Application of edible coating on Strawberry: A Review

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Abstract:

From the recent years various methods are emerging out to prevent the fruits and vegetables from spoilage throughout their supply chain to meet the high demands of the consumers. Edible coating has considered as the best method due to its functional barrier properties such as gases and moisture permeability, maintains the freshness, color, TSS, improves the fruit appearance, increases the shelf life period, reduces the microbial and fungal attack. Strawberry is highly perishable fruit because it is easily prone to microbial attack and has a very less life span. It has proven that Strawberries coated with various types of edible coating has a better quality by maintaining the freshness, respiration rate, long shelf life, firmness, TSS, color and free from microbial decay.

Keywords: Strawberry, Edible coating, Composite, Shelf-life.

Introduction

Now a days the post-harvest losses is a most common problem in case of highly perishable and non-climacteric fruits like strawberry (Parveen et al., 2012) belongs to family of Rosacea which is grown throughout the world. In India it is mostly grown in temperate regions of Himachal Pradesh, Haryana, Jammu and Kashmir, Uttar Pradesh. Strawberry (Fragaria ananassa) has a good value addition and most popular fruit consumed in different processed forms like jellies, jams, yogurt, beverages, etc. (Nile & Park, 2014) because of its desirable characteristics like texture, color, rich in nutritional sources like vitamin C & antioxidants (Nadim et al., 2015). There are some health benefits of strawberry which can prevent the diseases like cardiovascular problems, cancer, diabetes, allergy relief, eye sight, neuronal disorder only because of antho-cyanine, anti-inflammatory functions, polyphenols, dietary fibers compounds present in it. (Nichenametla et al., 2006). In the time span of 14 years study OF HPFS revealed that anthocyanin content in strawberry can reduce the cardiovascular effects (Cassidy et al., 2010). Phytochemicals in strawberry can exert the anti-carcinogenic effects by detoxification of carcinogens and increase in serum antioxidant capacity (Wang et al., 2006). Strawberries can withstand up to 2-3 days at room temperature because it is highly sensible to external atmospheric conditions due to its high respiration rate and pathogenic effect (Zhang- Xiao, Peng & Salokhe 2003). It has a short shelf life because of its high respiration rate, water loss, mechanical injury, physiological deterioration, which can be caused during transportation and storage (Aday et al., 2013) and more resistant to bacterial spoilage and fungal attack which can grow easily because of its lower pH levels of 4.6. (Anonymus, 2015). Shelf life extension of strawberry can be achieved by one of the most promising method like edible coating which can maintain the fresh quality for several days when compared to normal storage at room
temperature (Dahl, 2013). Edible coating is one of the traditional methods used to reduce the microbial growth and minimize the loss of deleterious effect of fruits as well as vegetables also (Aloui and Khwaldia, 2016).

Edible coating is defined as thin layer and semipermeable membrane which act as a barrier against gases, water loss and reduces the respiration rate, enzymatic browning, volatile compounds between product and surrounding atmosphere (Dea et al., 2012). Edible coatings are of different types like Hydrocolloids, Lipid based and composite coating. (Donhowe and Fennema, 1993). Edible coating is the best method to reduce the post-harvest losses of fresh fruits in order to meet the demand of the consumers for safe and good quality of product. (Dahl, 2013). These types of edible coating can maintain the texture of the fruit (Choi et al., 2016; Karaca et al., 2014), reduce the skin bruising during handling and transportation (Kumar et al., 2018). Edible coating is the applied on outer surface on fruits and vegetables by increasing the shelf life and shine appearance to fulfill the consumers demand in terms of ecological and healthier foods (Espino –Diaz et al., 2010) by enhancing the nutritional composition of fruits and vegetables without affecting its quality. Coating represents as the hurdle technology without any changes in their structure for solid foods (Guilbert et al., 1995).

**Polysaccharides**

Polysaccharides are sub-divided into starch, cellulose, chitosan, pectin, alginate (Krochta and Johnson, 1997) and these polymers will act as good sacrificing agents by retarding moisture loss but it does not act as a good barrier against water vapor due to its hydrophilic nature (Kester and Fennema, 1986).

**Starch**

Starch based coating is a promising material to increase the shelf life of fruits which can be easily available at low cost (Alves et al., 2007) with the properties like antioxidants and antimicrobial to enhance the aesthetic appearance to food commodity (Jimenez et al., 2012). Starch is a natural polymer made up of amylase and amylopectin with helical linear polymer structure of glucose molecules which have the ability to form strong gelation properties (Alves et al., 2007) for better film forming ability to food commodity. Starch obtained in the form of natural and artificial from various sources such as corn, wheat, potato and rice (Vicentiniet et al., 2005). Strawberries coated with two groups of starch sources (HAC and MAC) were decreased the microbial decay, weight loss, maintained the firmness, turgency and surface color for longer period of time (Maria A Garcia et al., 1998). Previous studies proved that starch based coating can maintain the physiochemical properties (Thakur et al., 2018) which act as barrier between skin and outer environment of the fruit to prevent the water loss and modulation of gas diffusion rates (Nawab et al., 2017). Cassava starch with potassium sorbate as plasticizer has reduced the rate of respiration and improved resistance to water vapor to increase the shelf life (Garcia et al., 2010).
Chitosan

