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Edible coating/film and its application for minimally processed fruits and vegetables: A review

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Abstract
Fruits and vegetables are having high demand in the market because of its nutritional value. Due to their perishable nature, fruits and vegetables have a short shelf life. About 30% fruits and vegetables are affected or damaged by insects, microorganisms, pre and post harvesting condition during transport and preservation. The use of edible films and coatings incorporated with food grade additives has been constantly increasing in the food industry. The functionality and performance of edible films mainly depend on their barrier, mechanical and optical properties, which in turn depend on film composition and manufacturing process. Moreover, edible coating for fruits and vegetables can be especially designed to incorporate and/or controlled release antioxidants, vitamins, nutraceuticals, prebiotics and antimicrobial agents.

Keywords: Edible, coating/film, minimally, fruits and vegetables

Introduction
Edible coatings act as semipermeable barrier, applied over the fruit and vegetable surface, it manages the exchange of gases and moisture loss and thus perpetuates the freshness of fruit and vegetables (Vargas-Torre, 2017). An edible coating is widely used ongoing method for the extension and improvement of the shelf-life of the vegetables and fruits that work as an obstacle against the exchange of gases, moisture loss and microbial attacks by manipulating the environment inside the food stuff (Chiabrando, 2016). An optimal consumable coating is that which does not totally block exchange of gases but delay the degradation process with minimal effect on the quality of the product. The edible coating controls the change in the aroma, water content, taste, exchange of oxygen and carbon dioxide from the vegetable's (Athmaselvi *et al*., 2012). These edible coatings provide the barrier to the product same as modified atmospheric storage gives. The main advantage of the edible coating is that when the active ingredients can be incorporated into the polymer matrix and consumed with the food then there will be no harmful effects on the consumer and the products nutritional value (Chiabrando, 2016).

Fruits and vegetables are necessary components of the human diet because of their health and nutritional benefits. Advantages connected with their consumption (Sapper and Chiralt, 2018). They are known to be a storehouse for vitamins. Minerals, antioxidants, bioflavonoids, dietary fibers, and flavor components (Raghav, (2016, *et al*.). However, due to their short postharvest life, they are products with a relatively short postharvest life. They are susceptible to contamination since they are live tissues until they are used for eating. Physiological and metabolic alterations might be caused by physical or pathological factors. Resulting in significant economic losses. Respiration causes weight loss in fruits and vegetables during postharvest handling and storage, resulting in texture changes and surface shrinkage that shortens their shelf life (Sapper and Chiralt, 2018). The growing demand for fresh fruits and vegetables compels the food industry to explore new and better methods for preserving food quality and prolonging shelf life. Using edible films and coatings on food products is a novel way to address this issue (Swathi, *et al*., 2017).

Edible coatings have developed as a viable and environment friendly option for extending shelf life and protecting products from adverse environmental effects (Sapper and Chiralt, 2018). The food industry faces many challenges as they need to meet the desires of the consumers and use those ingredients which are natural and fulfills the technological roles of the processed food.

Thus this study was focused on the application of edible coating on fruits and vegetables.

Edible coatings and films

Edible coatings are a thin coated material that may be eaten and serves as a barrier to oxygen, external microorganisms, moisture, and solute movement in food. A semi-permeable barrier is applied in edible coating, with the goal of extending shelf life by reducing moisture and solute migration, gas exchange, oxidative reaction rates, and respiration, as well as reducing physiological disorders on fresh cut fruits. According to Pavlath and Orts (2009), various types of materials were applied as coating and wrapping various fruits and vegetables to enhance their shelf life, and this is considered an edible covering whether consumed with or without removal. Edible coatings should be stable at high relative humidity and are typically considered safe. Tasteless, colorless, and odorless edible coatings or edible films should have high mechanical characteristics. The gas barrier and moisture barrier qualities of edible coatings are high. Gas transfer rate (GTR) is influenced by both external and internal factors. External influences include atmospheric composition (O2, CO2, and ethylene ratios), temperature, and other stress factors, whereas internal determinants include species, cultivar, and growth state (Kluge *et al*., 2002) [27].

