R-2641
[1-10]

REVIEW ARTICLE   Agricultural Reviews, Volume Issue : ()

Physicochemical Alterations in Fruits Caused by Edible Coatings during Storage: A Review

Pooja Ahlawat[1], Anita Kumari[1], Sarita[1]

10.18805/ag.R-2641

ABSTRACT

Fruits and vegetables are especially perishable due to their 80-90% water content by weight. Several strategies have been developed to retain and extend the freshness of packaged, transported and stored goods. Edible coatings are thin films applied to the exterior of fruits and vegetables to protect them from moisture, air and microbes. In the development of edible coatings, polysaccharides, proteins, lipids, composites and resins are among the most often employed materials. Packaging fresh fruits and vegetables is essential for preventing further contamination, damage and loss of moisture. The physicochemical effects of edible coatings on whole fruits include enhanced hardness, higher titratable acidity (TA) and better vitamin C, whereas the effects on fresh cuts include reduced water loss, increased soluble solid content (SSC) and preservation of product colour. The bulk of the effects might have been observed in both whole and freshly sliced fruits. This has aroused the interest of scholars, resulting in extensive research.

Key words: Edible coating, Fresh-cut fruit, Fruit quality, Physicochemical, Shelf-life.

Fruits are nature's wonderful gift to humanity; they are life-enhancing medications rich in vitamins, minerals, antioxidants and phytonutrients (plant-derived micronutrients). Fruits and vegetables are universally acknowledged as the primary sources of vitamins, minerals, antioxidants and fiber in consumer diets. Simultaneously, their short shelf life is widely recognized, owing to their high moisture content (75-95%), which is the primary reason of their fast disintegration. Fruits are classified into two classes based on the processes that govern the ripening process. They are classified as climacteric or non-climacteric fruits in this regard. While fruits which are non-climacteric, do not continue to ripen after harvest, fruits which are climacteric, might ripen after harvest and release more ethylene than non-climacteric fruits, making them more susceptible to deterioration caused by bacteria. As a result, adequate packaging and coating technologies are required for these food products to have a respectable shelf life (Jafarzadeh *et al*., 2021).

Perishable fruit are prone to spoilage under ambient circumstances. Post-harvest losses can be reduced by extending shelf life by monitoring transpiration, respiration, microbial infection and preserving membranes from disorganization (Muhammad *et al*., 2021). To some extent, the aforementioned goals can be met by using edible organic and inorganic coatings such as growth regulators, wax emulsions, potassium and calcium chemicals, irradiation, anti-transparent substances, gel, oil, lipid, starch, packaging and wrapping materials and various types of storage used as postharvest treatments. Various international and national agencies, led by the FAO, undertook studies that revealed that almost one-third of all food produced on the earth and roughly half of all fruit and vegetables are lost. To improve shelf life and marketable time to simplify long distance transportation, edible coatings of wax, oils, natural ingredients and others have been utilized as an effective technique to preserve the quality of post-harvest fruits during storage. Semi-permeable coatings have gained popularity for decreasing moisture loss, transpiration, respiration and microbial assault while preserving hardness at ambient temperatures (Fig 1).

A huge number of novel edible materials have recently been produced; hence, the most recent studies on the issue are covered in this review. The aim of this review is to update knowledge on edible coatings on minimally processed and fresh vegetables, with an emphasis on composition, active components and their influence on physicochemical properties and shelf-life.

Edible coatings

A thin coating of edible components such as polysaccharide, protein and lipids acts as a barrier between food and the

[1]Department of Botany and Plant Physiolog, Chaudhary Charan Singh Haryana Agriculture University, Hisar-125 001, Haryana, India.

Corresponding Author: Pooja Ahlawat, Department of Botany and Plant Physiolog, Chaudhary Charan Singh Haryana Agriculture University, Hisar-125 001, Haryana, India.
Email: ahlawat.pooja.ezra@gmail.com

How to cite this article: Ahlawat, P., Kumari, A. and Sarita (2024). Physicochemical Alterations in Fruits Caused by Edible Coatings during Storage: A Review. Agricultural Reviews. doi: 10.18805/ag.R-2641.

Submitted: 05-05-2023 **Accepted:** 04-07-2024 **Online:** 08-10-2024

surrounding environment when applied as a thin film. These coatings prevent decay while maintaining product quality and enhance shelf life without generating anaerobiosis. They operate as moisture and gas barriers, slowing the ripening process of crops by limiting respiration rate. Edible coatings enhance functional characteristics by integrating antibacterial chemicals, antioxidants, minerals and vitamins (Manojj *et al*., 2021 and Hazarika *et al*., 2023). The components are applied to the food surface by brushing, dipping, or spraying the coating solution (Kocira *et al*., 2021 and Khare *et al*., 2017). According to the nature of the components employed in the creation of the coating solution, edible coatings are classified into three types. Alginates, proteins and polysaccharides are examples of hydrocolloids, as are lipids including acylglycerols, fatty acids, or waxes and the composites made by mixing molecules from the other two groups.

Hydrocolloids and lipids are commonly employed together because hydrocolloids are poor moisture barriers and lipids are poor gas barriers. The combination of both increases structural integrity and functional characteristics (Jafarzadeh *et al*., 2022). To increase their qualities, antimicrobial additives, antibacterial chemicals and emulsifiers can be added (Muhammad *et al*., 2021) (Fig 2). Edible and bio-based films are a rapidly evolving technology that provides an alternative to standard synthetic polymers, which pollute the environment severely (Fig 3). The primary benefits of ecologically friendly composites are that they are renewable and biodegradable. As a result, the creation of edible coatings has lately piqued the interest of researchers and consumers, owing to the wide range of uses provided by these materials. As Table 1 shows different combination of edible coatings used on various fruits. Those materials might be among the available food compounds that have not been investigated as edible packaging components or industrial by-products and trash that have a long-term utility.

Application techniques for edible films and coatings

The technique or process by which the coating or film clings to the food surface is referred to as the application method. (Fig 4).

I. Dipping

Dipping is the most frequent method for coating fruits and vegetables with very viscous coatings. The product is immersed in coating solutions for five to thirty seconds under regulated density and surface tension conditions.

II. Spraying

The spraying method is utilized for non-viscous liquids. The food product is delivered into the coating system and sprayed by regulating the ultimate drop size of the spray solution.

