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Application of Edible Coating to Fresh-cut and Minimally-processed Vegetables: A Review

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ABSTRACT

Edible films and coatings based on natural ingredients attract much interest today as an efficient, safe and ecologic approach for food products' quality and shelf-life enhancement. Edible films and coatings protect food from mechanical and microbial damage, reduce moisture and volatiles escape, inhibit biochemical deterioration processes and improve food appearance, as well as enhance the products' nutritional value. Advanced edible films and coatings can also serve as a matrix for the delivery of active agents such as natural antimicrobials, nutraceuticals, antibrowning agents and natural flavor and aroma compounds. For this purpose nano technology-based approaches can be exploited. The vegetables are more amenable crops for fresh-cut and minimally processed market that renders ready-to-cook produce that saves the time of today's engaged life. The cut surface of the cut vegetables is prone to loss of weight, moisture and nutrients though packed. This review deals with the application of the edible coating to the fresh-cut and minimally-processed vegetables to serve purpose increasing shelf-life by reducing the post-harvest losses. Various methods and materials employed in the edible coating of vegetables are also discussed in this review.

Key words: Chitosan, Edible coating, Fresh-cut vegetables, Minimally processed vegetables, Shelf life.

The vegetables partake in our daily diet as an indispensable constituent, being the reservoir of essential vitamins, minerals, antioxidants, bioflavonoids, dietary fiber and flavor compounds. The harvested vegetable produce hits our tables after undergoing the phase of post-harvest wherein they begin to dehydrate, deteriorate and lose their appearance, taste and nutritional value. As a result of inadequate handling, storage and microbial contamination, the post-harvest losses of vegetables experienced in recent decades are appalling with a notable loss of 25-30 per cent (Puttalingamma, 2015). Since the harvested vegetables consist of living tissues, they remain 'alive' even after harvesting and consequently undergo physiological and biochemical changes that cause detrimental quality and shelf life changes. The main postharvest phenomena *viz.*, respiration, transpiration and ethylene production are reported to contribute to the deterioration of the postharvest life of the vegetables (Olivas and Barbosa-Canovas, 2009) while the other factors of spoilage are loss of moisture, nutrients and minerals and nutritionally important pigments as well as spoilage due to microbial pathogens.

The quality of the vegetable produce is a product of organoleptic, nutritional and hygienic traits and is dynamic. Neither the producer nor the consumer could accept spoilage during post-harvest storage and can never compromise to produce quality be entertained. Besides, the consumer of today expects higher than ever before, demanding their food to be more nutritive, safer to eat with diverse variety and prolonged shelf life. In this context, the technique of edible coating emerges as a strategy to meet out the objectives of preventing spoilage during storage, prolonging produce shelf life colligating with the appealing visual aspect. Edible coatings are the cheaper alternative that is focused to avert the postharvest losses and being used for extending the postharvest life and lowering production cost.

The use of edible films has grown intensely since the mid-1980s but by no means it is a 21st century innovation, they were used at least as early as the 1100's, when merchants in citrus-growing regions of southern China used wax to preserve oranges shipped by caravan to the Emperor's table in the North. People in Europe for centuries preserved fresh fruit with "larding," a coating of the melted fat from hogs. Those coatings sealed off the fruit, preventing the exchange of gases with the air, essential for sustaining good quality.

The Ready-to-eat fruits and vegetables market now account for about 10 per cent of all produce sales, with sales exceeding $10 billion annually especially due to increase in the number of health-conscious consumers who look for more foods that require minimal preparation like cut fruit and premixed salads.

Fruits and vegetables skins provide natural protection against drying out, discoloration and other forms of

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spoilage. edible films, however, by regulating the transfer of moisture, oxygen, carbon dioxide, lipids, aroma and flavour compounds in food systems, edible films and coatings can increase shelf life and improve food quality. They generally provide the same protection against bacteria as the natural skin if the foods are handled under sterile conditions. The success of an edible film or coating in extending the shelf life and enhancing the quality of food strongly depends on its barrier properties to moisture, oxygen and carbon dioxide, which in turn depends on the chemical composition and structure of the film-forming polymer and the conditions of storage.