Chitosan is second most abundant polysaccharide which is a derived from the natural resources like marine diatoms (Shahidi et al., 1999) by deacetylation of chitin which does not cause any harm for the humans, pets, wildlife and environment (Aider et al., 2010). Chitosan is the most commonly used edible coating as it is of non-toxic nature, antioxidant, antifungal, better film forming characteristics (Shahidi et al., 1999). Chitosan can control the rate of gases i.e carbon-dioxide and oxygen more effectively, cease the growth of fungi so it can be applied as surface coating on strawberry to increase the shelf life (Gavara, 2008). Strawberries coated with chitosan were firmer, high titratable acidity, controlled the decaying process, modified the internal atmosphere in the tissue and fungistatic property had extended the shelf life when stored at 4 degree C (Ghaouth et al., 1991). Recent studies proved that chitosan treated strawberries has the higher potential to cease the growth of fungi (Han et al., 2004) and there is no change in the acceptance of strawberries from consumers in terms of sensory evaluation (Bautista-Banos et al., 2006). Chitosan for fresh cut strawberries has extended the shelf life by controlling the browning, decay percentage of product (Campnello et al., 2008). Chitosan with 1% calcium dips were proven that retention of firmness, ceases the growth of fungus, reduced weight loss, reduced damage on the fruit surfaces (Hernandez-Munoz, P et al., 2006). Chitosan with antibacterial & antioxidant agent like monomethyl fumaric acid has increased the shelf life from 4 days to 8 days by reduced the count of yeast, microbes and molds (Khan et al., 2019). Chitosan with Palmaira palamata kunzte algae has enhanced the anthocyanins, ascorbic acid, reduced the microbial load, respiration rate and nutrient loss (Rico et al., 2019). Chitosan with olive leaf extract and olive plant extract has shown the best result to inhibit the R. stolonifera due to its antifungal property on strawberries stored at cold storage (Khalifa et al., 2016). Strawberries coated with Chitosan can maintain higher amount of total polyphenols & total anthocyanins (Gol et al., 2013) and imparted sheen, delayed rancidity (Baldwin & Wood 2006).

Cellulose

Cellulose is extremely available since it is a renewable, biocompatible material and thus it emerges as a future key resource for planet (Singh et al., 2015). Cellulose can be found extravagantly and it is a linear compound of an hydro glucose (Kester & Fenema, 1986). As it comprising of a β 1-4 linked D-glucose molecules as result of it tend to make sturdy hydrogen bonded crystalline microfiber (Zugenmaier 2006). There are several cellulose derivates like Hydroxypropyl cellulose (HPC), Hydroxypropyl methyl cellulose (HPMC), Carboxy methyl cellulose (CMC) were produced commercially (Olivas & Barbula Canovas 2005). Applied to a spread on fruit to provide moisture, resist to gases for to develop adhesion of coating formulation (Kester & Fenema, 1986). Strawberries coated with Methyl cellulose (MC) has extended the shelf life by retarding the senescence process and shown more effective on inhibiting the mold infections, weight loss, color change, delayed the softening of the fruit because coating material acted as physical barrier for gases exchange between fruit and
external environment (Nadim et al., 2014) and reduced respiration rates, firmness (Maftoonazad & Ramaswamy, 2005). Bacteriocin film from Bacillus methyloptrophicus BM 47 is added to CMC to apply on fruit which tends to decrease the decay incidence & inhibit the fungal growth that leads to maintain the better quality, safety for processed strawberries (Tumbarski et al., 2019). Carboxymethylcellulose (CMC) with Lactobacillus plantarum strains has reduced the growth of yeast, molds and deterioration of ascorbic acid, phenol compounds rate (Khodaei et al., 2019).

Alginate

Alginate contains the distinctive colloidal properties which embrace emulsion stabilization and maintain better texture to the fruits (Rangel-Marron et al., 2014). In some studies Alginate were used with some compound like Ascorbic acid due to its anti-browning agent for to maintain the color retention, increased antioxidant and it is evaluated as a safe and best treatment (Maribel et al., 2013). One more component of alginate were used as coating material i.e Sodium Alginate it has the features of non-toxicity, biocompatibility, biodegradability & reproduceable for the gel formation easily in an aqueous solution (Aloui et al., 2014) and it prevent the weight loss, firmness (Olivas et al., 2007). 2 % Na-alginate improved the quality of the fruit by extending the storage life without any degradation of physiochemical properties. (Liu 2009). But some studies shows that there is an addition of compounds like antifungal which increases the anti-fungal properties of fruit and vegetables because of the attributes like antifungal, antioxidant were absent in the coating material so that some researchers like Su et al., 2006 has explained that Rhubarb extract has antifungal and antiseptic properties were added with Na-alginate to maintain the physiological metabolism & quality of the fruit has a better result and effective in decreasing the post-harvest diseases, better in retention of the sensory deterioration (Li, et al., 2019).

Pectin

Pectin may be a polyose created of galacturonic acids and these square measure thought of amorphous white color mixture sugar (Padmaja et al., 2015). It could be soluble part of natural fiber derived from cell walls of plants (Martinon et al., 2014) were used pectin and different material for the development of multi composite coating system to increase the shelf life of the fruits. The fruits like apples, guava contains the high amounts of pectin in their aged stage. (Mohnen, 2008). The High DM (Degree of Methyl esterification) (50%) pectin were used as a preservatives in jellies, jam glazing cakes, high sugar content and Low pectin shows DM of 20%-30% were obtained by de esterification of High amounts pectin under controlled conditions and these low DM Pectin were used as food coatings & thickening agents (Hua et al., 2015). Strawberries coated with pectin has decreased the rate of amendment within the firmness, weight loss and additionally reduced the spoilage of fruits from microbes infection. (Yosef 2014). The lower storage temperatures prevents the product by lower down the ripening, related physiochemical & quality attributes. ( Maftoonazad and Ramaswamy, 2019)
Gum Arabics

Gum Arabic is a polysaccharide used in food industries as coating, thickener, emulsifier, beverage (Patel & Goyal, 2015) because of its antioxidant capacity (Gado & Aldahmash, 2013; Montenegro et al., 2012) and antifungal activity against pathogenic bacterial and fungi (Bunyan, Hindi & Jebur, 2015). Gum Arabic coating with 15% is more favorable in increasing the shelf life of strawberry fruit by retaining or delaying fruit quality and biochemical means of preserving strawberry during cold storage (Tahir et al., 2018).

Guar gum

Guar gum obtained from the seed endosperm of Cyamopsis tetragonolobus with water absorption (Rao et al., 2010). It is used for various purposes like thickening agent, packaging material due to its non-toxic nature (Sharma et al., 2018), high mechanical strength, antibacterial properties. Guar gum as coating material has extended the shelf life of the fruit without any deterioration of quality attributes like weight loss, firmness and total soluble solids (TSS) (Minh et al., 2019).