III. Brushing

When preventing moisture loss is a difficulty, some items, such as fresh beans and strawberries, employ the brushing approach.

Effect of edible coatings on physicochemical properties of fruits

a. Physiological loss in weight (PLW)

The most visible physiological change in citrus fruits after harvest is the loss of water by transpiration, which results in a loss of fruit weight and volume, as well as wilting and shriveling of the fruits. These modifications have an impact on the look of the fruits and impair their marketability. Physiological weight loss is mostly caused by evaporation and transpiration of water from fruit, as well as respiration and physiological processes that occur in fruits after harvesting. Duong *et al*. (2022) created an edible covering substance based on alginate and various $CaCl_2$ solution concentrations to extend the shelf life of rose apple fruits during cold storage. In comparison to the alginate films,

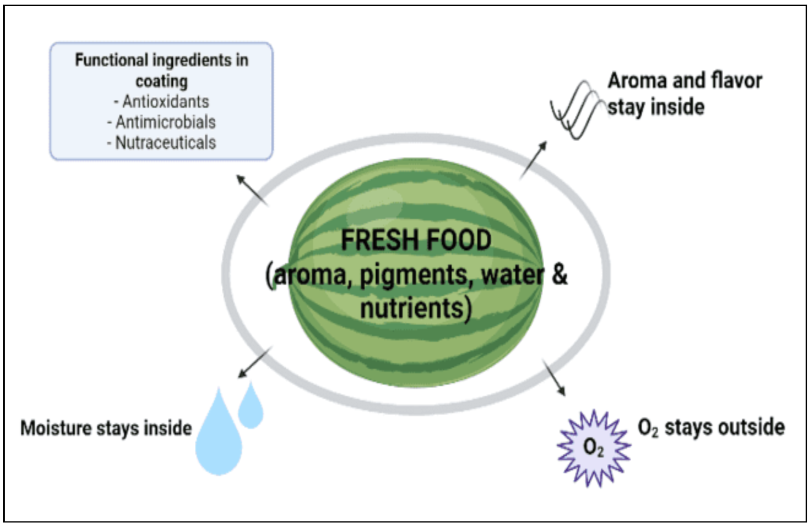

Fig 1: Effects of coatings on fruits in enhancing the shelf life.

the addition of $CaCl_2$ solutions reduced water vapor permeability and oxygen permeability. The coated samples had a considerably lower respiration rate and weight loss, as well as a delayed chilling damage, according to the physiochemical data. Basiak *et al*. (2019) investigated the effects of two distinct starch-based edible coatings on plums, one comprising simply starch and the other containing starch and whey protein. When the coatings were applied in a three-layered model, the results revealed that the starch and starch-whey protein coatings enhanced the overall resistance in the water vapor channels of individual plums by 60-75% at high transpiration potentials. Mango (Gill *et al*., 2015), grapes (Shiri *et al*., 2011) and kinnow (Ahlawat *et al*., 2018a) have all shown an increase in PLW during storage.

b. Decay loss

Spores of several microorganisms can be found in the atmosphere. Fruits are particularly prone to microbial contamination due to their high moisture content. Fruits have a hard surface at the solid mature stage, therefore spores from diverse microorganisms cannot penetrate the fruit surface. As fruits ripen, they soften, allowing more microorganisms to assault the fruit surface, resulting in increased decay loss. Das *et al*. (2020) evaluated the antibacterial and antibiofilm properties of newly developed edible nano-emulsion coatings utilizing sodium alginate and essential oil derived from sweet orange. Salmonella and Listeria were chosen as pathogenic bacterial strains for this investigation. The edible nano-emulsion coatings did not allow bacterial growth of the two tested microorganisms. In terms of the quality attributes of the coated tomato samples, it was discovered that firmness was significantly improved, up to 33% and weight loss was reduced up to 3-fold compared to uncoated samples. Gangwar *et al*. (2012) found that decay loss varied with storage duration (0-15 days) in different Aonla (*Emblica officinalis*) or Indian gooseberry cultivars maintained at room temperature. After 15 days of storage, the fruits of Aonla cultiver NA-7 had the lowest decay loss (15.12%), whereas the fruits of cultivar Banarasi had the highest decay loss (19.33%).

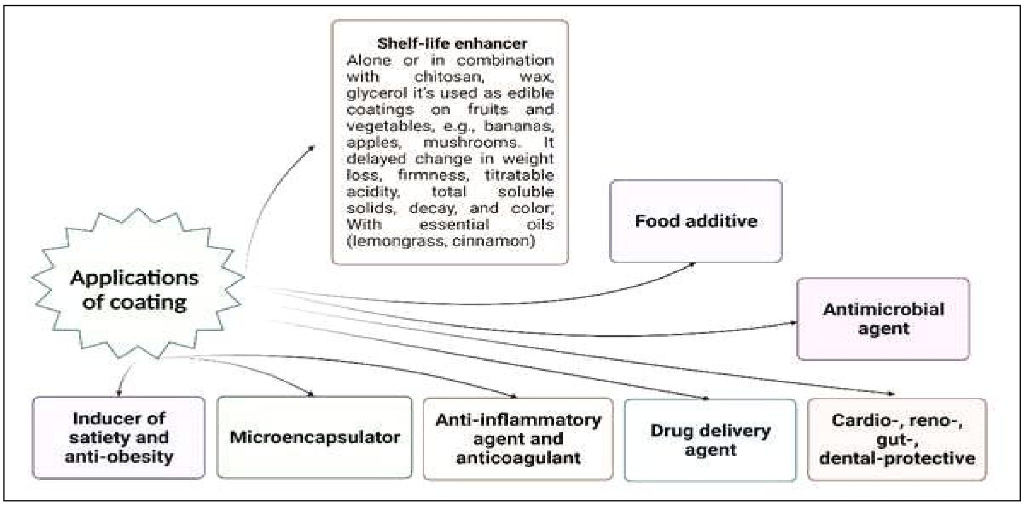

Fig 2: Applications of edible films and coatings.