Ongoing researches on edible films are consistently being made. In the last three decades, considerable progress has been made in developing these materials driven by the increasing consumer demand for safe, high-quality, convenient food with good shelf lives, along with an ecological awareness of the limited natural resources and the environmental impact of packaging waste. Ahead are the various aspects of edible coatings having the shelf life of vegetables is its focus.

Materials for edible coatings used in vegetables

The basic components of our everyday foods (carbohydrates, proteins and lipids) are the ingredients of the edible coating. As a general rule, polysaccharides are used to control gas transmission from product to outer environment; fat to reduce water transmission; protein for mechanical stability (Palvath and Orts, 2009). The important prerequisite is that the material used should be a GRAS (Generally Recognized As Safe) compound.

Polysaccharide based edible coatings

The polysaccharide coatings are either gum-based or starch-based. The polysaccharide gums easily form films of good tensile strength. The formation of micelles enables the gums with their film-forming ability and the structural differences of gums are attributed to the presence or absence of branching, electrical charge and molecular weight. The commonly used gums are Agar (from red seaweed), Alginate (*Laminaria* sp., *Macrocystis pyrifera*, *Ascophyllum nodosum*), Carrageenan (*Eucheuma* spp.), Gaur gum (*Cyamopsis tetragonoloba*), Gum Arabic (*Acacia* spp.), Konjac gum (*Amorphophallus* spp.), Pullalan (*Aureobasidium pullulans*) and Xanthan gum (*Xanthomonas campestris*).

The starches commonly occur in seeds, roots and tubers and best-used starches for edible coating are arrowroot, barley, cassava, corn, pea, potato, rice, sago, sorghum and wheat. Based on the amylose content, they are classified as high-amylose, regular and waxy starches.

Chitosan

Among polysaccharides of plant and animal origin, chitin-derivative chitosan is becoming a leader in edible films and coatings due to its unique properties. Chitin, the second most ubiquitous natural polysaccharide after cellulose, obtained from the crustacean shells (crabs and lobsters). This close resembles of cellulose is sought after the following traits in edible coatings (No *et al.*, 2007).

- Antimicrobial activity.
- Barrier against moisture and gases.
- Antioxidant property.
- Protection of nutrients, texture, aroma and quality of the coated item.

Protein-based edible coatings

The protein-based coatings are prepared from solutions comprising three main components *viz.*, protein, plasticizer and solvent. The properties of the protein coating are influenced by the intrinsic properties of the coating or the extrinsic processing factors. The intrinsic properties of the protein include amino acid composition, crystallinity, hydrophobicity/hydrophilicity, surface charge, pI, molecular size and three-dimensional shape. Extrinsic factors include processing temperature, drying conditions, pH, ionic strength, salt-type, relative humidity during processing and storage, shear and pressure.

The commonly used animal-origin proteins for coating purposes are the casein and whey protein. The common plant proteins are wheat protein, soy protein and corn zein. The water-insoluble nature, glossy and grease-proof coating with low water vapor permeability makes the corn zein protein unique from any other agricultural protein and thus have potential usage in biodegradable packing.

Lipid-based edible coatings

The basic need for lipid coating is barricading the moisture transport to or from the produce and its atmosphere, due to its relatively low polarity. In general, the lipid-based coatings are often used supported on polysaccharide (polymer) structure matrix, for mechanical strength. Paraffin wax, carnauba wax (Copernica cerifera), beeswax (white wax) and Candelilla wax are more employed. Resin (wood resin) and rosin (coumarone indene) are allowed in the vegetable coating.

Incorporation of active ingredients into edible coatings

One of the typical distinctive functions of the edible coatings is their ability to blend with active ingredients into their matrix for improving coating functionality. These ingredients are classified into three classes (Dhall, 2013).