Protein

Protein based edible coatings were obtained from the various sources of plants and animals such as corn zein, whey protein, soy protein, egg albumen, wheat gluten (Baldwin et al., 1996). It has the ability to create a barrier property against mechanical strength, organoleptic (Krochta et al., 2000) and also it maintain the aroma, good oxygen permeability but it lacks moisture barrier due to its hydrophilic nature (Miller et al., 1997).

Corn zein

Corn zein is an alcohol soluble protein (Balmacela & Rha, 1974) which is produced as a co-product from the rapidly growing oil & bioethanol industries. It is considered as a major component as coating for the production of confectionary products, nuts, candy because of its hydrophobic nature, better film and fiber forming characteristics and it act as a good barrier against for oxygen & lipids (Aydt et al., 1991). Commercially it is used in the field of packaging & coating material because of its desired gas permeability that can suppress the rate of respiration of various fruits. Though it cannot protect the whole fruit which grows on ground (Melon) due to its antimicrobial development. It is a safe and eco-friendly material which can be easily transformed to a bio-coating with resistance against heat, humidity & abrasion (Sun et al., 2006), antibacterial activity and desired selective permeability (Mushtaq et al., 2018). Some studies show that corn zein has a good effect in storage of fruits by delaying the color changes (Park et al., 1994).
Wheat gluten

Wheat gluten is a co-product obtained from the recovery of wheat starch in wet processing of wheat flour commercially. It consists of two compounds, i.e., glutenin's and gladins (Shewry et al., 1999). Wheat gluten were modified to improve the functional properties like solubility, emulsifying & foaming ability through physical, chemical and enzymatic methods (Lens et al., 1999). It has good film forming ability, good oxygen barrier through enzymatic & chemical protein treatments but it lacks good barrier property against water vapor due to its hydrophilic nature. Coating with wheat gluten can protect the fruits from loss of moisture (Tanada-Palmel et al., 2000), retard the senescence process, improve the retention of firmness, reduce loss of weight and delayed the infected fruits (Tanada-Palmu et al., 2005).

Soy protein

Soy protein were classified into 2S, 7S, 11S and 15S fraction on the basis of relative sedimentation rates (Gennadios et al., 1994). Soy protein film was made from isolated soy protein (ISP) or heated soy milk. ISP films were transparent, cheaper and easily available plant protein source with nutritional quality, bio compatibility and bio degradability (Cao et al., 2007). Soy protein is a highly asparagine and glutamine residues, thermal treatment of ISP film forming solution can have better mechanical and homogeneous films (Cao et al., 2007) and also ISP with low oxygen permeability prevents the food from oxidative deterioration (Brandenburg et al., 1993). Soy protein cysteine based coating improved the storage period to 9 days in eggplant (Ghidelli et al., 2014) and helps in preventing the antioxidant capacity (Ghidelli et al., 2015). It has the ability to develop promising and unique food packaging technique. Soy protein isolate with honey improved the shelf life by maintaining the physiochemical and microbiological attributes in fruits (Yousuf et al., 2019).

Whey protein

Whey is generated from the manufacturing process of cheese in the liquid form by the coagulation of the milk. Whey protein has the high nutritional and functional properties like high tensile strength and ability to form a film (Gago et al., 2001). Whey protein isolates have good barrier properties to oxygen, flavor (Tereza & Krochta 2000) and it can also control enzymatic browning, act as a natural anti-oxidant (Tien et al., 2001). Whey protein used along with plasticizers because it lacks water vapor permeability and film formed is brittle in nature which is formed with denaturation of whey (McHugh et al., 1994). Whey protein is applied on strawberries which is stored by freezing the coating material prevent the sample from weight loss after thawing and maintained all the quality parameters in rapid freezing (Saazo et al., 2004).

Gelatin

Gelatin is produced by denaturation of protein, collagen which is found in skin, bones and connective tissues of animals, fish because it contains high content of amino-acids glycine, proline and hydro proline it possess
better thermal stability (Gomez-Guillen et al. 2007). Gelatin provides protection against oxygen and light (Gennadios et al., 1994).

**Lipid Based Coating**

Lipid based edible coating consists of acetylated mono glycerides, natural waxes and mineral or vegetable oils and surfactants as they provide shiny and glossy appearance for fruits and vegetables (Dhall 2013). Lipid based coating has good moisture barrier, good compatibility rather than other coating materials other hand it may cause undesirable organoleptic properties because of its greasy surface and lipid rancidity (Lin and Zhao, 2007).

**Waxes**

It is of different types such as bee wax, paraffin wax, carnauba wax and candelilla wax.

**Carnauba wax**

It is also known as the “Queen of wax”. Carnauba wax is a vegetable wax which is obtained from the leaves of Carnauba and it is the hardest wax, less solubility, comprises with aliphatic esters & diesters of cinnamic acid (Zlokainik 2012). Carnauba wax (E903) were considered as a agent for coating in EU with some standards limits for the usage i.e. 200mg/kg surface treatment on fresh fruits and 500 mg/kg for confectionery products (European Food Safety Authority 2012). It has an anti-plasticizing effect (Talens et al., 2006). Rodrigues et al., 2013 it is considered as best treatment for film due to its biodegradability nature. Under ambient conditions the carnauba wax has increased the shelf life of the fruits (Ribeiro et al., 2005) and it can retain the functional properties of several tropical, sub-tropical and temperate fruits and vegetables in cold storage (Eum et al., 2009). It improves glossy appearance, water loss, prevent shriveling to maintain the quality of the fruit (Bai et al., 2003). It can be mixed with nisin to maintain the quality of the fruit from many micro-organisms (Park 2000) and reduces weight loss, delay in color changes, and texture can be maintained without any change in the sample (Puttlingam 2014) due to its high permeability of oxygen and carbon dioxide (Mannheim 1996).

**Paraffin wax**

It is produced from the portion of crude petroleum and contains a solid hydro carbon. It has limited use on the raw fruits and vegetables but it act as barrier for humidity (Shih et al., 2011) and shiny glossy appearance.