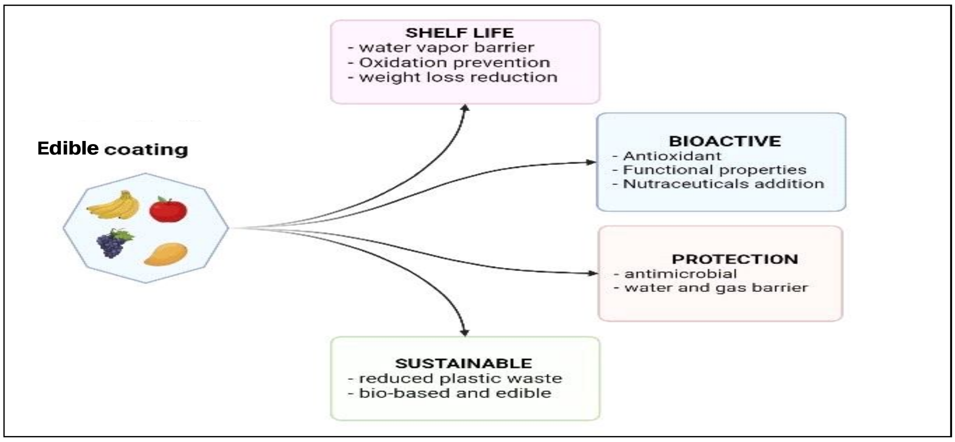

Fig 3: Benefits of edible coatings.

c. Firmness

The degree and amount of firmness loss during storage is one of the key parameters used to predict fruit quality and post-harvest shelf life. Fruit softening is caused by a biochemical process that involves the breakdown of pectin and starch by enzymes such as wall hydrolases. Edible coatings and packaging materials enhanced fruit firmness because coatings limit water loss. Oyom *et al*. (2022) used an edible coating formulation incorporating modified starch from sweet potatoes and cumin essential oil on pear samples in research (*Pyrus bretchneideri* Rehd). The coating method employed in the testing was dipping the sterilized samples into the coating solutions and the coated samples were kept at 25°C for 28 days. Because of the adhesiveness of the modified starch coating, which created a thin layer on the pear and kept the pericarp and freshness, the coating treatment was able to control the respiration rate, postpone weight loss and maintain flesh firmness after 21 days. According to Bishnoi *et al*. (2014), there was no significant difference in hardness between uncoated

Table 1: List of fruits coated with edible coatings.

Fruits and vegetables	Edible coatings	References
Strawberry	Chitosan nanoparticles	Abu Salha and Gedanken, 2021
	Orange peel essential oil + carnauba wax	Saeed *et al*., 2021
	Carboxymethyl cellulose (CMC) + low methoxyl pectin + Persian gum + tragacanth gum	Khodaei *et al*., 2021
Peach	Essential oils of cinnamon, basil and thyme	Ayub *et al*., 2021
	Methylcyclopropene + Aloe arborescens	Sortino *et al*., 2020
	Rhubarb (*Rheum rhaponticum* L.) extract	Li *et al*., 2019
Banana	Starch + chitosan	Alam *et al*., 2020
	Chitosan	Ali and Hamid 2021
Kinnow mandarin	Chitosan + Alginate	Puri and Kumar 2021
	CMC + chitosan + beeswax	Baswal *et al*., 2021
	Gum Arabic	Ahlawat *et al*., 2018b
Guvava	Aloe vera gel + salicylic acid + Benzyl adenine	Momin *et al*., 2018
	Guar gum	Kabbashi *et al*., 2018
	Arabic gum + Aloe vera + garlic extract	Anjum *et al*., 2020
		Kumar *et al*., 2023
Tomato	Candelilla Wax + *Flourensia cernua* Bioactives	Ruiz-Martínez *et al*., 2020
	Chitosan-Pullulan composite edible coating	Kumar *et al*., 2021
	Enriched with pomegranate peel extract	Firdous *et al*., 2020
	Aloevera gel	Karmakar and Roy 2023
Mango	Chitosan + Aloe vera	Shah and Hashmi 2020
	Chitosan + Mentha EO	de Oliveira *et al*. 2020
	Cassava starch + chitosan coatings	de Oliveira *et al*., 2018
Grapes	Chitosan + Gum ghatti	Eshghi *et al*., 2021
	Native and octenyl succinic anhydride modified wheat starch coatings	Punia *et al*., 2019
	pectin edible coating obtained from orange peels + lemon essential oil	Breceda-Hernandez *et al*., 2020
	Alginate + galactomannans + cashew gum + gelatin	de Souza *et al*., 2021
Persimmon	Gum Arabic	Saleem *et al*., 2020
	Carboxy methyl cellulose + sodium alginate	Hegazy, 2017
	Pectin + guar gum	Elabd and Gomaa 2017
Apple	Aloe vera gel	Farina *et al*., 2020b
	Fenugreek + flaxseed polysaccharides-based coating	Rashid *et al*., 2020
	Rice starch + sucrose fatty acid ester + glycerol	Thakur *et al*., 2019
Papaya	*Aloe vera* gel	Farina *et al*., 2020b
	manioc starch + clove essential oil	de Vasconcellos Santos
	Mentha essential oils	Batista *et al*., 2020
		dos Passos Braga *et al*., 2020
Plum	Pectin	Panahirad *et al*., 2020
	Alginate + Chitosan + Gellan gum + Gum Arabic	Fawole *et al*., 2020

and coated plums after 8 days of storage at ambient temperatures, while coated plums remained much firmer even after 16 days of storage.

d. Total soluble solids (TSS)

A total soluble solid defines the quality of fruits, which include 90% sugars and 10% minerals and acids. TSS increases during storage due to starch breakdown into soluble sugars. According to Ali *et al*. (2010), there was a progressive rise in soluble solid content over the whole storage time of tomato fruits, which was 20 days. The soluble solid level was much greater in control fruit (10.1%) than in coated fruit, with the lowest soluble solid concentration (6.5%) reported in fruit coated with 20% gum arabic, indicating that the coatings created a good semi permeable membrane surrounding the fruit. According to Mohammed *et al*. (2014), chitosan coating treatment delayed the decline in total soluble solids concentrations from 19.5% on the first day of storage to 17.8% on the 60th day of storage when compared to control fruits (13.7%). Din *et al*. (2015) investigated the influence of edible coatings, such as black cumin oil, bitter mustard oil and mustard oil, on kinnow fruit preservation for up to 30 days. The TSS of all treatments ranged from 12.43 to 12.52°brix. Khaliq *et al*. (2016) discovered that chitosan 1% and gum arabic 10% coating treatments effectively prevented the growth of TSS throughout a 28-day storage period.

