of fruits and vegetables. These can also be safely eaten as part of the product and do not add unfavourable properties to the foodstuff (Baldwin, 1994)**.** Edible coatings or films increase the shelf life of fruits and vegetables and are environment friendly. In recent years, new edible films and coatings have been developed with the addition of various and edible herbs, antimicrobial compounds to preserve fresh fruits and vegetables (Silvia *et al*., 2011)**.** Edible coatings also help to prevent loss of firmness and moisture. They control maturation, development and respiratory rate. Edible coatings prevent oxidative browning and decrease growth of microorganism in fruits and vegetables for example, Tomato, Cucumber, and Cherries etc., (Kumar and Bhatnagar, 2014) [27]**.** Edible coatings or edible films are contributed to enhance the shelf life of fruits and vegetables by reduction of moisture loss solute migration and gas exchange etc.; as well as by reducing the physiological disorders. Edible coatings have high potential to control browning, discolour activity, off flavour, microbial activity of fruits and vegetables and to extend shelf life (Dhall, 2013) [9]. According to Baldwin, 1995, the main purpose of edible coating for fruits and vegetables is basically to increase the natural barrier, if already present and to replace it in

the cases where handling and washing have partially removed or altered it. Moreover, one of the most important things of this edible coating is the fact that they can be eaten together with the fruits and vegetables.

History

Edible coatings or edible films have been used for centuries in the food industry to preserve food products this is not a new preservation technique. For example waxing on fruits and vegetables and cellulose coating in meat casings (Jamie, 2012) [20]. Edible coatings have been used since 12th century in China. It was not until 1922 the waxing on fruits was invented and first time was commercially applied on fruits and vegetables (CPMA, 2014) [5]. Edible films and coatings form a barrier for chemical, physical and biological changes (Skurtys *et al*., 2005) [52].

At the time of purchasing fruits and vegetables, consumer judge the freshness and quality of the produce on the basis of its appearance (Kader, 2002) [22]. The most common and challenging problem are to maintain and control fresh quality, growth of spoilage and pathogenic microorganism in fresh cut fruit industry. The solution of this problem is edible coating (Rojas-Grau *et al*., 2007). Nawab *et al.*, (2017) [37] told that the edible coatings form a semi-permeable barrier to gas exchange and water vapor, results in alteration of respiration rate, reduction of weight loss, and delay of senescence. In addition to acting as gas and moisture barriers, the coatings control microbial growth, preserve the texture, color and moisture of the product, and thus effectively prolong the shelf life of the product. Recently, various edible coatings were applied successfully for preserving fruits and vegetables such as orange, apples, grapefruit, cherries, cucumber, strawberry, tomato and capsicum were applied successfully. Edible coating of fruits and vegetables is successful or not totally depends on the control of internal gas composition (Salleh, 2013) [50].

Definition

Edible coatings are defined as the thin layer of material which can be consumed and provide a barrier to oxygen, microbes of external source, moisture and solute movement for food. In edible coating a semi permeable barrier is provided and is aimed to extend shelf life by decreasing moisture and solute migration, gas exchange, oxidative reaction rates and respiration as well as to reduce physiological disorders on fresh cut fruits (Baldwin *et al*., 1996)

According to Pavlath and Orts (2009) [42], different type of materials were used for coating and wrapping various fruits and vegetables to extend their shelf life, and this is eaten together with foods, with or without removal is considered an edible coating. Edible coating or edible films provide shiny appearance to fruits and vegetables. Thickness of edible coating is generally less than 0·3 mm (Tharantharn, 2003). The main characteristic feature of edible coating is to increase shelf life of fresh or processed fruits and vegetables and it is protected from postharvest damages and environmental damages. An edible coating protects outer membrane of fresh fruits and vegetables (Mohamed *et al*., 2013) [33]. The edible coatings are served as carrier of texture enhancer, antioxidants and it is used as a nutraceutical. Under high relative humidity, edible coating should be stable, generally recognised as safe. Edible coating or edible films are mostly tasteless, colourless and odourless they should have good mechanical properties. Edible coatings have good gas barrier and moisture barrier properties (Unduranga *et al*., 1995) [58].