**Candelilla wax**

It is obtained from Candelia plant, Candelilla wax has the properties like emulsifying (Baldwin et al., 1997) increases oxygen permeability (Alleyne and Hagenmaier 2000). Samples coated with candelilla wax can inhibit the fungal contamination, increased the shelf life (Saucedo-Pompa et al., 2009), delay ripening process, firmness, weight loss (Tomas et al., 2005), reduce moisture uptake and delay oxygen rancidity. Some studies shown that usage of candelilla wax with salt has reduced the post-harvest diseases, less amount of decay incidence after storage (Gamage et al., 2004) and it can control pathogen on various fruits (Yousef et al., 2012).
Bee wax

It is produced from honey bees. wax coating helps to prevent visual quality, maintains the quality attributes like aroma, color, texture, appearance of the product and extend the shelf life (Sajid et al., 2019) because it has the resistance towards moisture and gas permeability and to enhance functional characteristics like physical and mechanical properties of the films.

Essential oils

Essential oils have been proved to be an good antimicrobial agents, and usage for retaining fruit quality and delaying fungal decay is limited due to their volatility (Mohammedi et al., 2015). Thymol plays a important role in controlling of molds which can damage to the highly perishable crops like strawberry from fungal decay (Valenzuela et al 2015). As Thymol is a natural essential oil with properties like antioxidant and antifungal agent (Campos et al., 2011) and most effective in controlling of Botrytis cinerea (Robledo et al., 2018). Application of essential oils can be used to reduce the grey mold and soft rot incidences by more than 70% after 14 days of storage (Reddy et al., 1998). Lavender essential oil can also reduce the effect of inhibit Botrytis cinera (Rattanapitigorn et al., 2006). Essential can improve the susceptibility of pathogen in order to lower their capacity to overcome gastrointestinal stress and for safe consumption (Viera et al., 2019). In vivo conditions of coated strawberries with Basil essential oil can extended the shelf life by controlling gray mold infection and maintain all the quality attributes (Marjanlo et al., 2010). Strawberries coated with Rosmarinus officinalis and Thymus vulgaris has delayed the change in weight loss, TSS and decreased the decay percentage to extend the shelf life (Alikhani et al., 2012). Strawberries coated with CEO cumin essential oil has shown significant effect against fungal infection without any change in other quality parameters (Asghari et al., 2009). Salvia officinalis (SEO) essential oil on strawberry decreased the fungal infection and storage period increased over to transit to foreign market (Nabigol et al., 2014).

Cactus mucilage edible coating

Mucilages are hetero-polysaccharide’s obtained from plant stems (Trachtenberg & Mayer 1982) which contains the residues of D-galacturonic acid, D-galactose, D-xylose, L-arabinose, L- rhamnose (Gravies and Paroles 1979). By cactus mucilage edible coating can improve the texture, greater firmness to extend the shelf life of strawberry can be maintained with physical and sensory properties without any undesirable changes (Del-Valee et al., 2004).
Composite edible coatings