e. Specific gravity

Due to higher transpiration and respiration during storage, fruits lose more weight than volume during storage. As a result, specific gravity decreased as the storage duration lengthened. Singh *et al*. (2012) documented a decrease in specific gravity during storage in mango. Kumari (2016) determined that the specific gravity of Aonla fruits fell from 1.11 to 0.91 after 15 days of storage at room temperature. Singh *et al*. (2012) discovered a reduction in specific gravity as the storage time (0-10 days) progressed in Amrapali Mango. Amrapali Mango had a maximum specific gravity of 0.99 on the first day of storage and a minimum specific gravity of 0.79 on the tenth day of storage. Fruit specific gravity increases as the maturity index progresses and fruit ripeness at harvest impacts its quality and storage life.

f. Juice content

The juice content reduces with storage time. Fruit weight was closely connected to a decrease in liquid percent. Increased evapotranspiration and catabolic processes in the fruits might explain the declining trends in juice content. Kaur and Kumar (2014) evaluated the impact of mandarin fruits treated with $CaNO_3$ (0.5% and 1.0%), $CaCl_2$ (1% and 2%) for 45 days of storage and found that $CaNO_3$ (1%) treated fruits had the highest juice percentage, 43.53%, when compared to control fruits (39.56%). Bhatnagar *et al*. (2015) found that the juice recovery percentage of kinnow fruits varied from 41.11% (at the Chattargarh 1 orchard) to 51.39% (at the Khajuwala 1 orchard). Ahlawat *et al.* (2018c) investigated the effect of Gum Arabic edible coating on Kinnow juice content. On a mean basis, regardless of storage length, fruits coated with gum arabic 10 per cent (27.20%) had the highest juice content, followed by fruits coated with gum arabic 5 per cent (27.18%).

g. Acidity

Citrus organic acids, particularly citric acids, serve as a reserve source of energy. The acidity of fruits can change depending on ripeness and storage temperature. This is

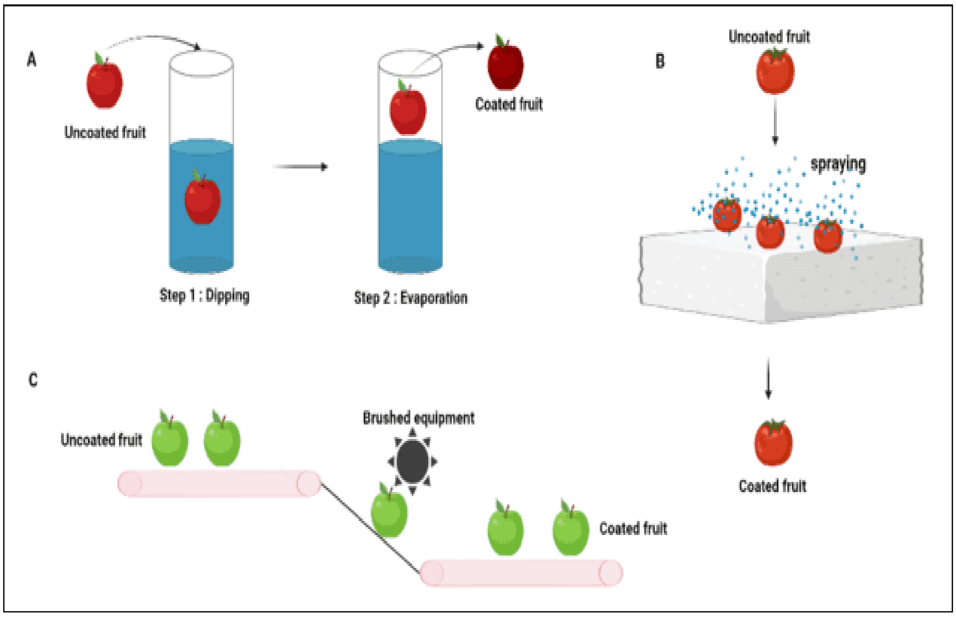

Fig 4: Different methods of application of coating on fruits.

clear because acids may have been used in various physiological processes (for example, respiration) and may have remained on the fruits throughout storage. This might possibly be attributed to an increase in the activity of the enzyme invertase, which is responsible of converting acids into sugars. Muley *et al*. (2020) evaluated the effects of a new functional coating comprised of whey protein isolate, chitosan and glycerol on the shelf-life extension of strawberries. The films were cast at temperatures above 60°C and many physical studies were carried out (antioxidant activity, color, oxygen transfer rate, crystallinity, *etc*.). Fresh strawberry samples were covered with these films and stored for eight days at two different temperatures (5°C and 20°C). The samples were subjected to a range of biochemical and physical examinations in order to determine their shelf-life. The coated samples displayed lower titratable acidity, weight loss, pH, color changes, total phenolics and DPPH levels. In terms of shelf-life extension, the untreated samples had a shelf life of 3 to 5 days while the coated samples had a shelf life of 5 to 8 days. According to Ali *et al*. (2015), fruit acidity decreased with increasing storage period for all treatments up to 63 days, but the decrease in acidity was slightly less for coated kinnow mandarins (from 1.01% to 0.81% for natural fruit coating and from 1.03% to 0.82% for Fomesa) than for uncoated ones (from 1.02% to 0.79%). Grapes (Shiri *et al*., 2011), Kinnow (Ahlawat *et al*., 2018a) and Aonla (Kumari, 2016) all have shown a decrease in acidity during storage. It has been found that many fruits treated with edible coatings and films retain titratable acidity.

