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Edible Coating from Food Processing By-Products for Packaging of Fruits and Vegetables

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ABSTRACT

Edible coating is considered to be a clean, eco-friendly technology for reducing the post-harvest losses of fruits and vegetables by modifying the internal environment through selective gaseous (CO_2/O_2) exchange, controlling the moisture migration, and providing the mechanical barrier properties for protection from external environment. Edible coating is considered to be a tool for incorporation of active components such as bioactive compounds, essential oil for improving the microbial safety and quality attributes of fresh produce. The edible is made up of different types of biopolymers such as polysaccharides, lipids, proteins alone or in combination and these polymers are also widely used in food processing industries for manufacturing of various food products. The diversion of industrial biopolymers for food packaging applications has created a threat to global food security. On another hand, food industries are generating enormous by-products from the processing of foods and their disposal are creating a huge environmental problems. These by-products are rich source of polysaccharides, proteins and other bioactive compounds that can be used as a replacement of conventional biopolymer for development of edible coatings. Moreover the use of by-products for the edible coatings not only provides a sustainable solution of waste management of by-products but also promote circular economy. In this review the food processing by-products that have potential for packaging applications for fruits and vegetable are explored and their beneficial effects on the extension of shelf life of fresh produce are reviewed and discussed.

Keywords: Edible, Coating; By-Products; Fruits and Vegetable; Packaging; Shelf life.

1. INTRODUCTION

Fruits and vegetables are considered to be highly perishable commodity due to the inherent water content (80-90% by weight). The reasons for short shelf life of fruit and vegetables is that they continue to respire even after the harvest which results in increased metabolic activity and finally senescence of fresh produce (Maringgal et al., 2020). The extension of shelf life depends on the i) reduction in physiological loss of weight; ii) reduction or delay in ripening associated biochemical changes; iii) delay in onset of surface microbial growth. (Dhall et al., 2013). The various technologies such as packaging of fruit and vegetable are using plastic based biopolymers such as polystyrene, polypropylene wraps, modified atmosphere packaging using low density polyethylene packages, control atmospheric packaging for extension of shelf life but the disadvantage of using synthetic polymers are that they are resistant to degradation (Mangaraj et al., 2021). In addition, plastic based polymers contribute to environmental pollution and emission of greenhouse gases (Mangaraj et al., 2019a; Tripathi et al., 2014). In recent time edible coating is emerged as new eco-friendly technology that aims at modifying the internal environment of individual fruit in such a way it positively affect the shelf life by maintain overall quality attributes. The edible coatings are made up of edible polymers that are completely biodegradable and can be directly eaten with the food product (Yadav et al., 2021a). Edible coatings are made up of biopolymers such as polysaccharides (corn starch, cassava starch, pectin, gums), lipids (paraffin, waxes, oils) and proteins (casein, gluten, zein) or their combination (Suhag et al., 2020). In today times, the diversion of food based biopolymers towards the food packaging related application is creating a threat to food security. So, various researches are working on utilization of food industry by products to extract biopolymers and finding on sustainable solution for the usage of biopolymer for food packaging applications. According to FAO it is estimated that 1.3 billion tonnes of food in the form of by-products, domestic household waste is being lost in the food chain contributing to huge economic losses (FAO, 2015). Moreover, the disposal the food waste has caused serious impact on the environment in the form of soil and water pollution. Food processing by-products from fruit and vegetables in the form of peel, seeds, and stone contains significant amount of starches, cellulose, hemicellulose;

animal processing by-products such as skin, bones contains proteins such as gelatin and collagen that can be exploited for edible coating application for fruits and vegetables (Yadav et al., 2021b). In this regards, this review paper aims at reviewing the biopolymers from the food processing by-products, their applications as an edible polymers for enhancing the shelf life of fruits and vegetables.

2. EDIBLE COATINGS

Edible coatings are thin layer of sheets usually less than 10 µm which is directly formed on the product exhibiting the targeted functions. The methods employed for edible coating on the surface of the product are mainly dipping, spraying and brushing; the former method is widely used for coating of fruits and vegetables (Yousuf et al., 2018; Bharti et al., 2020). The main purpose of using edible coating is to modify the internal environment of the product in such a way that it positively affects the shelf life without altering the sensory properties. In addition, edible coating plays an important role in improving the barrier properties such as gaseous transmission, water vapour permeability and protects the product from physical, chemical and microbial damage (Benbettaieb al., 2019). Further, edible coatings have added advantages to consumers as they can be directly eaten without unpacking or discarding the wrapper. The edible coatings are considered to be environment friendly as they are developed from the renewable sources that are completely biodegradable in nature. The materials used for development of edible coatings have Generally Recognised as Safe (GRAS) status as per US FDA (Kumar and Neeraj, 2019; Garcia et al., 2017)