Composite or multiple edible coating is a new approach in combined form with usage of each type of edible coating such as polysaccharides, proteins and lipids to enable us to utilize the distinct functional characteristics of each type (Kester and Fenneman’s, 1986). Robertson 2009 reported that Composite coating may be heterogeneous in nature to enhance and improve the mechanical strength, gas, moisture barrier properties of edible coating. The combination of carrageenan and bee wax with plasticizers like Glycerol, glucose and fructose were applied on fresh cut mangoes as it shown a good results by extending the shelf life for 6 days in 6°C storage by maintain the pH, reduces the weight loss, ceases the growth of microbes, increases TSS and it has improved the film parameters like water vapor transmission rate and thickness (Afifah et al., 2019). In strawberries the combination of cellulose nano crystals and lemon grass with essential oil with apple pectin extract were used to minimized the mass loss, maintained the level of TSS without any change in physio-chemical properties (Silva et al., 2019). Chitosan and bee wax were coated on the samples to maintain the fruit quality by preventing against disease occurrence and it also transported to a longer distance because the coated samples were maintained freshness without any change in its quality attributes (Eshetu et al., 2018). Rao et al., 2010 reported that the usage of 85% chitosan mixed with 15% guar gum has shown a best results in lowering oxygen permeability, improving mechanical strength properties. 1% chitosan and 15% guar gum extended the shelf life period of the coated samples (Huang et al., 2019). The usage of HMC with 20% bee wax prevented the product from delaying ripening process, firmness, shelf life were extended upto 6 days at normal room temperatures (Formiga et al., 2019). Sodium alginate 3% and 9% cinnamon essential oil were controlled the growth of the fungus (Kaoetankou et al., 2018). Chitosan beads were trapped and gradually release of Eos in the vapour phase inside the package will inhibit the grey mold rot in Strawberry (Moreno 1973). Samples coated with starch – gellan in the ratio of 80: 20 has reduced the weight loss, firmness, rate of respiration, decay of fungus and also these coating solution with thymol essential showed the best result in preventing the sample from grey mold (Sapper et al., 2019). Lemon essential oils were added to the Chitosan based coating to improve the barrier against water vapor transfer (Perdones et al., 2012). Corn starch with plasticizer were used to extend the storage period of the sample nearly up to 28 days because it act as an antimicrobial agent and also the coating solution with sunflower oil has maintained the selective gas permeability and reduced the weight loss. Over all it has maintained the quality attributes of the sample without any spoilage (Garica et al., 2001). Modified bee wax were also used combinely with chitosan as three layered coatings (bee -wax- chitosan -bee wax) to reduce the losses in terms of antifungal infections, weight loss, respiration rate, firmness (Velickova et al., 2013). Zein with essential oils with the incorporation of eugenol (EUG), carvacrol (CAR), thymol(THY) into the films has shown the best results of the coated samples by acting as a antimicrobial to cease the growth of the pathogenic bacteria (Boyacı et al., 2019). In fresh cut strawberries under refrigerated conditions the application of gellan based coating incorporated with geraniol or pomegranate extract were reduced the effect of mesophilic and psychrophilic
bacteria, yeast and molds (Tornadoni et al., 2018). Chitosan and zein film (1:1) ratio showed the best results in minimizing the weight loss, rate of respiration (Zhang et al., 2019). Gum Arabic coating of 15% is mixed with cellulose derivatives (Malmiri et al., 2011) or chitosan can increase the TSS valve (Gol et al., 2013) and lower the respiration rates of strawberries (Ayala–Zavala et al., 20005). Sodium alginate with the gelatin were used to improve the physical properties and antioxidant activity on the strawberries (Dou et al., 2018). Carboxy methyl cellulose is incorporated with garlic essential oil which is rich in allicin can inhibit the growth of microorganisms (Corozo–Martinez et al., 2008). CMC /GEO composite coating can be very useful method to improve the quality of strawberries to maintain higher concentrations of total phenols and anthocyanins of strawberries (Dong and Wang 2017). The strawberry samples were coated with Chitosan and incorporation of thymol/Ne–quinoa protein were acted as anti-fungal agent on the samples and increased the shelf life upto10days under refrigerated conditions. (Robledo et al., 2018). For Edible Active coating based on pullulan and Pectin is a complex anionic polysaccharide present in the cell wall of many fruits and vegetables (Ijma et al., 2000) along with Chitosan that exhibits the bactericide and fungicide activities (Campos et al., 2011). Pectin–EACs were used to reduce weight loss and fruit softening delayed alteration of color and TSS content as it is helped to reduce the microbial growth, chitosan–EAC helped to preserve the organoleptic properties of strawberries. Chitosan beads with lavender or red thyme essential oil were coated on the sample to cease the growth of Botrytis cinereal and it has marketable acceptance due to its sensory properties without any deterioration (Sanagsuwan et al., 2016). Coating of strawberries with Amaranthus crventhus flour and stearic acid were retarded the senescence process, minimizing weight loss, color changes, firmness retention under refrigerated conditions (Colla et al., 2016). Gum Arabic with chitosan showed best results in firmness retention, delay ripening process (Maqbool et al., 2010). The coatings with Gum Arabic and roselle extract has been inhibited the growth of microbes, enzyme activities, decreased the degradation of anthocyanins a, weight loss, improved the firmness of the fruit in cold storage (Yang et al., 2019). Coating with alginate and chitosan as layer by layer has a better results as it reduced the growth of bacteria, fungi and yeast count by 1-2log CFU and degradation of texture is reduced, gas exchange permeability (Povereno et al., 2013). Strawberries coated with soy protein and wheat gluten with the addition of thymol essential oil showed the good results without changing any content of physio-chemical properties and also it reduced the decay from yeast&mold (Amal et al., 2010). Chitosan coated strawberries which is kept in clamshell boxes at 2°C & 88-89% RH for one week has maintained its firmness, texture and appearance with acceptance of the consumers in the market (Han et al., 2005). Cassava starch with 0.05% potassium sorbate maintained the physiochemical properties by reduced the rate of respiration, and enhanced the resistance to water vapor (Garcia et al., 2010). Modified chitosan with bioactive compounds such as Oregano extract, limonene, piper mint, red thyme has proven the best preservative agent to increase the shelf life of strawberries because it inhibited the growth of total flora&molds (Vu et al., 2010). Chitosan with FFD film forming dispersion in added with lemon essential oil has improved the antifungal activity, reduced the rate of respiration and prevented from spore suspension of B. cinerea thus extending the shelf life of strawberry (Perdones et al., 2012). Chitosan with combination of CMC & HPMC at 1% has decreased the decay percentage, delayed loss of weight and maintained
all the quality parameters to extend the shelf life of strawberries. (Gol et al., 2013). Chitosan with bark essential oil cinnamon has decreased the degradation rate, ceases the growth of microbes and enhanced the physiochemical properties. (Aghaei et al., 2019). Combination of banana starch and chitosan with the addition of Alo- vera gel has decreased the decay of fungus, prolonged the storage period nearly up to 15 days. (Pinzon et al., 2019). Strawberries coated with milk protein like whey protein and caseinate by irradiation has decreased the level of fruit contamination and enhanced the barrier properties (Vachon et al., 2003).

Conclusion and Future prospects

Edible coatings are more convenient and safe to their synthetic analogs in order to enhance the storage period of fruits and vegetables. The highly perishable fruits like strawberries needs prevention during storage against spoilage because there is a huge demand for the fresh quality and nutritious product of fruits from the consumers. Thus there is an emerging development of post-harvest strategies for maximizing the shelf life and quality without any loss of nutrition and organoleptic properties. Edible coating is considered as a good technique for preserving the fruits in food industry due to its low cost and easier way. Various coating materials can be used for coating like hydrocolloids, proteins and lipids which is an ecofriendly and can be eaten along with the fruits.

From this review it has been concluded that strawberries coated with various edible coating materials has shown better performance by maintaining the firmness, pH, TSS, respiration rate, gas and moisture permeability, color, reduced the decay percentage from microbial such as Botrys cinerea and fungal attack such as R. Stolonifer and extended the more shelf life at different conditions. Composite edible coating showed better performance in maintaining the quality parameters of strawberries when compared with single layer coating as alternative method of coating.

References

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**Table-1 Effect of Edible Coating on Strawberry**