h. Ascorbic acid

Ascorbic acid is essential in human nutrition. When exposed to oxygen, ascorbic acid is extremely reactive and easily oxidized. The drop in ascorbic acid concentration in fruits during storage might be attributed to ascorbic acid oxidase enzyme converting ascorbic acid to dehydro-ascorbic acid. Temperature and storage time have been shown to influence the ascorbic acid concentration. Paladugu and Gunasekaran (2017) investigated the effect of gum arabic used as an edible covering on tomatoes preserved for 28 days. The highest ascorbic acid level was found in control fruit (27 mg/100 g), while the lowest was found in fruit coated with 1.5% gum arabic (14 mg/100 mg). Javed *et al*. (2015) measured ascorbic acid content in guava fruits treated with 0, 1, 2 and 3% calcium lactate for up to 24 days. The lowest ascorbic acid content was found in fruits treated with 0% calcium lactate (318 mg/100 g) and the highest was found in fruits treated with 3% calcium lactate (337 mg/100 g). This was owing to the coating's low oxygen permeability, which delayed the deteriorative oxidation process of the ascorbic acid content. According to Ali *et al*. (2015), the highest ascorbic acid content was found in kinnow mandarins coated with Fomesa (26.06%), followed by those coated with natural fruit coating (26.05%) and the lowest ascorbic acid content was found in uncoated kinnow mandarins (24.77%) after 20 days of storage. These findings are consistent with prior research, which discovered that the ascorbic acid concentration of waxed and unwaxed kinnow fruits declined during low-temperature storage and that coated fruits had greater ascorbic acid amounts than uncoated ones (Mahajan *et al*., 2013).

i. Sugars

The amount of sugar in fruit impacts its sweetness and flavor. TSS is closely connected to changes in sugar concentration during storage. The conversion of starch and polysaccharides into soluble sugars, as well as fruit drying, are likely to cause a rise in sugars during storage. Javed *et al*. (2015) investigated the effect of various calcium lactate concentrations (0, 1%, 2% and 3%) on guava fruits stored for up to 24 days. Sugar content was highest in control fruits (8.88 g/100 g) and lowest in fruits treated with 3% calcium lactate (9.94 g/100 g). According to Athmaselvi *et al*. (2013), aloe vera coated tomatoes had a greater sugar content (4.31 mg/100 g) than uncoated tomatoes (3.49 mg/100 g). According to Pawar *et al*. (2011), the total and reducing sugar content of sapota fruit rose considerably after storage, rising from 14.40% and 8.90% to 19.12% and 11.08%, respectively. Catharanthus reducing sugars surged first and then progressively reduced, whereas non-reducing sugars decreased initially and eventually grew.

j. Enzymatic studies

a) Pectin methylesterase (PME), polygalacturonase (PG) and cellulase

Softening changes, including a loss of brittleness and stiffness, are the most prominent indicators of kinnow degradation; these changes have a direct impact on the quality of the fruits as well as their storage life. The action of enzymes such as pectin methylesterase (PME), polygalacturonase (PG) and cellulase on polysaccharides such as pectin, hemicellulose and cellulose present in the cell wall has been related to the disassembly and destruction of cell wall structure and composition. Pectin methylesterase hydrolyzes pectins, which are the principal elements of the fruit's middle lamella and primary cell wall, in higher plants to produce demethylated pectins that are more readily hydrolyzed by polygalacturonase.

Furthermore, polygalacturonase catalyze the hydrolysis of (1→4) galacturonan linkages in demethylated pectins, resulting in shorter chains and the depolymerization and dissolution of pectins. Vishwasrao and Ananthanarayan (2017) investigated the effect of treating sapota fruits (a big berry) with an edible covering made of methyl cellulose (MC) and palm oil (PO) on shelf life. During postharvest ripening, the examined fruit samples demonstrated lower pectin methylesterase activity. Overall, the edible coating consisting of methyl cellulose (MC) and palm oil (PO) preserved the treated sapota fruit samples, prolonging the shelf life by three days at 24.1°C and 65.5% RH compared to the control samples. Ahlawat *et al.* (2018d) studied kinnow fruits coated with varying concentrations of gum arabic, calcium lactate and glycerin and found that their combination resulted in a progressive increase in PG activity during storage, but the increase was much greater in the control throughout the entire storage period. Glycerin 2.5 per cent treated fruits (0.125 units/g FW) had the highest PG activity (0.127 units/g FW). Gum Arabic 10% + Glycerin 2.5% coated fruits had the lowest PG activity, 0.120 units/g FW. The reduced activity of polygalacturonase in coated fruits might be attributed to the coating successfully preventing access of pectinolytic enzymes to the cell wall substrate and so helping to retain fruit firmness.

b) Free radical scavenging activity (DPPH)

The DPPH (1,1-Diphenyl-2-Picryhydrazyl radicle) is widely acknowledged as a stable free radical and DPPH radical-scavenging by antioxidants has been linked to their hydrogen donating capacity. Wani *et al*. (2021) investigated the edible coatings of Arabic gum, xanthan gum with 1% w/v lemon grass essential oil and carrageenan. The results revealed that the coated strawberry samples reduced weight loss, better retimed ascorbic acid, had higher antioxidant activity and increased firmness. The anthocyanins levels and phenolic compounds were retained in the edible films containing carrageenan gum after storage. Furthermore, the coatings containing carrageenan gum produced the greatest results in terms of quality preservation during storage.

Khaliq *et al*. (2016) investigated the effects of 10% gum arabic, 3% calcium chloride and their combination on mango over 28 days. Based on the results collected, they determined that the DPPH radical scavenging activity of fruit treated with gum arabic 10% and calcium chloride 3% + gum arabic 10% was substantially greater (60%) than in the control fruit 28%. Javed *et al.* (2015) measured antioxidant activity in guava fruits that had been dipped in 1, 2 and 3% calcium lactate solutions for 5 minutes and kept for up to 12 days. The greatest decrease in antioxidant activity was observed in the control group, which varied from 34.00% to 24.67% and 15.67% from 0 to the 6^{th} and 12^{th} days, respectively and for calcium lactate 1% and calcium lactate 2%, the values varied from 34.33% to 26.33% and 34.33% to 29.33% from 0 to the 6^{th} day, respectively.

CONCLUSION

Recent research on newly developed coverings for fresh and minimally processed fruits and vegetables is presented in this article. Recent developments in this field include the widespread use of chitosan or alginate as the principal ingredient in edible coatings. A fuller understanding of the mechanism of edible functional coatings, as well as consumer marketing, could assist in expanding their fruit and vegetable preservation applications. In addition, edible coatings and films have the potential to be a very appealing method for delivering bioactive compounds to enhance bioavailability. Due to the very specific coating technology applied to different fruits and/or vegetables, with various proposed goals (ranging from extending shelf life to preserving a high nutritional value or enhancing certain nutritional characteristics of the products), this topic is perennially relevant and experiments must be conducted beginning with known data.

Conflict of interest

All authors declare that they have no conflict of interest.