Antimicrobial agents

The antimicrobial edible coatings offer inhibitory effects on spoilage and pathogenic bacterial and fungi. They include organic acids (acetate, benzoate, lactate, sorbate), fatty acid esters (glyceryl monolaurate), polypeptides (lysozyme, peroxidase, lactoferrin, nisin), plant essential oils (cinnamon, oregano, lemongrass), nitrites and sulfites.

Texture enhancers and stabilizers

Calcium salts

The loss of firmness in fruit tissues is mainly due to the action of pectinases. One of the best ways to control tissue softening is treatment with calcium salts. The calcium salts

Table 1: Effect of edible coating on fresh-cut vegetables.

Crop	Composition of edible coating	Effect of coating	Reference
Carrot	Chitosan	Prevention of surface whitening, reduced microbial contamination, improved phenolic content	Simões *et al.,* 2009
Asparagus	CMC-Sucrose composite	Retarded moisture loss, reduced basal hardening, lowered purple color development in the basal part and improved shelf life	Tzoumaki *et al.,* 2009
Lotus root	Chitosan-ascorbic acid-citric acid composite	Inhibited browning and extended shelf-life	Xing *et al.,* 2010
Tomato	Gum Arabic	Lowered respiration rate and ethylene production, maintained anti-oxidant capacity and delayed ripening	Ali *et al*., 2013
Carrot	Pectin	Well preserved firmness and color characteristics, improved microbiological stability and reduced weight loss	Ferrari *et al.,* 2013
Watermelon	Alginate-cinnamaldehyde composite	Reduced microbial activity, maintained quality and sensory traits and extended shelf-life	Sipahi *et al.,* 2013
Eggplant	Soy protein isolate (SPI)	Improved shelf-life	Ghidelli *et al.,* 2014
Cantaloupe	Chitosan	Minimized tissue softening, improved visual quality and prolonged shelf-life	Martiñon *et al.,* 2014
Sweet Potato	Cassava starch + Ascorbic acid	Prevented enzymatic browning, retained the freshness and improved nutritional quality	Ojeda *et al.,* 2014
Bell Pepper	Chitosan-alginate composite	Inhibited microbial activity, enhanced fruit texture, prolonged storage	Poverenov *et al.,* 2014
Pumpkin	Carrageenan	Reduced microbial infection and improved color and texture	Genevois *et al.,* 2015
Eggplant	Carnauba wax	Reduced moisture loss, maintained firmness and prolonged shelf-life	Singh *et al.,* 2016
Taro	Chitosan	Reduced moisture loss and microbial load, extended shelf-life and enhanced sensory traits	Sanna *et al*., 2017

form a cross-linked network, increasing the mechanical strength, thus delaying the tissue softening and subsequent senescence.

Plasticizers

The edible coating formulated with polysaccharides and proteins are stiff and brittle due to their extensive interaction between the molecules. Therefore, a plasticizer is essential for such materials to enable them with plasticity and more functionality. Glycerol, acetylated monoglyceride, polyethylene glycol and sucrose are common plasticizers used.

Emulsifiers

Being surface-active agents of amphiphilic nature, they not only reduce the surface tension of water-lipid or water-air interfaces but also modify the surface energy to control adhesion and wettability of the coating surface (Krochta, 2002).

Neutraceuticals

Many efforts and experiments have been made in the process of incorporation of minerals and minerals into edible coatings to enhance the nutritional value of some vegetables. Many studies have validated the successful application of Vitamin C, E and Calcium incorporation into fresh produce through the edible coating. Antioxidants such as BHA, BHT, ascorbic and citric acid prevent the enzymatic browning and in vegetables and mushrooms (Dhall, 2013).

Methods of application of edible coatings

Below are the methods of application of the edible coating to the whole/fresh-cut/minimally processed fruits and vegetables.