<table>
<thead>
<tr>
<th>Coating material</th>
<th>Functional ingredient</th>
<th>Amount incorporated</th>
<th>Test conditions</th>
<th>Antimicrobial</th>
<th>Effect</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starch</td>
<td>Potassium sorbate</td>
<td>0.2(w/v)</td>
<td>0°C &amp; 84%RH</td>
<td>Sorbic acid</td>
<td>Inhibited the growth of mesophilic, yeast, molds and extended the shelf life nearly 28 days</td>
<td>Garcia <em>et al.</em>, 2001</td>
</tr>
<tr>
<td>Chitosan</td>
<td>Nutraceuticals calcium gluconate</td>
<td>5.0(w/v)</td>
<td>2°C&amp; 88% RH</td>
<td>Vitamin E</td>
<td>Increased nutrient content, delayed change in color, reduced decay incidence</td>
<td>Han <em>et al.</em>, 2004</td>
</tr>
<tr>
<td>Chitosan</td>
<td>Calcium gluconate</td>
<td>0.5%(w/v)</td>
<td>10°C&amp;70% RH</td>
<td>Sorbic acid</td>
<td>Doesn’t help in firmness retention</td>
<td>Muraz <em>et al.</em>, 2008</td>
</tr>
<tr>
<td>Alginate</td>
<td>Oleic acid</td>
<td>0.7</td>
<td>10°C-re Refrigeration &amp;25°C Cambient</td>
<td>Green tea extract</td>
<td>Controlling Murine Noro Virus and Hepatitis A viruses</td>
<td>Irenefako <em>et al.</em>, 2018</td>
</tr>
<tr>
<td>Candelilla wax</td>
<td>Glycerol Gallic acid</td>
<td>0.3% 0.15%</td>
<td>25°C</td>
<td>B.substilis HFC013</td>
<td>Reduced deterioration, reduced decay fruit against R.stolonifer</td>
<td>Zamudio <em>et al.</em>, 2016</td>
</tr>
<tr>
<td>Chitosan</td>
<td>Beewax</td>
<td>10gm</td>
<td>20°C&amp;35-40% RH for 7 days</td>
<td>Sorbic acid</td>
<td>Prevented from fungal infection, retention of firmness, color</td>
<td>Elenaveliclova <em>et al.</em>, 2013</td>
</tr>
<tr>
<td>Ingredient</td>
<td>Component</td>
<td>Concentration</td>
<td>Temperature</td>
<td>Antimicrobial Effect</td>
<td></td>
<td></td>
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<tr>
<td>Starch</td>
<td>Sunflower oil</td>
<td>2g/l</td>
<td>0°C &amp; 84% RH</td>
<td>Inhibited the growth of Botrytis cinerea &amp; Rhizopus Extended the shelf life</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chitosan</td>
<td>Essential oils</td>
<td>2%</td>
<td>0°C</td>
<td>Inhibited the growth of Bacterium, yeast, mold. Mycelial growth of Aspergillus niger &amp; R. stolonifer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gellan</td>
<td>Geranoin</td>
<td>720µg/ml</td>
<td>5°C -7 days</td>
<td>Inhibited the growth of mesophilic bacteria, yeast, mold, psychrophillic bacteria, improved the texture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starch</td>
<td>Essential oil</td>
<td>2%</td>
<td>25°C &amp; 65% RH for 14 days</td>
<td>Delayed ripening process, inhibit the growth of molds, fungus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zein</td>
<td>Essential oil</td>
<td>1.3%</td>
<td>10°C</td>
<td>Inhibited the growth of Pathogenic bacteria, E. coil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chitosan</td>
<td>------</td>
<td>1%</td>
<td>13°C &amp; 95% RH</td>
<td>Control the post harvest decay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMC+Chitosan</td>
<td>Essential Oil</td>
<td>0.1%</td>
<td>1°C</td>
<td>Reduced the microbe growth, yeast and molds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chitosan</td>
<td>Essential Oil</td>
<td>1:3</td>
<td>1°C &amp; 90% RH in PET trays</td>
<td>Prevented from fungal decay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td>Type</td>
<td>Concentration</td>
<td>Temperature</td>
<td>Other Conditions</td>
<td>Effect</td>
<td>Reference</td>
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<tr>
<td>CMC</td>
<td>Essential oil</td>
<td>2%</td>
<td>20°C&amp; 35-40% RH</td>
<td>Garlic essential oil</td>
<td>Delayed senescence &amp; maintained nutritional content</td>
<td>Dong &amp; Wang 2017</td>
</tr>
<tr>
<td>Sodium alginate</td>
<td>Essential oil</td>
<td>9%</td>
<td>25°C</td>
<td>Cinnamon</td>
<td>Controlled growth of fungus</td>
<td>Kapetanakou et al., 2018</td>
</tr>
<tr>
<td>Chitosan</td>
<td>Essential oil</td>
<td>4:1</td>
<td>PET boxes kept at 4°C</td>
<td>Oleic acid</td>
<td>Color retention, decrease in respiration rate, prevented against fungal infection</td>
<td>Vargas et al., 2006</td>
</tr>
<tr>
<td>Cellulose</td>
<td>Essential oil</td>
<td>0.12ml</td>
<td>10°C</td>
<td>Lemongrass EO with apple pectin</td>
<td>Reduced the weight loss, maintained the level of TSS</td>
<td>Dasliver et al., 2019</td>
</tr>
<tr>
<td>Carrageenan + Bee wax</td>
<td>Plasticizer</td>
<td>1%</td>
<td>6°C</td>
<td>Glycerol, glucose, fructose</td>
<td>Retard the growth of microbes, increases TSS, reduced the weight loss</td>
<td>Afifah et al., 2019</td>
</tr>
<tr>
<td>Corn starch</td>
<td>Plasticizer</td>
<td>20g/l</td>
<td>0°C&amp; 84.8% RH</td>
<td>Glycerol, sorbitol, potassium sorbate</td>
<td>Inhibited the growth of yeast, molds and microbes</td>
<td>Garica et al., 2001</td>
</tr>
<tr>
<td>Chitosan</td>
<td>Fungicide chemical</td>
<td>2%(w/v)</td>
<td>13°C&amp; 45% RH</td>
<td>TBZ</td>
<td>Reduced the growth of B.cinera &amp; Rhizopus spp, retarded the ripening process</td>