REFERENCES

Abu Salha, B. and Gedanken, A. (2021). Extending the shelf life of strawberries by the sonochemical coating of their surface with nanoparticles of an edible anti-bacterial compound. Applied Nano. 2: 14-24.

Ahlawat, P., Bala, S. and Kumar, J. (2018a). Effect of post-harvest treatments of gum arabic, calcium lactate and glycerin on biochemical constituents of kinnow. Crop Research. 53: 154-159.

Ahlawat, P., Bala, S. and Kumar, J. (2018b). Effect of different coatings on free radical scavenging activity of kinnow fruits. Journal of Pharmacognosy and Phytochemistry. 7: 3067-3068.

Ahlawat, P., Bala, S. and Kumar, J. (2018c). Effect of different chemical treatments on shelf life of kinnow fruits. International Journal of Current Microbiology and Applied Sciences. 7: 3209-3215.

Ahlawat, P., Bala, S. and Kumar, J. (2018d). Effect of different chemical treatments on enzymes activity of Kinnow fruits. Journal of Pharmacognosy and Phytochemistry. 7: 1811-1814.

Alam, M., Hossain, M.A. and Sarkar, A. (2020). Effect of edible coating on functional properties and nutritional compounds retention of air-dried green banana (*Musa sapientum* L.). IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT). 14: 51-58.

Ali, A., Maqbool, M., Ramachandran, S. and Alderson, P.G. (2010). Gum arabic as a novel edible coating for enhancing shelf-life and improving postharvest quality of tomato (*Solanum Lycopersicon* L.) fruit. Postharvest Biology and Technology. 58: 42-47.

Ali, A.M., Zulfiqar, A., Arif, A.M., Khan, A., Iqbal, Z. and Khan, M.A. (2015). Effect of natural and synthetic fruit coatings on the postharvest quality of kinnow mandarins. Agriculture Engineering International. 17: 197-206.

Ali, M.N. and Hamid, N.A. (2021). The effect of chitosan coating on post-harvest quality of banana in cold storage. ESTEEM Academic Journal. 17: 85-92.

Anjum, M.A., Akram, H., Zaidi, M. and Ali, S. (2020). Effect of gum arabic and Aloe vera gel based edible coatings in combination with plant extracts on postharvest quality and storability of 'Gola' guava fruit. Scientia Horticulturae. 271: 109506.

Athmaselvi, K.A., Sumitha, P. and Revathy, B. (2013). Development of *Aloe vera* based edible coating for tomato. International Agrophysics. 27: 369-375.

Ayub, H., Ahmad, A., Amir, R.M. and Irshad, G. (2021). Multivariate Analysis of Peach Quality Treated with Essential oil Coatings. Journal of Food Processing and Preservation. 45: 15083.

Basiak, E., Linke, M., Debeaufort, F., Lenart, A. and Geyer, M. (2019). Dynamic behaviour of starch-based coatings on fruit surfaces. Postharvest Biology and Technology. 147: 166-173.

Baswal, A.K., Dhaliwal, H.S., Singh, Z., Mahajan, B.V.C. and Kalia, A. (2021). Edible coatings maintain the phytochemicals in cold-stored 'Kinnow' mandarin ('*Citrus nobilis*' Lour x '*C. deliciosa*' Tenora) fruit. Australian Journal of Crop Science. 15: 1332-1338.

Bhatnagar, P., Sharma, M.K. and Singh, J. (2015). Analysis of fruit quality of kinnow mandarin hybrid in arid irrigated areas of Rajasthan. HortFlora Research Spectrum. 4: 52-55.

Bishnoi, A., Chawla, H.M. and Rani, G. (2014). Extension of shelf life of plum by formulation developed from oligomer isolated from lac. International Journal of Advances in Chemical Engineering and Biological Sciences. 1: 85-88.

Breceda-Hernandez, T.G., Martínez-Ruiz, N.R., Serna-Guerra, L. and Hernández-Carrillo, J.G. (2020). Effect of a pectin edible coating obtained from orange peels with lemon essential oil on the shelf life of table grapes (*Vitis vinifera* L. var. Red Globe). International Food Research Journal. 27: 585-596.

Das, S., Vishakha, K., Banerjee, S., Mondal, S. and Ganguli, A. (2020). Sodium alginate-based edible coating containing nano emulsion of Citrus sinensis essential oil eradicates planktonic and sessile cells of food-borne pathogens and increased quality attributes of tomatoes. International Journal of Biological Macromolecules. 162: 1770-1779.

De Oliveira, A.M.F., Rocha, R.H.C., Guedes, W.A., Dias, G.A. and De Lima, J.F. (2018). Use of Chlorella sp. for coating 'tommy atkins' mango fruits stored under refrigeration. Semina: Ci^encias Agrarias. 39: 565-572.

de Oliveira, K.Á.R., da Conceição, M.L., de Oliveira, S.P.A., Lima, M.D.S., de Sousa Galvão, M., Madruga, M.S. and de Souza, E.L. (2020). Postharvest quality improvements in mango cultivar Tommy Atkins by chitosan coating with (*Mentha piperita* L.) essential oil. The Journal of Horticultural Science and Biotechnology. 95: 260-272.

de Souza, W.F.C., de Lucena, F.A., da Silva, K.G., Martins, L.P., de Castro, R.J.S. and Sato, H.H. (2021). Influence of edible coatings composed of alginate, galactomannans, cashew gum and gelatin on the shelf-life of grape cultivar 'Italia': Physicochemical and bioactive properties. LWT. 152: 112315.

de Vasconcellos Santos Batista, D., Reis, R.C., Almeida, J.M., Rezende, B., Bragança, C.A.D. and da Silva, F. (2020). Edible coatings in post-harvest papaya: Impact on physical-chemical and sensory characteristics. Journal of Food Science and Technology. 57: 274-281.

Din, A., Nadeem, M., Rafique, M. and Shabbir, M.A. (2015). Development and application of edible skin coatings to improve the quality of kinnow during storage. Acta Scientiarum. 37: 111-116.

dos Passos Braga, S., Magnani, M., Madruga, M.S., de Souza Galvão, M., de Medeiros, L.L., Batista, A.U.D. and de Souza, E.L. (2020). Characterization of edible coatings formulated with chitosan and Mentha essential oils and their use to preserve papaya (*Carica papaya* L.). Innovative Food Science and Emerging Technologies. 65: 102472.