Properties

Properties of edible coatings are based on their molecular structure, molecular size and its chemical composition (Arvanitoyanni and Gorris, 1999) [1]. These properties are following-

- Edible coatings have good barrier properties to water, moisture, O_2, CO_2 and ethylene.
- It improves appearance and mechanical handling to maintain structure and colour of fruits and vegetables.
- Edible coatings contains active components such as antioxidants, vitamins, etc., they enhance nutritional composition of fruits and vegetables without effecting its quality.
- These coatings provide a protective covering on fruits and vegetables and enhance their shelf life.

Advantages: Advantage of edible coatings are included (Park, 1999).

1. Edible coatings improve retention of acids, colour, flavour and sugar.
2. Maintain quality of fruits and vegetables during storage.
3. Reduce weight loss and firmness loss.
4. Decrease polymer packaging and waste.
5. Edible coatings can be consumed along with fruits and vegetables, they contain health beneficial nutrients.

Disadvantages: Edible coatings have some disadvantages (Ghaouth *et al*., 1991) [10].

1. Thick coating can prohibit Oxygen exchange, causes off-flavour development.
2. Edible coatings have good gas barrier properties which causes anaerobic respiration due to this normal ripening process is disturbed in fruits and vegetables.
3. Some edible coatings are hygroscopic in nature, which helps to increase microbial growth.

Edible Coating Applied on Different Fruits and Vegetables

Fresh fruits and vegetables are highly perishable and approximately 50% fresh produce are deteriorated during harvest, handling, transportation and storage. Edible coatings play a very important role to handle this situation. Edible Coatings are applied on whole and fresh-cut fruits and vegetables (Youssef *et al*., 2015) [65]. Fruits and vegetables which has been coated are-

Fruits: Edible coated fruits are Orange, Apple, Grapefruit, Cherry, Papaya, Guava Lemon, Strawberry, Mango, Peach etc. and fresh-cut Apple, fresh-cut Peach, fresh-cut Pear etc.

Vegetables: Tomato. Cucumber, Capsicum, Cantaloupe and minimally processed Carrot, fresh-cut Potato, fresh-cut Cabbage, fresh-cut Tomato slices, fresh-cut Onion, Lettuce.

Classification of edible coatings

Edible coatings are having hydrophobic group, for example lipid-based or waxes, and hydrocolloids or hydrophilic group, for example polysaccharides-based, protein-based or combination of both groups to improve function of edible coating (Warriner *et al*., 2009) [61]. Edible Coatings are not chemically synthesised and it is natural. It is generally used for good appearance and preservation of fruits and vegetables.

The main advantages of edible coating are its edibility, non-toxic nature and cost effective as compared to other synthetic coating (Prasad and Batra, 2015) [43]. Edible coating materials are generally made up of polysaccharides, proteins and lipids (Pascall and Lin, 2013) [41]. The edible coatings are mainly divided into three classes; these are following- (Donhowe and Fennema, 1993) [8].

1. Hydrocolloids: e.g., polysaccharides, proteins and alginate.
2. Lipids: e.g., fatty acids, acryl glycerides and waxes.
3. Composites: e.g., protein/protein, polysaccharides/protein, lipid/polysaccharides

Edible coating materials are produced with a variety of natural substances such as polysaccharides, protein, lipids by the addition of surfactants and plasticisers. The function and performance of edible coating mainly depends on its mechanical, barrier and colour properties, which control the gas transfer and moisture loss of fruits and vegetables (Lin and Zhao, 2007) [29].