<td>Zhang &amp; Quantick 1998</td>
</tr>
<tr>
<td>Chitosan + HPMC</td>
<td>Plasticizer</td>
<td>0.3%</td>
<td>5°C &amp; 50% RH</td>
<td>Potassium sorbate</td>
<td>Reduced the growth of mold, yeast, microbes, Cladosporium spp, Rhizopus spp</td>
<td>Park et al., 2005</td>
</tr>
<tr>
<td>pectin</td>
<td>---</td>
<td>3%(w/v)</td>
<td>4°C polystyrene</td>
<td>---</td>
<td>Reduced the rate of</td>
<td>Munoaz et al., 2018</td>
</tr>
<tr>
<td>Material</td>
<td>Chemical</td>
<td>Concentration</td>
<td>Temperature</td>
<td>Treatment/Condition</td>
<td>Result</td>
<td>Reference</td>
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<tr>
<td>Gelatin</td>
<td>Essential oil</td>
<td>1%</td>
<td>4°C</td>
<td>Mentha pulegium</td>
<td>Protected 60% strawberries deterioration, reduced growth of yeast, mold</td>
<td>Aitboulah et al., 2018</td>
</tr>
<tr>
<td>Chitosan + CMC</td>
<td></td>
<td>1%</td>
<td>0°C kept in PET</td>
<td></td>
<td>Firmness retention</td>
<td>Yan et al., 2019</td>
</tr>
<tr>
<td>Carrageenan + Plasticizer</td>
<td></td>
<td>0.75% (w/v)</td>
<td>0-5°C &amp; 85-90% RH</td>
<td>glycerol</td>
<td>Improved the firmness and reduced the decay from microbes</td>
<td>Ribeiro et al., 2006</td>
</tr>
<tr>
<td>Soy protein + Wheat gluten</td>
<td>Essential oil</td>
<td>1%</td>
<td>0°C &amp; 90-95% RH</td>
<td>Thyme essential oil</td>
<td>Reduced the decay from yeast, molds and maintained all level of physiochemical properties with out any change</td>
<td>Amal SH et al., 2010</td>
</tr>
<tr>
<td>Chitosan</td>
<td></td>
<td>1%</td>
<td>2°C &amp; 88-89 % RH kept in clam shell boxes for 1 week</td>
<td></td>
<td>Maintained firmness, texture, appearance. It does not change any astringency of strawberry</td>
<td>Han et al., 2005</td>
</tr>
<tr>
<td>Chitosan</td>
<td>Bioactive compound</td>
<td>0.2% (w/v)</td>
<td>4°C</td>
<td>Oregano extract (OR) Limonene (LIM) Pepper mint</td>
<td>Inhibited the growth of total flora, moulds and extended shelf life</td>
<td>Vu et al., 2010</td>
</tr>
<tr>
<td>Chitosan with FFD fil forming dispersion</td>
<td>Essential oil</td>
<td>1:3</td>
<td>5°C</td>
<td>Lemon essential oil</td>
<td>Improved antifungal activity, helps in spore suspension of B. cinerea and reduced the rate of respiration</td>
<td>Perdones et al., 2012</td>
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<tr>
<td>Chitosan + CMC Chitosan + HPMC</td>
<td>-----</td>
<td>1%</td>
<td>1°C &amp; 70-75% RH</td>
<td>-----</td>
<td>Reduced the decay percentage, delay in weight loss change and extended the shelf life by maintain all the quality attributes</td>
<td>Gol et al., 2013</td>
</tr>
<tr>
<td>Chitosan</td>
<td>----------</td>
<td>1%</td>
<td>15°C</td>
<td>----------</td>
<td>In fresh cut strawberries it Controlled browning, reduced decay, extended the shelf life</td>
<td>Campaniello et al., 2008</td>
</tr>
<tr>
<td>Chitosan</td>
<td>-----</td>
<td>1%</td>
<td>20°C</td>
<td>Calcium gluconate</td>
<td>Reduced surface damage on fruit, retention of firmness, delaying fungal decay, reduced weight loss</td>
<td>Hernandez-Munoz et al., 2006</td>
</tr>
<tr>
<td>Chitosan Essential oil</td>
<td>1.6%</td>
<td>15°C</td>
<td>Bark essential oil cinnamon</td>
<td>Cease the growth of microbes, decreased the degradation rate and improves physiochemical properties.</td>
<td>Aghaei et al., 2019</td>
<td></td>
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<tr>
<td></td>
<td>Antioxidant</td>
<td>Concentration</td>
<td>Temperature</td>
<td>Antimicrobial</td>
<td>References</td>
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<tr>
<td>Chitosan</td>
<td>1%</td>
<td>10°C</td>
<td>Monomethyl fumaric acid</td>
<td>Increased the shelf life by lowering the count of yeast, molds and microbes.</td>
<td>Khan et al., 2019</td>
<td></td>
</tr>
<tr>
<td>CMC carboxy methyl cellulose</td>
<td>Probiotic strains</td>
<td>8 pellets</td>
<td>4°C kept in PET</td>
<td>Lactobacillus plantarum</td>
<td>Reduce the growth of yeast, mold, and decreased deterioration of ascorbic acid, phenolic compounds and decay percentage. Khodaei et al., 2019</td>
<td></td>
</tr>
<tr>
<td>Banana starch + Chitosan</td>
<td>Biocontrol agent</td>
<td>20%</td>
<td>8°C &amp; 70% RH kept in PET</td>
<td>Alovera gel</td>
<td>Decreased the decay fungus, prolonged storage period upto 15 days. Pinzon et al., 2019</td>
<td></td>
</tr>
<tr>
<td>Aloe Vera gel</td>
<td>-----</td>
<td>100%</td>
<td>1°C &amp; 50% RH</td>
<td>-----</td>
<td>Delayed senescence, ripening process, and incidence of microbial, and it has fresh appearance. Nasrin et al., 2017</td>
<td></td>
</tr>
<tr>
<td>Basil essential oil</td>
<td>-----</td>
<td>250 µL /L</td>
<td>Invivo</td>
<td>-----</td>
<td>Prevention from gray mold infection and maintained all the quality attributes. Marjanlo et al., 2010</td>
<td></td>
</tr>
<tr>
<td>Rosmarinus officinalis &amp; Thymus vulgarus</td>
<td>-----</td>
<td>0.2g</td>
<td>5°C</td>
<td>-----</td>
<td>Dealyed change in weight los, TSS and reduced decaying percentage. Alikhani et al., 2012</td>