Edible coating on fruits and vegetables

Fruits and vegetables are highly perishable and approximately 50% fresh produce are deteriorated during harvest, handling, transportation and storage. Edible coatings play a very important role to handle this situation. Horticultural crops are intrinsically more prone to deterioration because to their high moisture content, especially in tropical climates. They are biologically active, undergoing transpiration, respiration, ripening, and other biochemical processes that cause them to lose quality. As their shelf life is well recognized, owing to their high moisture content (75-95%), which is the primary cause of their spoilage. Fruits and vegetables deterioration is clearly explained by their nature as living items that go through normal maturation, ageing, and degradation processes. Edible Coatings are applied on both whole and fresh-cut fruits and vegetables (Youssef *et al*., 2015). Minimal processing of fruits and vegetables removes the natural protection and become vulnerable to pathogens, necessitating the use of coatings as a commercial practice to restore the natural protection that interferes with the regulation of CO2 and O2 exchange with the environment in the harvested product (Gutiérrez, 2004). The preservation of the freshness of fruits and vegetables with the use of edible coatings is continually increasing importance for the market and customers when giving a safe product (Velásquez *et al*., 2014). Herrera (2012) considered product transpiration to be the most major cause of quality loss and economic value loss in fresh vegetables, as evidenced by weight loss, inconsistent consistency, and withering, all of which have a significant impact on appearance. Edible coatings alter the environment by forming a semipermeable barrier to the flow of O2, CO2, moisture, and solutes, lowering respiration, water loss, and oxidation reaction rates (Maqbool, 2010) [3]. Fruits and vegetables with edible coatings or edible films have a glossy appearance. The edible layer is usually less than 0.3 mm thick. The main benefit of edible coating is that it extends the shelf life of fresh or processed fruits and vegetables while also protects them from postharvest and environmental damage (Valverde, 2005).

Fruits and vegetables are coated by dipping in, brushing or by spraying with edible material so a semi leaky membrane is created on the surface by that it suppress the respiration rate, controls wet loss ((Figure 1). Polysaccharides, proteins, lipids, and composites are the most common types of edible films and coatings (Valencia-Chamorro, 2010). Edible film or coating on the surface of fruits and vegetables extends the shelf life and acts as a barrier to gas transmission as well as microbes (Raghav *et al*., 2016; Valverde, 2005). Various forms of nanocomposite films and edible coatings are now widely employed on fresh fruits and vegetables to extend their shelf life utilizing the same principles as modified environment approaches, which have demonstrated to be effective in preserving the quality of fruits and vegetables. The activity of these edible films is based on the production of a semi permeable safety barrier around the vegetables and fruit, which reduces the loss of quality features significantly. The comparatively high quantity of these features has helped to maintain them. Starch, pectin, carrageenan, alginate, chitosan, and xanthan gum are examples of biopolymers which are widely utilized in the production of edible films and food coatings. Numerous research have already proved the effective impact of chitosan and alginate-based suitable for eating coatings at the first-class renovation of end result and vegetables. These coatings make certain a widespread barrier in opposition to water launch and behave as micro-environments making sure a superior awareness of gases and main to delays in ripening, which is equal to an extended renovation period. Chitosan, active chitosan, and chitosan nano-formulation are excellent ingredients for creating edible adhesions of fruit products such as chopped pineapple, chopped cherry tomatoes etc. various chitosan solutions (high molecular weight, medium molecular weight, and low molecular weight). Samples were stored for 16 days at a temperature of 25 ◦C. The results showed that chitosan-based adhesion of high cells resulted in delayed maturation of treated samples, which resulted in significantly higher titratable acidity, fruit firmness, and reduced weight loss, ethylene production, and respiratory rate. In addition, studies have shown that mango fruits that are high in molecular weight chitosan are able to maintain their ascorbic acid and DPPH levels during storage. It can be said that the covered mango samples were of better quality compared to the controls and other samples, and their shelf life was greatly improved.

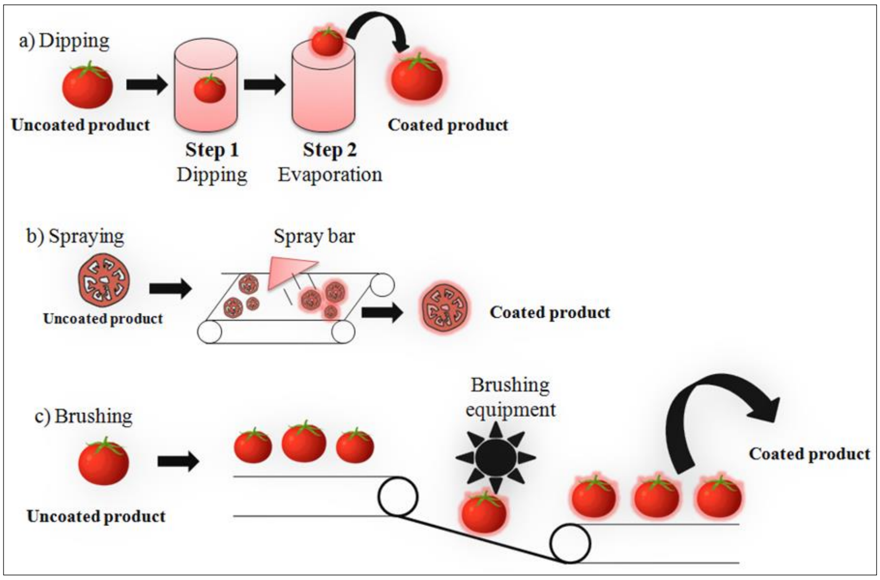

Fig 1: Edible coating of tomato by (a) dripping, (b) spraying and (c) brushing

Edible coating applied on different fruits and vegetables

Fresh fruits and vegetables are highly perishable and approximately 50% fresh produce are deteriorated during harvest, handling, transportation and storage. Edible coatings play a very important role to handle this situation. Edible coatings are applied on whole and fresh-cut fruits and vegetables (Youssef *et al.*, 2015). Fruits and vegetables coated by applying different methods *viz*. Dipping, brushing, extrusion, spraying, and solvent casting have been shown in Table 1.