Hydrocolloids: Hydrocolloids are originated from animals, vegetables, microbial or synthetic, they are hydrophilic polymers. They have hydroxyl group and may be poly-electrolytes such as Alginate, Carrageenan, Pectin, Carboxy Methyl Cellulose, Xanthan gum and Gum Arabic. Today, hydrocolloids are used in wide range as a coating forming solution to coat and control the colour, texture, flavour and shelf life of fruits and vegetables (Williams and Phillips, 2000). Generally, all hydrocolloids are partially or completely dissolve in water and principle use of this is to increase the viscosity of the aqueous phase (continuous phase) i.e., gelling agent thickness. They act as an emulsifier due to this stabilising effect. The hydrocolloids are divided into two classes-

- Polysaccharide based
- Protein based

Polysaccharide-based: The most common polysaccharides used for edible coating of fruits and vegetables are chitosan, starch, alginate, cellulose, pullulan, carrageenan, gellan gum etc. Polysaccharides based edible coatings having poor moisture barrier properties, it is water soluble. But it contain moderately low O2 permeability. Mostly, polysaccharides based edible coatings are applied on fresh and minimally processed fruits and vegetables, by creation of modified atmosphere condition to reduce their respiration rate. Its improved mechanical handling property and additives carrying capacity (Bai and Plotto, 2012) [2].

Polysaccharides give crispiness, hardness, compactness, thickening quality, adhesiveness and viscosity to a variety of edible coatings. Polysaccharides are made up of polymer chain, having excellent gas barrier properties, resulting in desirable modified atmosphere that extend the shelf life of the fruits and vegetables without forming anaerobic conditions. These coatings are given below-

Cellulose Derivative

Cellulose is easily found in nature. It is made from long chain of anhydro-glucose polymer. Cellulose is reacted with alkali, then it is treated with appropriate chemical reagent and then it forms substitute of cellulose chain of anhydro-glucose monomers. This pro cess has been done under controlled conditions. The substitution reagents are given below-

a. Methyl cellulose- formed by chloromethane,
b. Hydroxypropyl cellulose (HPC)- substitute reagent is propylene oxide,
c. Hydroxypropyl Methyl Cellulose (HPMC)- mixed substitution of chloromethane & propyl oxide,
d. Methyl ethyl Cellulose (MEC)- mixed substitution of chloromethane &chloroethane,
e. Carboxy Methyl Cellulose (CMC) - monochloroacetic acid.

Methyl Cellulose, HPMC, HPC, CMC films or coatings contain film forming characteristics (Murray, 2010).

Starch Derivatives

Starch is the most common polysaccharide. Starches are obtained from cereal grains such as wheat, maize, rice etc., and cereal grains are belong to Poaceae family. Potato and other tubers, legumes are also good source of starch (Walstra, 2003) [60]. Starches are composed of anhydro-glucose units. Starch is a homopolymer composed of polysaccharides components- one is water soluble amylose and second is water insoluble amylo-pectin. On the other hand the amylose are a linear or unbranched chain of D-glucose (1-4 linkage) and the amylopectin is a branched chain of glucose (1-6 linkage). Amylose are good starch derivatives for film and coating material coatings and films of high amylose corn starch or potato starch are contained high stability during long period preservation. These chains are held by the help of glucosidic linkage. Starch derivatives are breakdown by the help of amylase and the final product is dextrin. Starch amylose for example corn starch is excellent source for coating and film production (Mark *et al.*, 1966) [31]. Corn starch based films and coatings demonstrated of physical characteristics resemble to plastic films and coatings, they are tasteless, odourless and colourless and non-toxic. It is biologically absorbent, semi-permeable to oxygen and carbon-di-oxide.

Chitosan

Chitosan is derived from chitin, it is an edible polymer. Chitin is mainly found in crustacean animal shells. Chitosan is the most common non-toxic and natural product after cellulose for formation of edible coating (Shahidi *et al.*, 1999) [51]. Chitosan having good character feature without addition any type of additive and antioxidants such as it contains good O2 barrier and CO2 permeation and antimicrobial activity against microorganism. Chitosan has excellent mechanical properties. Viscosity of chitosan is very high similar to the natural gums. Chitosan are made up of transparent and clear coatings, increase shelf life of fruits and vegetables. Its coating are normally smooth, shiny, cohesive and without cracks on surface (Reiberro *et al*., 2007) [46].