Dipping

It is the most common method employed for edible coating. The coating is given to produce as it gets dipped into the edible film-forming formulation. The formulation should necessarily have appropriate density, viscosity and surface tension to give a thick coating layer over the produce. This technique is done through three-stage *viz.,* immersion and dwelling, deposition and evaporation.

Brushing

Brushing is the controlled spreading of a suspension onto the material surface and further dried. This method is also called as spreading and considered as an effective alternative against the large dimension films. The wetting degree, spreading rate and the contact angle measurement are to

Table 2: Effect of edible coating on minimally-processed vegetables.

Crop	Edible coating/ Minimal processing	Effect of coatin	Reference
Carrot	Cellulose-based edible coating	Reduced white blush formation and enhanced shelf-life	Emmambux and Minaar, 2003
Garlic	Chitosan/acetic acid	Reduced microbial activity and weight loss and enhanced shelf-life	Geraldine *et al*., 2008
Broccoli	Chitosan/mild heat shock application	Reduced microbial activity, weight loss, and enzymatic browning, delayed yellowing of broccoli florets	Ansorena *et al.,* 2011
Carrot	Tapioca starch/ decolorized Hsian-Tsao leaf gum (dHG)	Retarded white blush formation, reduced weightloss and increased visual traits	Lai *et al*., 2013
Radish	Chitosan/MAP	Elevated sensory acceptability, retarded browning, and microbial load	Pushkala *et al*., 2013
Pumpkin	Xanthan gum	Reduced weight loss and microbial activity, maintained firmness and color	Cortez-Vega *et al.,*2014
Cassava	Starch/antioxidants, drying at 18°C for 1 hour	Reduced browning, improved visual appearance and extended shelf-life	Coelho *et al.,*2017
Carrot	Alginate/Probiotic and coconut water	Reduced microbial activity and extended storage	Shigematsu *et al*., 2018
Pumpkin	chitosan + lauric acid/ vacuum impregnation	Reduced weight loss and microbial activity and maintained firmness	Soares *et al.,* 2018
Yams	cactus mucilage/cassava starch/glycerol	Reduced dehydration, maintained visual and sensory parameters and prevented browning	Morais *et al.,* 2019

be carefully evaluated for efficient spreading over the surface by the particular liquid formulation.

Spraying

When the coat forming solution doesn't have good viscosity, then the spraying technique is deployed. A typical spraying system produces fine spray with drop size distribution up to 20 µm.

Solvent casting

It is the most used application method of hydrocolloid edible films. Water or water-ethanol dispersions of the coating formulation is spread on a suitable substrate and dried.

Although coating application methods are diverse, their selection relies on the desired product, coating thickness, solution rheology and drying technique employed.

Application of edible coatings to fresh-cut and minimally processed vegetables

The highly engaged life of today has buildup the demand for fresh-cut and minimally processed vegetables, as they provide a ready-to-cook product. The fresh-cut as well as the minimally processed vegetables are subjected to primary processing operations such as cutting, dicing, slicing, *etc*. leaving the portions of cut pieces naked. Though these cut pieces are packed, the loss due to respiration and gaseous exchange between internal and external atmosphere is unavoidable. To overcome the problems originating from the cut surface, the edible coating can be a potential candidate in the way of extending shelf-life of fresh-cut and minimally processed vegetables. The application of the edible coating to fresh-cut (Table 1) and minimally processed vegetables (Table 2) and their effects are given in the tables.

Future outlook

The hydrophilicity of some edible coating materials does not offer a good moisture barrier. Researches are needed to be focused on formulating formulations with high-moisture barrier property and improved functionality. There is also a necessity to develop novel coating application techniques to increase the coating efficiency, adhesion and durability. For antimicrobial packaging, the nanomaterials, particularly Ag nanoparticles can be incorporated into the coating formulation to improve its antimicrobial activity. After all, the sensory qualities are to be taken prime most importance and not a compromise should be made between the quality and shelf-life of the cut vegetables.

Conflict of Interest: None.