Duong, N.T.C., Uthairatanakij, A., Laohakunjit, N., Jitareerat, P. and Kaisangsri, N. (2022). An innovative single step of cross-linked alginate-based edible coating for maintaining postharvest quality and reducing chilling injury in rose apple cv.'Tabtimchan'(*Syzygium samarangenese*). Scientia Horticulturae. 292: 110648.

Elabd, M.A. and Gomaa, R.B. (2017). Extending the shelf life of persimmon. Journal of Food and Dairy Sciences. 8: 377-382.

Eshghi, S., Karimi, R., Shiri, A., Karami, M. and Moradi, M. (2021). The novel edible coating based on chitosan and gum ghatti to improve the quality and safety of 'Rishbaba'table grape during cold storage. Journal of Food Measurement and Characterization. 15: 3683-3693.

Farina, V., Passafiume, R., Tinebra, I., Scuderi, D., Saletta, F., Gugliuzza, G. and Sortino, G. (2020b). Postharvest application of aloe vera gel-based edible coating to improve the quality and storage stability of fresh-cut papaya. Journal of Food Quality.

Fawole, O.A., Riva, S.C. and Opara, U.L. (2020). Efficacy of edible coatings in alleviating shrivel and maintaining quality of Japanese plum (*Prunus salicina* Lindl.) during export and shelf-life conditions. Agronomy. 10: 1023.

Firdous, N., Khan, M.R., Butt, M.S. and Shahid, M. (2020). Application of aloe vera gel based edible coating to maintain postharvest quality of tomatoes. Pakistan Journal of Agricultural Sciences. 57(1).

Gangwar, S., Shukla, H.S., Katiyar, D. and Pandey, V. (2012). Effect of calcium nitrate on physico-chemical changes and shelf-life of aonla (*Emblica officinalis* Gaertn) fruits. Hort Flora Research Spectrum. 1: 253-258.

Gill, P.P.S., Jawandha, S.K., Kaur, N., Singh, N. and Sangwan, A. (2015). Effect of LDPE packaging on post-harvest quality of Mango fruits during low temperature storage. The Bioscan. 10: 177-180.

Hazarika T.K., Lalhriatpuia C., Ngurthankhumi Rody, Lalruatsangi Esther, Lalhmachhuani H. (2023). Edible Coatings in Extending the Shelf Life of Fruits: A Review. Indian Journal of Agricultural Research. 57(5): 555-558. doi: 10.18805/IJARe.A-5725.

Hegazy, A.E. (2017). The effect of edible coating on the quality attributes and shelf life of persimmon fruit. Curr. Sci. Int. 6: 880-890.

Jafarzadeh, S., Nafchi, A.M., Salehabadi, A., Oladzad-Abbasabadi, N. and Jafari, S.M. (2021). Application of bio nanocomposite films and edible coatings for extending the shelf life of fresh fruits and vegetables. Advances in Colloid and Interface Science. 291: 102405.

Jafarzadeh, S., Mehrdad, F., Sajed Amjadi, V.J.K., Hadi, A.F.G. and Masoumeh, Z. (2022). Plant protein-based nanocomposite films: A review on the used nanomaterials, characteristics and food packaging applications. Critical Reviews in Food Science and Nutrition. 1-27.

Javed, M.S., Randhawa, M.A., Butt, M.S. and Nawaz, H. (2015). Effect of calcium lactate and modified atmosphere storage on biochemical characteristics of guava fruit. Journal of Food Processing and Preservation. 39: 1-10.

Kabbashi, E.B., Abdelrahman, G.H. and Abdlerahman, N.A. (2018). Regular article guava (*Pidium guajava* L.) fruit coating with gum-arabic for quality and fruit fly control. Journal of Experimental Sciences. 9: 01-04.

Karmakar Anindita, Roy Ambuza (2023). Enhancement of shelf life of tomato using edible coating. Bhartiya Krishi Anusandhan Patrika. 38(2): 145-150. doi: 10.18805/BKAP621.

Kaur, N. and Kumar, A. (2014). Impact of post-harvest treatments on shelf life of Kinnow mandarin. International Journal of Advanced Research. 2: 290-295.

Khaliq, G., Mohameda, M.T.M., Ghazali, H.M., Ding, P. and Ali, A. (2016). Influence of gum arabic coating enriched with calcium chloride on physiological, biochemical and quality responses of mango (*Mangifera indica* L.) fruit stored under low temperature stress. Postharvest Biology and Technology. 111: 362-369.

Khare, A.K., Abraham, J.J.R., Rao, V.A., Babu, N.R., Ruban, W. (2017). Effect of chitosan and cinnamon oil edible coating on shelf life of chicken fillets under refrigeration conditions. Indian Journal of Animal Research. 51(3): 603-610. doi: 10.18805/ijar.v0iOF.7834.

Khodaei, D., Hamidi-Esfahani, Z. and Rahmati, E. (2021). Effect of edible coatings on the shelf-life of fresh strawberries: A comparative study using TOPSIS-Shannon entropy method. NFS Journal. 23: 17-23.

Kocira, A., Kozłowicz, K., Panasiewicz, K., Staniak, M., Szpunar-Krok, E. and Hortyñska, P. (2021). Polysaccharides as edible films and coatings: Characteristics and influence on fruit and vegetable quality-A review. Agronomy. 11: 813.

Kumar, N., Neeraj, Pratibha and Trajkovska Petkoska, A. (2021). Improved shelf life and quality of tomato (*Solanum Lycopersicum* L.) by using chitosan-pullulan composite edible coating enriched with pomegranate peel extract. ACS Food Science and Technology. 1: 500-510.

Kumar, R., Sharma, P., Sharma, T. and Ranaut, S. (2023). Enhancement of shelf life of guava fruits by application of chitosan-based nanoemulsion. Asian Journal of Dairy and Food Research. doi: 10.18805/ajdfr.DR-2052.

Kumari, P. (2016). Studies on biochemical and antioxidant changes in aonla (*Emblica officinalis* G.) and its different products during storage. Ph.D Thesis, CCS Haryana Agricultural University, Hisar, India.

Li, X.Y., Du, X.L., Liu, Y., Tong, L.J., Wang, Q. and Li, J.L. (2019). Rhubarb extract incorporated into an alginate-based edible coating for peach preservation. Scientia Horticulturae. 257: 108685.