3. COMPONENTS OF EDIBLE COATING

The components used for fabrication of edible coatings consisting of biopolymer matrix for forming the structure of edible coating, solvents such as water, ethanol and additives such plasticizers and other active ingredients. The biopolymer matrix is made up of polysaccharide, lipids and proteins along or in combination (Umaraw et al., 2020; Mangaraj et al., 2019a; Falguera et al., 2011). The selection of biopolymer for edible coating depends on the type of product, storage condition (temperature, relative humidity) and desired properties such as mechanical strength, gaseous and water permeability (Hamed et al.,2021). The edible coatings based on type of biopolymers is categorised into hydrocolloid based coatings, lipid based and composite coatings. Hydrocolloid based edible coatings is made up of protein (gelatin, collagen, gluten, whey isolates, casein, pea protein), polysaccharide (cellulose, hemicellulose, chitosan, starches, sea weeds and gums). The hydrocolloid based edible coatings generally possess good mechanical and gaseous permeability properties but have poor permeability to water vapours (Kumar and Neeraj 2019). The lipid based edible coatings is made up of waxes (carnauba, paraffin and bee wax) , fatty acids, resins, essential oil (rosemary, peppermint, clove, cinnamon) and possess excellent barrier property to water vapour but lacks in mechanical properties (Bourtoom, 2008; Valenzuela et al., 2013). To overcome the limitations of lipid and hydrocolloid based edible coatings, composite coatings are made by blending both hydrocolloids and lipids components in a single matrix (Dhumal and Sarkar, 2018; Anjum, 2020)

In order to maintain the integrity of the coating solution the plasticizers are generally added to enhance the compatibility between the bio polymeric matrix and the solvent by forming hydrogen, hydrophobic bonding and ionic interactions (Otoni et al., 2017). Plasticizers such as polyols (glycerol, sorbitol, xylitol), oligosaccharide such as sucrose, lipids (Tween 80, phospholipids, lecthins) are widely used in development of edible coatings (Thakur et al., 2019). The main advantage of using the plasticizer is to enhance mechanical properties, maintain coating integrity and reduce brittleness (Suhag et al., 2020)

4. MODE OF ACTION OF EDIBLE COATINGS ON FRUITS AND VEGETABLES

Fruits and vegetable after harvesting continue to respire and consume O2 and releasing carbondioxide gas. Edible coating on the surface of fruit and vegetable creates a semi permeable membrane which allows selective permeation of O2 which results in decrease in respiration that in turn delays the ripening changes and eventually extends the shelf life of fresh produce (Pinzon et al., 2020; Nair et al., 2018; Yadav et al., 2021b). In addition, edible coating provides an extra layer on the surface of fruits leading to coating of stomata thereby reduces the transpiration rate and maintain the reduction in physiological loss of weight during storage (Salehi, et al., 2020). The edible coating on fruit and vegetable also carries bioactive compounds such as essentials oil which plays a major in reduction of microbial load and help in improving the shelf life (Murmu et al., 2018).

5. BY-PRODUCTS FROM THE FOOD PROCESSING WASTE

The by-products are the secondary products that are obtained during the manufacturing of food or agro produce that have a potential value for the further usage (Castro-Munoz et al., 2018). The food processing industry generates enormous amount of by-products from the animal (livestock, poultry, diary), fisheries including aquaculture, agricultural (fruits and vegetables, cereals, bakery) processing (Aspevik et al., 2017; Hamed et al., 2021). The figure 1 depicts the by-products and biopolymers obtained from the food processing industry. The by-products from the food processing waste such as cellulose, pectin, starches and mucilage's from the fruits and vegetable residues, whey from cheese processing, gelatine from the meat processing by-product possess excellent filmogenic properties and can be used as a packaging material for edible coating of food products (Yadav et al., 2021b) Moreover the bioactive compounds such as anthocyanins from grape pomace, polyphenols from the apples pomace, can be utilized for enhancing the quality of the coated product (Dilucia et al., 2020).