<td></td>
</tr>
<tr>
<td>Ingredient/Process</td>
<td>Concentration</td>
<td>Temperature</td>
<td>Shelf Life</td>
<td>Antifungal Effect</td>
<td>Reference</td>
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<tr>
<td>Cumin essential oil</td>
<td>250µl/L</td>
<td>3°C</td>
<td>-----</td>
<td>Inhibited the incidence of fungus and storage period were increased</td>
<td>Asghari <em>et al.</em>, 2009</td>
<td></td>
</tr>
<tr>
<td><em>Salvia officinalis</em> essential oil</td>
<td>60µl/L</td>
<td>3°C</td>
<td>-----</td>
<td>Prevention from fungal infection</td>
<td>Nabigol <em>et al.</em>, 2014</td>
<td></td>
</tr>
<tr>
<td>Whey protein + caseinate</td>
<td>1:1</td>
<td>1°C</td>
<td>-----</td>
<td>At 32 kGy irradiation of coating solution reduced the level of contamination &amp; improved barrier properties</td>
<td>Vachon <em>et al.</em>, 2003</td>
<td></td>
</tr>
<tr>
<td>Chitosan processing residue extracts</td>
<td>19 &amp; 20 gL (w/v)</td>
<td>Cold storage</td>
<td>Olive leaf extract(OLE) &amp; Olive plant extract(OPE)</td>
<td>Antifungal effect against <em>R. stolonifer</em></td>
<td>Khalifa <em>et al.</em>, 2016</td>
<td></td>
</tr>
<tr>
<td>Yam starch</td>
<td>4g</td>
<td>4°C &amp; 85%RH</td>
<td>-----</td>
<td>Firmness retention and reduced weight loss, extended the shelf life to nearly 21 days</td>
<td>Mali <em>et al.</em>, 2003</td>
<td></td>
</tr>
<tr>
<td>Guargum</td>
<td>15%</td>
<td>1°C</td>
<td>-----</td>
<td>Retained the sensorial properties, color, firmness, and enhanced antioxidant activity.</td>
<td>Tahir <em>et al.</em>, 2018</td>
<td></td>
</tr>
<tr>
<td>Ingredient</td>
<td>Modification</td>
<td>Temperature</td>
<td>Results</td>
<td>Authors, Year</td>
<td></td>
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<tr>
<td>Cajan cajan seeds gum</td>
<td>1%</td>
<td>5°C</td>
<td>Delayed the change in TSS, prevented sensorial changes</td>
<td>Robles et al., 2018</td>
<td></td>
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</tr>
<tr>
<td>Paraffin wax</td>
<td>100%</td>
<td>4°C</td>
<td>Delayed the weight loss, TSS &amp; retention of firmness</td>
<td>Hazarika et al., 2018</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium alginate</td>
<td>Sunflower oil 0.2%(w/w)</td>
<td>4°C</td>
<td>Promoted water loss to extend the shelf life</td>
<td>Parreidt et al., 2019</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starch+ Chitosan + Plasticizer &amp; EO</td>
<td>0.02% 0.5%</td>
<td>4°C</td>
<td>Inhibited the decay incidence, delayed change in TSS, TPC, anthocyanin content, reduced weight loss</td>
<td>Badawy et al., 2016</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chitosan + corn starch</td>
<td>Essential oil 6.4%</td>
<td>25°C&amp;50%RH</td>
<td>Reduced the loss of nutritional valve, reduced the growth of B.cinera, E.coli, Rhizopus</td>
<td>Wang et al., 2019</td>
<td></td>
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</tr>
<tr>
<td>Alginate +Soyproteína</td>
<td>2.5% &amp; 3%</td>
<td>1°C&amp;85%RH</td>
<td>Solid content of strawberries were maintained without any change</td>
<td>Ahmed et al., 2014</td>
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<tr>
<td>Gelatin</td>
<td>Nanocrystals</td>
<td>5g</td>
<td>25°C</td>
<td>Cellulose nano crystals from eucalyptus fibers</td>
<td>Retention of Ascorbic acid and extended the shelf life by acting as a antimicrobial agent</td>
<td>Fakhouri et al., 2014</td>
</tr>
<tr>
<td>Pullulan</td>
<td>---</td>
<td>10%</td>
<td>4°C &amp; packed in a polyethylene terephalate</td>
<td>--</td>
<td>Extended the shelf life for 5 days and retention of firmness</td>
<td>Eroglu et al., 2014</td>
</tr>
<tr>
<td>Xanthan gum</td>
<td>Plasticizer</td>
<td>1%(v/v)</td>
<td>4°C</td>
<td>Glycerol</td>
<td>Maintained the firmness, color ,TSS, anthocyanins and reduced the weight loss</td>
<td>Savia et al., 2015</td>
</tr>
<tr>
<td>Alginate</td>
<td>Essential oil</td>
<td>0.15%</td>
<td>0.5°C</td>
<td>Eugenol (eug)</td>
<td>Decreased microbial spoilage , maintained sensory and nutritional attributes</td>
<td>Guerreiro et al., 2015</td>
</tr>
<tr>
<td>Chitosan</td>
<td>Algae</td>
<td>2:1(v/v)</td>
<td>4°C&amp;7075% RH kept in temperature controlled chamber for 10 days</td>
<td>Palmaria palanata kuntze (Pc)</td>
<td>Enhanced anthocyanins, ascorbic acids and reduced the nutrient loss, respiration rate and microbial load on ready— to eat strawberries.</td>
<td>Rico et al., 2019</td>
</tr>
<tr>
<td>Chitosan</td>
<td>Isolated bacteria from strawberry</td>
<td>2*10^5 conidia per millimeter</td>
<td>13°C&amp;95% RH</td>
<td>B.cinera R.stolonifer</td>
<td>Reduced the fruit decaying, inhibited the growth of fungus, mold</td>
<td>Ghaouth et al., 1991</td>
</tr>
<tr>
<td>Cassava starch</td>
<td>Plasticizer</td>
<td>0.05%</td>
<td>5°C</td>
<td>Potassium sorbate</td>
<td>Reduced the respiration rate, extended the shelf life by improving the resistance of water vapor but it does not change any physiochemical properties</td>
<td>Garcia et al., 2010</td>
</tr>
</tbody>
</table>