Gums

Mostly all gums are polysaccharides it consists of sugars. Gums are used for preparation of edible coating on fruits and vegetables because of its texture capability. Generally, gums are divided into three parts-

a. Exudate gums (e.g., gum Arabic)
b. Extractive gums (e.g., guar gum)
c. Microbial fermentation gums (e.g., xanthan gum).

Gums are soluble in water. Xanthan gums are prepared by microbial extraction by fermentation process. It is rapidly spread in water due to this high viscosity are found readily in cold and hot both stages. A mixture of gum Arabic, guar gum and xanthan gum are used to form equal coatings with good adhesion property in wet batters. In mesquite gum formation a coating by the addition of a little quantity of lipid, it shows excellent water barrier property (Mei *et al*., 2006) [32]

Alginate

Alginate is obtained from brown seaweed, which is related to the Pheophyceae family. Alginate contains salts of Alginic acid. Alginate having a linear chain copolymer of D-mannuronic acid L-guluronic acid monomers, the chemical formula of alginate is $(C_6H_8O_6)$ n. It is found in white, yellow, fibrous powder form. Alginate is commonly used in form of Sodium alginate this is extracted from brown algae. Alginate contain excellent barrier for moisture and water vapour (Robertson, 2009) [49].

Alginate maintains good properties useful in food application. It has a unique colloidal property, which contains stabilising, thickening, suspending coating or film producing gel forming and stabilising emulsion. Alginate coating materials are made by the use of divalent cations such as Ca, Mg, Mn, Al etc.; it is used as gelling agent. Alginate has some desirable properties including reduction of shrinkage, moisture retention, colour and odour of food. Strong edible coatings or films are made from alginate and present formally poor water resistance due to own hydrophilic nature (Brochard *et al*., 2005) [4].

Pectin

Pectin is a group of polysaccharides which is derived from plant; it is naturally found in fruits and vegetables. Pectin is good for low moisture fruits and vegetables but is not a good moisture barrier. It is a heterogeneous group of acidic polysaccharides. It is commonly found in peel of citrus fruits and apple pomace. HMP (High Methoxy Pectin) are excellent pectin compound for producing good film and coating. The mixture of citrus pectin and high amylose starch provided a pliable film and coating. These are stable at the temperature of 180˚C; pectin is dissolved in poly vinyl alcohol (Fang and Hanna, 2000) [12].

Carrageenan

Carrageenan is water soluble polymer; it contains a linear chain of partially sulphated galactans, which have ability to forming coating or film material forming. Carrageenan is a sulphated polysaccharide, extracted from cell wall of different red seaweeds belongs to the family Rhodophyceae. Carrageenan coatings or films form a gelation mechanism during moderate drying process lead to a 3-dimansional network form by polysaccharide double helical and to a solid coating or film after solvent evaporation (Karbowiak *et al*., 2006) [23].

Agar

Agar gum are obtained from red seaweed Rhodophyceae family, it is a galactose polymer. Agar is hydrophilic colloidal in nature it contains a mixture of agro pectin and agrose. It is used widely in microbiological media to give firmness. Agar forms a strong gel melting point for above the initial gelation temperature. Agar gels are set on cold temperature and melt on high temperature. Because of their capacity to form hard gel at low concentration and of its extraction (Stanley, 1995) [54]. Agar is widely used in food industry.

Protein-Based Edible Coating: Protein based edible coatings are derived from animals and plants. The plant based protein edible coating material are milk protein casein, whey protein, zein (from maize), gluten (from wheat), soy protein etc. and the animal based protein are egg albumen, collagen etc. Protein based edible coating consist excellent barrier properties for aroma, oil and oxygen and it gives strength but it is not effective barrier for moisture. The reason of its excellent barrier property for oxygen is its tightly packed hydrogen bonded structure. Protein based edible coating has good O_2 barrier property at low relative humidity. Protein based coating are not good barrier for water vapour due to its hydrophilic nature but it consist good organoleptic and mechanical properties (Krochta, 2002) [26]. According to Valencia and Do Amaral Sobral (2018) [59] polysaccharides and protein are the vastly used structural resources for edible coatings. They are more tasteless, transparent and neutral, than those produced from lipids. Garrido *et al.,* (2018) [15] stated that edible coatings and films formed from polysaccharides or proteins usually provides good mechanical strength and good oxygen barriers. However, these materials are hydrophilic in nature, thus they are considered as poor water vapor barriers.