REFERENCES

Ali, A., Maqbool, M., Alderson, P.G., Zahid, N. (2013). Effect of gum arabic as an edible coating on antioxidant capacity of tomato (*Solanum lycopersicum* L.) fruit during storage. Postharvest Biology and Technology. 76: 119-124.

Ansorenaa, M.A., Marcovichb, N.E., Roura, S.I. (2011). Impact of edible coatings and mild heat shocks on quality of minimally processed broccoli (*Brassica oleracea* L.) during refrigerated storage. Postharvest Biology and Technology. 59: 53-63.

Coelho, D.G. andrade, M.T., De Melo Neto, D.F., Ferereira-Silva, L., Simoes, A.D.N. (2017). Application of antioxidants and edible starch coating to reduce browning of minimally-processed cassava. Rev. Castinga. 30(2): 503-512.

Cortez-Vega, Renzo, W., Piotrowicz, B. and Beatriz, I. (2014). Influence of different edible coating in minimally processed pumpkin (*Cucurbita moschata* Duch). International Food Research Journal. 21(5): 2017-2023.

Dhall. R.K. (2013). Advances in edible coatings for fresh fruits and vegetables: A review. Critical Reviews in Food Science and Nutrition. 53(5): 435-450.

Emmambux, N.M. and Minnaar, A. (2003). The effect of edible coatings and polymeric packaging films on the quality of minimally processed carrots. J. Sci. Food Agric. 83: 1065-1071.

Ferrari, C.C., Sarantópoulos, C.I., Carmello-Guerreiro, S.M. and Hubinger, M.D. (2013). Effect of osmotic dehydration and Pectin edible coatings on quality and shelf life of fresh-cut melon. Food Bioprocess Technol. 6: 80-91. https://doi.org/10.1007/s11947-011-0704-6.

Genevois, C.E., de Escalada Pla, M.F., Flores, S.K. (2015). Application of edible coatings to improve global quality of fortified pumpkin. Innovative Food Science and Emerging Technologies.http://dx.doi.org/10.1016j.ifset.2015.11.001.

Geraldine, R.M., de Fa´tima, N., Botrel, D.A., de Almeida, L. (2008). Characterization and effect of edible coatings on minimally processed garlic quality. Carbohydrate Polymers. 72: 403-409.

Ghidellia, C., Mateosb, M., Rojas-Argudoa, C., Pérez-Gago, M.B. (2014). Extending the shelf life of fresh-cut eggplant with a soyprotein–cysteine based edible coating and modi fied atmosphere packaging. Postharvest Biology and Technology. 95: 81-87.

Krochta, J.M. (2002). Proteins as Raw Materials for Films and Coatings: Definitions, Current Status and Opportunities. In: Protein-based Films and Coatings. [(eds) Gennadios A.], Boca Raton, Fla. CRC Press. p 1-41.

Lai, T., Chen, C. and Lai, L. (2013). Effects of tapioca starch/ decolorized hsian-tsao leaf gum-based active coatings on the quality of minimally processed carrots. Food Bioprocess Technol. 6: 249-258. https://doi.org/10.1007/s11947-011-0707-3.

Martiñon, M.E., Moreira, R.G., Castell-Perez, M.E. and Gomes, C. (2014). Development of a multilayered antimicrobial edible coating for shel-flife extension of fresh-cut cantaloupe (*Cucumis melo* L.) stored at 4°C. Food Science and Technology. 56: 341e350.

Morais, M.A., Fonseca, K.L., Viegas, E.K., de Almeida, S.L., Maia, R.K.M., Silva, V.N.S. and Simoes, A.N. (2019). Mucilage of spineless cactus in the composition of an edible coating for minimally processed yam (*Dioscorea* spp.). Journal of Food Measurement and Characterization. https://doi.org/10.1007/s11694-019-00120-9.

No, H.K., Meyers, S.P., Prinyawiwatkul, W. and Xu, Z. (2007). Applications of chitosan for improvement of quality and shelf life of foods: A review. Journal of Food Science. 72(5): 87-100.