Mahajan, B.V.C., Dhillon, W.S. and Kumar, M. (2013). Effect of surface coatings on the shelf life and quality of kinnow fruits during storage. Journal of Postharvest Technology. 1: 8-15.

Manojj, D., Yasasve, M., Hariharan, N.M. and Palanivel, R. (2021). Application of Edible Coatings and Packaging Materials for Preservation of Fruits-Vegetables. In *Coatings* Springer, Cham. pp. 59-79.

Mohammed, R.S., Abou Zeid, A.H., El Hawary, S.S., Sleem, A.A. and Ashour, W.A. (2014). Flavonoid constituents, cytotoxic and antioxidant activities of *(Gleditsia triacanthos* L). leaves. Saudi Journal of Biological Sciences. 21: 547-553.

Momin, M.C., Kabir, J. and Jamir, A.R. (2018). Effect of different post-harvest treatments and prepackaging on storage behavior of guava (*Psidium guajava*) cv, Khaza. International Journal of Current Microbiology and Applied Sciences. 7: 3186-3195.

Muhammad, R.K., Fabio Angelo Di, G.E.T. and Muhammad, B.S. (2021). Recent advances in biopolymeric antioxidant films and coatings for preservation of nutritional quality of minimally processed fruits and vegetables. Food Packaging and Shelf Life. 30: 100752.

Muley, A.B. and Singhal, R.S. (2020). Extension of postharvest shelf life of strawberries (*Fragaria ananassa*) using a coating of chitosan-whey protein isolate conjugate. Food Chemistry. 329: 127213.

Oyom, W., Xu, H., Liu, Z., Long, H., Li, Y., Zhang, Z. and Prusky, D. (2022). Effects of modified sweet potato starch edible coating incorporated with cumin essential oil on storage quality of ‘early crisp’. LWT. 153: 112475.

Paladugu, K. and Gunasekaran, K. (2017). Development of gum arabic edible coating formulation through nanotechnological approaches and their effect on physicochemical change in tomato (*Solanum Lycopersicon* L) fruit during storage. International Journal of Agriculture Sciences. 9: 3866-3870.

Panahirad, S., Naghshiband-Hassani, R. and Mahna, N. (2020). Pectin-based edible coating preserves antioxidative capacity of plum fruit during shelf life. Food Science and Technology International. 26: 583-592.

Pawar, C.D., Patil, A.A. and Joshi, G.D. (2011). Physicochemical parameters of sapota fruits at different maturity stages. Karnataka Journal of Agricultural Sciences. 24: 420-421.

Punia, S., Sandhu, K.S., Dhull, S.B. and Kaur, M. (2019). Dynamic, shear and pasting behavior of native and octenyl succinic anhydride (OSA) modified wheat starch and their utilization in preparation of edible films. International Journal of Biological Macromolecules. 133: 110-116.

Puri, H. and Kumar, A. (2021). Impact of chitosan and alginate based edible coating on shelf life and postharvest quality of kinnow mandarin. Current Journal of Applied Science and Technology. 40: 36-47.

Rashid, F., Ahmed, Z., Hussain, S., Kausar, T., Nadeem, M., Ainee, A. and Mehmood, T. (2020). Optimization of Fenugreek and Flax Polysaccharides based Edible Coating Formulation to Preserve the Quality and Storability of Apple after Harvesting. Journal of Food Processing and Preservation. 44: 14812.

Ruiz-Martínez, J., Aguirre-Joya, J.A., Rojas, R., Vicente, A., Aguilar-González, M.A., Rodríguez-Herrera, R. and Aguilar, C.N. (2020). Candelilla wax edible coating with flourensia cernua bioactive to prolong the quality of tomato fruits. Foods. 9: 1303.

Saeed, M., Azam, M., Saeed, F., Arshad, U., Afzaal, M., Bader Ul Ain, H. and Nasir, Z. (2021). Development of Antifungal Edible Coating for Strawberry Using Fruit Waste. Journal of Food Processing and Preservation. 45: 15956.

Saleem, M.S., Ejaz, S., Anjum, M.A., Nawaz, A., Naz, S., Hussain, S. and Canan, İ. (2020). Postharvest Application of Gum Arabic Edible Coating Delays Ripening and Maintains Quality of Persimmon Fruits During Storage. Journal of Food Processing and Preservation. 44: 14583.

Shah, S. and Hashmi, M.S. (2020). Chitosan-aloe vera gel coating delays postharvest decay of mango fruit. Horticulture, Environment and Biotechnology. 61: 279-289.

Shiri, M.A., Ghasemnezha, D.M., Bakhshi, D. and Dadi, M. (2011). Changes in phenolic compounds and antioxidant capacity of fresh-cut table grape (*Vitis vinifera*) cultivar 'Shahaneh' as influence by fruit preparation methods and packaging. Australian Journal of Crop Science. 5: 1515-1520.

Singh, P., Singh, M.K., Kumar, V., Kumar, M. and Malik, S. (2012). Effect of physicochemical treatments on ripening behavior and post-harvest quality of Amrapali Mango (*Mangifera indica* L.) during storage. Journal of Environmental Biology. 33: 227-232.

Sortino, G., Saletta, F., Puccio, S., Scuderi, D., Allegra, A., Inglese, P. and Farina, V. (2020). Extending the shelf life of white peach fruit with 1-methylcyclopropene and aloe arborescens edible coating. Agriculture. 10: 151.

Thakur, R., Pristijono, P., Scarlett, C.J., Bowyer, M., Singh, S.P. and Vuong, Q.V. (2019). Starch-based edible coating formulation: Optimization and its application to improve the postharvest quality of "Cripps pink" apple under different temperature regimes. Food Packaging and Shelf Life. 22: 100409.

Vishwasrao, C. and Ananthanarayan, L. (2017). Delayed post harvest ripening associated changes in *(Manilkara zapota* L.) var. Kalipatti with composite edible coating. Journal of the Science of Food and Agriculture. 97: 536-542.

Wani, S.M., Gull, A., Ahad, T., Malik, A.R., Ganaie, T.A., Masoodi, F.A. and Gani, A. (2021). Effect of gum Arabic, xanthan and carrageenan coatings containing antimicrobial agent on postharvest quality of strawberry: Assessing the physicochemical, enzyme activity and bioactive properties. International Journal of Biological Macromolecules. 183: 2100-2108.