Casein and Whey Protein

Casein is a milk protein, it is found in the form of micelles consisting all casein species. Casein is commonly used in preparation of emulsion because it is amphipathic in nature and containing hydrophilic and hydrophobic ends. Caseinate is the most common casein product; this is easily dissolved in water. Casein could be mostly used for edible coating because casein edible coatings are easy to form.

Zein proteins are obtained from maize, made from corn gluten flour. Zein protein is immiscible in water, it dissolved in aq. Alcohol, glycol esters. Zein protein having good film and coating producing, adhesive and binding properties. Corn-Zein protein is effective to prevent colour change, firmness, weight loss and it increases shelf life of fruits and vegetables, it has good barrier property to O2. Corn-Zein coating and films having excellent barrier property to water vapour, about 800 times higher than other edible coatings and wrapping films. All properties of zein coatings depend upon coating thickness (Park *et al*., 1994) [40].

Lipid Based Edible Coating

The lipid based edible coatings are used from many years for preservation of fruits and vegetables. They provide shiny and glossy appearance to food. Most common lipid based coating materials are carnauba wax, bees wax, paraffin wax, and mineral or vegetable oil. Lipids are having good water barrier capacity (Morillon *et al*., 2002) [35]. Wax coatings contain very good moisture barrier properties as compare to other lipid based coating and non-lipid coating. Oil, fat and wax based coatings are not easily applied to the surface of fruits and vegetables because of its greasiness and thickness and it gives rancid flavour (Robertson, 2009) [49]. Combination of lipid and polysaccharides, protein are used in coating material improve their barrier properties. Galus and Kadzińska (2015) [13] stated that the hydrophilic character of polysaccharide and protein-based materials can be improved efficiently by combination of lipids. Most common lipid based coating materials are as follows-

- Waxes
- Lacs

- Fatty acids and alcohols
- Acetylated glycerides
- Cocoa-based material

This classification is based on the chemical nature of molecules such hydrocarbon chain, polar compound, chain length, no. of acetylation and unsaturation etc., (Debeaufort *et al*., 1998) [6]

Composites Based Edible Coating

Composites or Multicomponent films and coatings contain combination of protein, polysaccharides and lipid based material. This is used to enhance and improve mechanical strength, moisture and gas barrier properties of edible coatings and films. According to Han *et al.,* (2005) [17], composites are divided into two categories given below-

- Bilayer composites
- Conglomerates

Bilayer composites consist two layers combined with same or different coating materials such as protein/protein, polysaccharides/protein, lipid/lipid, lipid/polysaccharides etc., (Yong *et al.,* 2002) [63]. In this type of coating materials include Sucrose, propylene, monoglycerides, proteins, water, waxes and fatty acids.

Plasticizers

Plasticizers are mixed in solution of edible coating for increase mechanical property. These contain low molecular weight, it is mixed with protein coating material for enhance and change its structural ability. Water is also natural and effective plasticizer. The most common plasticizers added in coatings are Glycerol, fatty acids, Sorbitol, propylene glycol, sucrose polyethylene glycol and monoglycerides (Sothernvit and Krochta, 2005).