Table 1: Coating material used for edible coating of Fruits and vegetables

Si No	Fruits and vegetables	Used edible coating	References
1	Mexican guava fruits	Potato starch and pectin	Quezada *et al*., 2003 [40]
2	Raspberry	Chitosan-based coating containing 5% calcium-based texture enhancer	Han *et al*., 2004 [22]
3	Strawberry	wheat gluten-based coatings and bilayer coating of wheat gluten and lipids	Palmu and Grosso, 2005 [49]
4	Fresh-cut apple	Vanillin, oregano oil, lemongrass	Rojas-Grau *et al*., 2006 [43]
5	Strawberry	Coating with soy or wheat gluten protein	Amal *et al*., 2010 [6]
6	Blueberry	CMC, Chitosan, Monoglycerides, Sodium alginate, Calcium Caseinate, Sodium alignate, pectin, sodium alignate plus pectin	Duan *et al*., 2011 Mannozzi *et al*., 2017
7	Cucumber	Pectin-based (pectin, sorbitol, beeswax, water and emulsifying agent).	Moalemiyan and Ramaswamy, 2012 [32]
8	Star fruit	Chitosan and palm stearin	Zaki *et al*., 2012 [52]
9	Strawberry	Chitosan coatings	Perdons *et al*., 2012
10	Apples	Sodium caseinate and glycerol.	Shariatifar and jafarpour, 2013 [47]
11	Cucumbers	Carboxymethyl cellulose and corn starch	Oluwaseun *et al*., 2013 [35]
12	Tomato	Aloe veragel	Athmaselvi *et al*., 2013
13	Cantaloupe	Aloevera gel	Yulianingish *et al*., 2013
14	Grapes	Aloevera gel Native and octenyl succinic anhydride modified wheat starch coatings	Chauhan *et al*., 2014 Punia *et al*., 2019
15	Strawberry	Arabic gum& Arjan gum psyllium mucilage	Yarahmdi *et al*., 2014
16	Tomato	Guar gum	Arkendu *et al*., 2014
17	Grape fruit	Aloe vera	Javed *et al*., 2016
18	Banana	Cellulose nanomaterials emulsion as coatings	Deng 2017
19	Orange	Sellac, gelatin and persian gum as alternate coatings	Khorram *et al*., 2017
20	Guava	Guar gum	Momin *et al*., 2018
21	Kinnow mandarin	Hydroxyl-propyl-methylcellulose coating combination with caC12 and Mgso4 Polysaccharides from opuntia coating in Kinnow	Gao *et al*., 2018
22	Papaya	Carboxymethylcellulose coating with essential oil	Zillo *et al*., 2018
23	Mango	Cassava starch and chitosan coatings	Oliveira *et al*., 2018
24	Guava	Aloe vera-Xanthan gum	Abraham and Banerjee., 2018 [1]