Ojeda, G.A., Sgroppo, S.C. and Zaritzky, N.E. (2014). Application of edible coatings in minimally processed sweet pota toes (*Ipomoea batatas* L.) to prevent enzymatic browing. International Journal of Food Science and Technology. 49: 876-883.

Olivas, G.I. and Barbosa-Canovas, G. (2009). Edible Films and Coaings for Fruits and Vegetables In: [Embuscado, M.E and Huber, K.C. (editors)]. Edible Films and Coatings for Food Applications Springer Science and Business Media. p. 211-244.

Pavlath, A.E. and Orts, W. (2009). Edible Films and Coatings: Why, What and How? In: [Embuscado, M.E and K.C. Huber, (editors)]. Edible Films and Coatings for Food Applications. Springer Dordrecht Heidelberg, London, New York.

Poverenova, E., Zaitseva,Y., Arnona,H., Granita,R., Alkalai-Tuviaa, S., Perzelana,Y., Weinberga, T. and Fallik, E. (2014). Effects of a composite chitosan-gelatin edible coating on postharvest quality and storability of red bell peppers. Postharvest Biology and Technology. 96: 106-109.

Pushkala, R., Raghuram, P.K. and Srividya, N. (2013). Chitosan based powder coating technique to enhance phytochemicalsand shelf life quality of radish shreds. Postharvest Biology and Technology. 86: 402-408.

Puttalingamma, V. (2015). Post harvest losses of fruits, vegetables and its safety-A review. International Journal of Advanced Research. 3(1): 906-911.

Sanaa S.H.A., Mohamed, E.N. and Abdou, E.S. (2017). Effect of edible coating on extending the shelf life and quality of fresh cut taro. Am. J. Food Technol. 12: 124-131.

Shigematsu, E., Dorta, C., Rodrigues, F.J., Cedran, M.F., Giannoni, J.A., oshiiwa, M. and. Maura, M.A. (2018). Edible coating with probiotic as a quality factor for minimally processed carrots. J Food Sci Technol. https://doi.org/10.1007/s13197-018-3301-0

Simõesa, A.D., Tudelab, A., Allendeb, A., Puschmanna, R. and Gil, M.I. (2009). Edible coatings containing chitosan and moderate modified atmospheres maintain quality and enhance phytochemicals of carrot sticks. Postharvest Biology and Technology. 51: 364-370.

Singh, S., Khemariya, P., Rai, A., Rai, A.C., Koley, T.K. and Singh, B. (2016). Carnauba wax-based edible coating enhances shelf-life and retain quality of eggplant (*Solanum melongena*) fruits. Food Science and Technology 74: 420-426.

Sipahi, R.E., Castell-Perez, M.E., Moreira, R.G., Gomes, C. and Castillo, A. (2013). Improved multilayered antimicrobial alginate-based edible coating extends the shelf life of fresh-cut watermelon (*Citrullus lanatus*). Food Science and Technology. 51:9e15.

Soares, A., Ramos, A.M., Vieira, E.N.R., Vanzela, E.S.L., de Oliveira, P.M. and Paula, D.A. (2018). Vacuum impreg nation of chitosan-based edible coating in minimally pro cessed pumpkin. International Journal of Food Science and Technology. https://doi.org/10.1111/ijfs.13811

Tzoumaki, M.V., Biliaderis, C.G. and Vasilakakis, M. (2009). Impact of edible coatings and packaging on quality of white as paragus (*Asparagus officinalis*, L.) during cold storage. Food Chemistry. 117: 55-63.

Xing, Y., Li, X., Xu, Q., Jiang, Y., Yun, J. and Li, W. (2010). Effects of chitosan-based coating and modified atmosphere packaging (MAP) on browning and shelf life of fresh-cut lotus root (*Nelumbo nucifera* Gaerth). Innovative Food Science and Emerging Technologies. 11: 684-689.