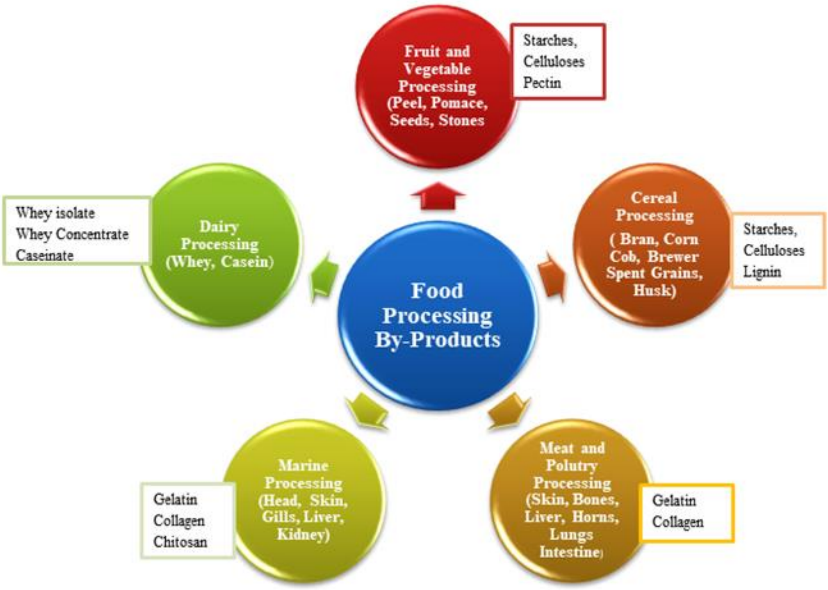

Fig 1: Biopolymers obtained from the food processing byproducts.

6. BY-PRODUCTS COATING APPLICATIONS ON FRUITS AND VEGETABLES

Starches:

Starches are the polysaccharide made up of repeated units of glucose molecules and have an excellent film forming properties. The starch based edible coatings have good mechanical strength and barrier properties for gaseous transmission which makes them suitable for coating of fruit and vegetables (Thakur et al., 2019). Starches such as corn, rice, wheat are widely used for the preparation of edible film and coating but due to their food usage the researchers in recent times are focussing on extraction of starches from the unconventional sources such as fruit and vegetables processing by products (Mangaraj et al., 2019b; Mangaraj et al., 2019c). Various researchers have reported the extraction of starches from seeds of mango kernel, jackfruit, tamarind and peels of banana by methods such as wet grinding, centrifugation and enzymatic methods. Nawab et al., 2017 reported that edible coating from mango kernel seed starch was effective in delaying the ripening associated changes in tomato stored at room temperature after 20 days of storage. Rodrigues et al., 2020 also reported that jackfruit starch was effective in maintain the quality attributes of mango fruit stored at room temperature and RH 87 ± 2% RH for 12 days by decreasing the respiration rate.

Cellulose:

Cellulose is biopolymer that is abundantly present in the cell wall of plants and have good mechanical strength and barrier properties for transmission of gasses especially carbon dioxide (Malmiri et al., 2011). The derivatives of cellulose such as carboxy methyl cellulose is widely used for the the edible coating of the fruits due to its high molecular weight providing mechanical stability to coatings (Panahirad et al., 2021). The food processing by-products such as peel, pomace of fruits are rich source of cellulose that can be used for the edible coating of fruits and vegetables. In a study by Pangesti et al., 2015 reported that edible coating made from carboxy methyl cellulose derived from the pineapple core was effective in maintaining the shelf life of tomato stored at room temperature for 20 days. The increase in shelf life is due to decrease in respiration rate and reduction in the ripening associated changes.

Gelatin:

Gelatin is water soluble, fibrous protein based biopolymers that is obtained from the partial acid or alkali hydrolysis of collagen (Shankar et al., 2016). Gelatin is extracted from the meat/ marine processing by-product such as animal skin, bones, tendons, fish heads, fins. Gelatin has good coating forming properties due to its gelling and emulsion forming functional properties that provide the structural integrity to the coating solution and widely used for the coating application of food fruits and vegetables (Ramos et al., 2016). The study conducted by Aitboulahsen et al., 2018 reported that gelatin based edible coating blended with *Mentha pulegium* essential oil was effective in extending the shelf life by reducing the microbial load and maintain the quality characteristics during storage period of 13 days at 4°C. In another research by Lopez-Palestina 2018 reported that gelatin based edible coating incorporated with tomato oily extract had maintained the quality attributes of garambullo fruit for a storage period of 15 days at 5 °C.