Moalemiyan and Ramaswamy (2012) [32] studied coating cucumber with pectin-based emulsions which consisted of pectin, sorbitol, beeswax, water and an emulsifying agent. In 2013, Shariatifar and jafarpour reported that weight loss of apples was significantly reduced when coating was done with emulsion consisting of sodium caseinate and glycerol. Oluwaseun *et al*. (2013) [35] studied the difference between CMC coated and uncoated cucumbers and reported that cucumbers coated with carboxymethyl cellulose and corn starch showed a significant delay in weight loss when compared to uncoated ones. In 2005, Palmu and Grosso studied the effect of coating on refrigerated strawberry quality. Different wheat gluten-based coatings and bilayer coating of wheat gluten and lipids were prepared and it was found that in all the treatments, total soluble solids increased significantly with storage time. Only fruit covered with the bilayer film showed no significant effect. Amal *et al*. (2010) [6] reported that in strawberry fruit, edible coating with soy or wheat gluten protein maintained total soluble solids (TSS). On the other hand, Perdons *et al*. (2012) observed that chitosan (1%) coatings had no significant effect in terms of the soluble solid content of strawberries. Han *et al*. (2004) [22] found that a chitosan-based coating containing 5% calcium-based texture enhancer enhanced the hardness of frozen-thawed raspberries by about 25% in comparison to uncoated raspberries. Coating cucumbers with pectin-based emulsions reduced firmness loss and increased storage life of cucumber fruit, according to Moalemiyan and Ramaswamy (2012) [32]. The hardness of star fruits was preserved by an edible covering made up of hydrophilic (chitosan) and hydrophobic (palm stearin) components, according to Zaki *et al*. (2012) [52]. In 2009, Kadu *et al*., discovered that fruits coated with GA3 (200 mg/l) solution showed better quality attributes than the control. They had lower physiological weight loss, shrivelling, spoilage, and higher firmness as well as a longer shelf life. They concluded that treatments with GA3 (150mg/l) and Cacl2 (6 and 4 percent) maintained fruit quality during storage in a polyethylene bag with KMno4 silica gel. The uncoated and unpacked fruits deteriorated faster. Quezada *et al*. (2003) [40] studied the coating of Mexican guava fruits with potato starch and pectin. Temperature was maintained at 25 ℃ with a relative humidity of 50-70%. Increase in the shelf life of fruit was observed as compared to uncoated fruit. Aslam *et al*. (2014) compared the fruit quality of guava cultivars such as 'Gola' and 'Surahi' during the summer and winter seasons. In the summer, 'Gola' showed better results than 'Surahi' in terms of fruit firmness and titratable acidity. However, the fruit quality of both types was highest in the winter, and it was observed that fruit picked in the winter had superior quality and appearance than fruit harvested in the summer. In 2014, Arkendu and his colleagues studied the impact of varied guar gum concentrations (4 percent, 6 percent, 8 percent, and 10 percent) on tomato shelf life and post-harvest losses was studied. Sensory evaluation revealed that 6 percent guar gum coating was effective in preserving the overall quality of tomato fruits during storage for up to 32 days when compared to fruits under control by delaying the ripening process. Therefore, this combination can be used for making edible coating. According to Ruelas-Chacon *et al*., (2017) [44], Guar gum increased the physiochemical, microbiological, and sensory quality attributes of Roma tomatoes, suggesting that it could be effective in delaying ripening at 22°C. Javed *et al*. (2016) concluded that, Grape fruit coated with 20% aloe vera concentration is the most effective, and this works as a moisture barrier, extending storage time. Over the course of the storage time, the coated and packaged grapes at 4℃ lost the least moisture, but the openly stored grapes in the incubator at 30℃ lost the greatest moisture. These studies suggested that combining low temperature storage with edible coating and packaging boosts marketability by lowering moisture loss. Gad and Zagzog (2017) [20] found that guava fruits coated with xanthan gum (1%) had the lowest decay percentage (7.00%) and the highest fruit firmness (644 g/cm2). On the other hand, fruits coated with xanthan gum (1 + 0.4%) chitosan nanoparticles had the lowest weight loss (0.05%) and the highest fruit firmness (644 g/cm2). Abraham and Banerjee (2018) [1] observed that, edible covering of Aloe vera-Xanthan gum blend gel substantially enhanced the shelf life of the guava by 14 days. The covered guava fruit had lost 2.6 percent of its weight after seven days, while the control fruit had dropped 4.7 percent. According to Ghatge *et al*. (2005) [21], with the increase in storage period, the acidity of pomegranate juice decreased continuously, regardless of post-harvest or storage conditions. In room temperature storage, the rate of acidity decline was faster than in low temperature storage. According to Gola and Kaithli, significant increase in ascorbic acid concentration was observed but only during transportation. It decreased significantly with increasing storage period, with the highest concentration found in CFB with paper cuttings.

Effect of edible coating on fruits and vegetables

Edible coatings are natural, biodegradable compounds and found to have significant advantages *viz*. act as a medium for texture enhancers, antioxidants, and nutraceuticals (Das, Dutta and Mahanta, 2013) [14].

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

(b) Weight loss of fruits and vegetables: The weight of horticulture product governs the returns of farmers. Transpiration is the main reason of loss of weight of particular product, which is determined by the change of water vapour pressure between the fruit and the atmosphere. Edible coatings perform as an added barrier between the fruit surface and atmosphere, thereby minimizing the weight loss (Zhang *et al*., 2018). Hazrati (2017) reported that coating of peaches with aloe vera L gel showed significantly positive effects on weight loss, change in colour and TSS over control.

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

Conclusion

Fruits and vegetables are perishable goods that must be handled with extreme caution to avoid spoilage. Between harvest and consumption, fresh fruits and vegetables lose a lot of their quality and quantity. The gaseous equilibrium between the consumption of oxygen and the production of carbon dioxide changes when the fruit is picked. Thus it becomes necessary to maintain quality and shelf life of fresh as well as minimally processed fruits and vegetables. Edible film or coating are found to be effective in maintaining the overall quality of the fruits and vegetables by providing them a better shelf life.

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