Applying Methods of Edible Coating

Edible coatings should be applied on fruits and vegetables by different methods. These methods are-

a. Dipping
b. Brushing
c. Extrusion
d. Spraying
e. Solvent casting

The dipping method is used widely for applying edible coatings on fruits and vegetables, in this method Fruits and Vegetables are dipped in coating solution for 5-30 sec. It is easy to apply on mostly fruits. Brushing method gives good result. Edible Coatings applied on generally, Beans and highly perishable Fruits and Vegetables such as strawberry, berries. Other three methods spraying, extrusion and solvent castings are also used in food industry. Extrusion method depends on thermoplastic properties of edible coatings; it is best technique for applying of EC for industrial purpose as compared to other methods (Valverde *et al*., 2005).

Herbal Edible Coatings: A New Concept

Herbal edible coating is a new technique for food industry. It is made from herbs or combination of other edible coatings and herbs, most common herbs used in Edible coatings are such as *Aloe vera* gel, Neem, Lemon grass, Rosemary, Tulsi and Turmeric. Herbs have antimicrobial properties, it consists vitamins, antioxidants and essential minerals (Douglas *et al.*, 2005).

As recently *Aloe vera* gel is widely used in coating on Fruits and Vegetables, because of its antimicrobial property, it also reduces loss of moisture and water. Ginger essential oil, clove bud oil, turmeric neem extract, mint oil, other essential oil and extracts are also used in edible coating of Fruits and Vegetables. Herbs are natural source of vitamins, minerals, antioxidants, beneficial for health act as a nutraceutical and medicines (Chauhan *et al*., 2014).

Effect of edible coatings on fruit crops

Effect on external appearance and glossiness

External appearance is an important aspect of the horticulture commodity. Rough physical management of fruits at postharvest phase is one of the major reasons to destroy of natural wax layer and bruising injury during the packing and transport operations. The edible coating offers a physical barrier between the fruit surface and the external surrounding of produces, which eventually lead to preservation of postharvest quality. Javanmard, (2011) [21] observed whey protein concentrate show high rate of glossiness, taste, color and minimum weight loss over gellan gum coatings.

Effect on fruit firmness and softening

Edible coating keeps the firmness by evading excessive transpiration and respiration those involved directly in lessening storage reserves. Edible coating directly shows effect on fruit firmness by decreases the activity of cell wall degrading enzymes and delaying ripening. It is known that calcium directly affects fruit firmness thus the incorporation of calcium in the edible coating was also showed high effective in increasing fruit firmness. Zhang *et al.,* (2018) [66] discovered weight loos of the apricot was significantly reduced by the soybean isolated protein combined with chitosan along with preventing decrease in firmness and benefiting external characters.

Effect on weight loss of fruits

The weight of horticulture product governs the returns of farmers. Transpiration is the main reason of loss of weight of particular product, which is determined by the change of water vapour pressure between the fruit and the atmosphere. Edible coatings perform as an added barrier between the fruit surface and atmosphere, by which transpiration occurs. Hazrati (2017) [18] reported that coating of peaches with aloe-vera L gel showed significantly positive effects on weight loss, change in color and TSS over control.

Impact on physiology of fruit

Physical state of the fruit is altered by the factor like fruit respiration, ethylene production rate etc. which plays important role in altering fruit physiology. An edible coating shows direct as well as indirect effect on the physiology of harvested commodities. Tesfay (2017) [55] demonstrated that avocado fruits (varieties Hass and Geem) showed lower respiration, ethylene production and higher firmness when coated with 1% carboxyl methylcellulose, moringa leaf and seed extract throughout the storage period.

Ethylene production and respiration

The edible coating stops the entry of oxygen inside the fruit which controls the ethylene production and drops respiration rate. Thus, the fruits remain fresh, firm, and nutritious for a longer period and their shelf life almost doubles. The natural coating on fruits, the type of added coating and amount of coating will extent the formation of the internal modified atmosphere (O2 and CO2).

Biochemical parameters

Other than physical and physiological changes, edible coatings have a direct and indirect part in altering the biochemical constituents, which are responsible for taste and shelf life of the fruits. These include viz. titratable acidity, total soluble solids and ascorbic acid. Hosseini (2018) [19] observed the reducing weight loss, positive effect in maintaining vitamin C, and good sensory acceptability of kumquats which are treated with chitosan coatings incorporated with savory and/or tarragon essential oils.