Whey Protein:

Whey is protein based biopolymer obtained as a by-product of cheese processing and widely used for the edible coating applications due to its nutritional content, low permeability of O2, aroma retention property and film forming capacity (Pierro et al., 2018). The various researches on whey protein based edible coatings used for coating of fresh and cut fruits and vegetable have demonstrated that extension of shelf due to better retention of oxygen, aroma and reduction in weight loss. A study by Ghavidel et al., 2013 reported that whey protein concentrate based edible coating was effective in extending the shelf life of fresh apple slices. A recent study conducted by Galus et al., 2021 reported that edible coating from whey protein isolate with lemon grass essential oil was effective in maintain the color, total phenols, flavonoids and sensory properties of fresh cut pears during its storage at 4 °C.

Chitosan:

Chitosan is polysaccharide based biopolymer and is a by-product of marine processing industry obtained from the chitin present in exoskeleton of crustacean and consist of N-acetyl-D-glucosamine and deacetylated D-glucosamine units (Jianglian and Shaoying, 2013; Iqbal et al., 2021). Chitosan is widely used for edible coatings due to its selective permability to O2/CO2 gases, mechanical properties. In addition, chitosan also possess antioxidant and antimicrobial properties that help in inhibition of surface microorganisms (Wang et al., 2018). A recent study by Saleem et al., 2021 reported that chitosan based edible coating was effective in maintaining the overall quality attribute of strawberries for 15 days at 4 ± 1 °C and 85 ± 5% RH. The coating was effective in delaying the softening and inhibiting the polyphenol oxidase enzymatic activity. In another study by Shamshad et al., 2021 concluded that chitosan based edible coating was effective in extending the shelf life of guava stored at room temperature by reducing the malondialdehyde levels and respiration rate. Paul et al., 2018 also investigated the application of chitosan based edible coating on tomato and found the coating was effective in preserving the quality attributes of tomato during storage.

Table1: Biopolymers from food processing for edible coating of fruits and vegetables.

By-product	Biopolymer matrix	Commodity applied	Key observation	References
Mango Kernel	Mango Kernel Seed Starch	Tomato	Reduction in respiration rate; maintains the overall quality parameters up to 20 days.	Nawab et al., 2017
Banana Pulp	Banana Starch	Mango	Reduction in weight loss; retention of firmness; extension of shelf life	Hernández-Guerrero et al., 2020.
Banana Peel	Banana tarch	Strawberries	Reduction in decay index; reduction in weight loss; extension of shelf life	Pinzon et al., 2020
Mango peel powder	Corn Starch	Apple Slices	Retention of firmness; increase in antioxidant capacity and total phenols	Rojas-Bravo et al., 2019
Pomegranate Peel	Chitosan, Pullulan	Mango	Reduction in weight loss; retention of antioxidant activity; maintains the overall quality parameters	Kumar et al., 2021a
Pomegranate Peel	Chitosan, Pullulan	Green bell pepper	maintains overall quality parameters; extension of shelf life, enhanced sensory attributes	Kumar et al., 2021b
Pomegranate Peel	Chitosan, Alginate	Guava	Retention of ascorbic acid and antioxidant capacity; improvement in quality attributes.	Nair et al., 2018
Gelatin	Cassava Starch, Chitosan	Guava	Delay in ripening associated changes; retention of firmness and reduction in loss of weight	Silva et al., 2021

Gelatin	Chitosan	Red bell peppers	Decrease in respiration rate; retention of firmness; extension of shelf life	Poverenov et al., 2014
Whey Protein Concentrate	Rosemary essential oil	Fresh Spinach	Reduction in total microbial and coliform count; reduction in weight loss and extension of shelf life	Abedi et al., 2021
Grapes seed	Procyanidins, Chitosan	Blue berries	Increase in antiradical activity; reduction in yeast and mould count	Mannozzi et al., 2018
Pineapple core extract	Konjac glucomannan	Apple fruit	Inhibition of enzymatic activity polyphenol oxidase; enhanced antioxidant activity	Supapvanich et al., 2012
Mango Peel	Mango seed extract	Peach	Increase in polyphenol content and antioxidant activity; extension of shelf life.	Torres-León et al., 2018

7. CONCLUSION

Food processing waste is largely underutilized, discarded as waste offers an excellent opportunity for the development of cost-effective biopolymers for food packaging applications. The various researchers have demonstrated that edible coatings from the food processing by-products have the capabilities of replacing and substituting the conventional biopolymers for the shelf-life extension of fruit and vegetables. The utilization of by-products for development of biopolymers can help in valorisation and improving the environmental sustainability by minimizing the by-product wastage along with reduction in usage of plastic-based polymers. Most of the researches related to edible coating from by-products is limited to the laboratory level and there is a need for upscaling the technology to industrial level that with economic viability. Further, the use of nano technological interventions can also be explored for improving the functional properties of edible coatings made from by-product of food processing.

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