Total phenolic and antioxidants

Presence of phenolic and antioxidants influences the shelf life of the fruits and vegetables. Presence of these compounds increases the resistance to various postharvest quality maintain factors. Shelf life of the fruits and vegetables increased by antioxidants from internal present and also by external application. Edible coatings have effect and ability to alter/ increase the antioxidant and also total phenolic content in harvested horticultural commodities shows same effect as antioxidants. Li (2017) [28] observed positive effects on fruit quality and highest relative activities of antioxidants enzymes in chitosan based strawberry fruits over alginate and pullulan coatings.

Lipid peroxidation and enzymatic activities

Edible coating shows influence on the cell wall related enzymes activity. The effect is reported in case of enzymes such as polyphenol oxidase, phenylalanine ammonia lyase, and malondialdehyde which have an important role in cell wall degradation and peel browning. Edible coatings also regulate the process of lipid peroxidation which is responsible for cell wall breakdown and free radicals' generation which eventually affects postharvest quality.

Table 1: Edible coating related works in Fruits and Vegetables

Sl. No.	Fruits and vegetables	Used edible coating	References
1.	Fresh-cut Apple	Vanillin, oregano oil, lemongrass	Rojas-Grau *et al*., 2006
2.	Blueberry	CMC, Chitosan, Monoglycerides, Sodium alginate, Calcium casienate.	Duan *et al*., 2011
		Sodium alignate, Pectin, Sodium alignate plus pectin	Mannozzi *et al*., (2017) [30]
3.	Tomato	*Aloe vera*gel	Athmaselvi *et al*., 2013
4.	Grapes	*Aloe vera* gel	Chauhan *et al*., 2014
		Native and octenyl succinic anhydride modified wheat starch coatings	Punia *et al*., (2019) [44]
5.	Strawberry	Arabic gum & Arjan gum Psyllium mucillage	Yarahmdi *et al*., 2014
6.	Cantaloupe	*Aloe vera* gel	Yulianingish *et al*., 2013
7.	Guava	*Aloe vera* gel, salicylic acid and Benzyl adenine	Momin *et al*., 2018
		Guar gum	Esameldin *et al*., (2018) [11]
8.	Banana	Cellulose nanomaterials emulsion as coatings	Deng (2017) [7]
9.	Kinnow mandarin	Chitosan based coatings with Cinnamaldehyde	Gao *et al*., (2018) [14]
		Hydroxyl-propyl-methylcellulose coating combination with CaCl2 and MgSo4	Randhawa *et al*., (2018) [45]
		Polysaccharides from opuntia coating in kinnow	Riaz *et al*., (2018) [47]
10.	Orange	Sellac, gelatin and Persian gum as alternate coatings	Khorram *et al*., (2017) [24]
11.	Papaya	Carboxymethylcellulose coating with essential oil	Zillo *et al*., (2018) [67]
12.	Mango	Cassava starch and chitosan coatings	Oliveira *et al*., (2018) [39, 67]

Conclusion

The edible coating is the most advanced technique in food packaging. Edible coating technology has been discovered to reduce waste materials in the packaging industry. These coatings are made from natural or synthetic components and these components are edible. The main structural components are starch, protein, fat, wax and oils and they have good gelation properties. To enhance their gelation properties and other characteristics like oxygen and water barrier properties added plasticizers. Good food grade plasticizers are glycerol, mannitol, sorbitol, and sucrose. Edible coatings are used to increase the shelf life of fruits and vegetables and retain their nutritional qualities as well as fresh attributes. There are various types of methods to apply edible coatings on fruits and vegetable surface like dipping, spraying, brushing, and film formation. Nowadays composite film/coating formation is more focusing area in the packaging industry. Composite film/coating carries more film functional properties than one component film/coating. Herbal coating is to enhance nutritional properties of food products by adding antioxidants and functional ingredients. It gives better results and health benefits.

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