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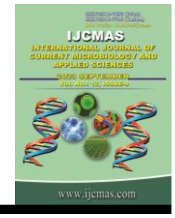

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Effects of Carbohydrate Based Coatings in Fruits During Storage: A Review

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A B S T R A C T

In the present times, fruits have a very high demand not only in India but also in other countries as it contains various vitamins and minerals. As we know, fruits have a limited shelf life leading to post harvest losses affecting consumer preference and marketability. Various methods have been discovered for increasing the shelf life and quality of fruits and ensuring the proper grading, packaging of fruits, and applying coatings on fruits by dipping, spraying etc. Various edible coatings like chitosan, alginate, pectin, *Aloe vera* etc act as barriers minimize the rate of respiration in fruits thus preventing their decay. These coatings help in reducing moisture loss, controls weight loss and increases antioxidant activity. The addition of substances like antioxidants, antimicrobials help in reducing the postharvest decay in fruits.

Introduction

In the present times, carbohydrate based edible coating have been thoroughly studied. Edible coatings can be considered a thin or a thick layer of substance which have been applied on commodities and covers the surface of products on which coatings are applied. Consumers these days prefer eatables which guarantee 100% safety because these days, a lot of chemicals are used in agricultural products which is harmful. Edible coatings are safe and are used on many products like fruits, vegetables etc and its application helps in preserving their quality by controlling the physiological, biochemical or oxidation process. Many active ingredients are present in edible coatings like colourings, flavours, and sweeteners which better the nutritional attributes of fruits and vegetables. Various types of edible coatings such as *Aloe vera* gel, chitosan, sodium alginate and gellan gum etc are known to show a positive development on increasing storage period for fruits, thereby decreasing the respiration rate, controlling weight loss, maintaining the firmness of fruits, increasing the antioxidant activity, and reducing moisture loss improves the quality of fruits in every aspect. They also help in giving fruits a good appearance and improves the quality with a barrier to outer elements. Fruits have a natural wax coating. It improves appearance of food, thereby preventing its deterioration and inducing antioxidants and antimicrobials for their safety.

The main aim is to study about edible coatings acting as carriers, and to maintain the quality and safety of fresh fruits. As we know, the postharvest losses in various commodities specially fruits are becoming a major problem in almost every country due to various factors such as weather, lack of proper storage facilities, improper packaging, bruising, and breaking of the skin and sometimes transporting to long distances. It was noted that during peak seasons, fruits and vegetables arrive in ample quantity in the market. Due to lack of storage facilities, they are not handled properly and due to rough and improper handling, the commodities get damaged and destroyed. This ultimately leads to deterioration of fruits which affects its marketing and consumer availability leading to economic loss. For preventing this loss, proper storage facilities like cold storage must be available. Since cold storage can sometimes be detrimental to the commodities which can lead to frost and chilling injury thus damaging the fruits. We must ensure that the commodities are stored in condition with appropriate temperatures.

After various edible coatings are made, they are to be applied on various products. For this, there are various methods by which edible coatings are applied on fruits which in turn is beneficial for prolonging the storage period of the fruits like dipping, brushing, extrusion, spraying and solvent casting. We must ensure that before applying the coatings, their quality should be tested. These methods maintain the quality of fruits for a prolonged time. The most popular and easy method by which different coatings are administered on fruits is the dipping method. The fruits and vegetables can be immersed in the coating solution for a few seconds. Brushing method has also proved to be beneficial in fruits. For commercial use, methods like spraying, extrusion and solvent casting have proved to be useful in the food industry for coating food products (Momin *et al.*, 2021).

Herbs can also be used for making different edible coatings. Herbal edible coatings preparation is a new and different process and many steps are involved in it i.e washing, drying, grinding, sieved Tulsi leaves powder, extraction, evaporating the extract of Tulsi and this extract to be added to coating solutions so that herbal edible coating is prepared. Tulsi extract, bee wax etc are herbal edible coatings which are even beneficial for health. These contain antioxidant and antimicrobial properties which helps them by upkeeping the physical and quality parameters of commodities for a good amount of time (Priya *et al.*, 2020). Neem oil extract which is made from neem is used on fruits as biodegradable edible coating in enhancing the duration for which the fruits are kept. (Chauhan *et al.*, 2014) found that neem extract possessed good antimicrobial properties and apple's storage life was extended up to 45 days. Many constituents of Tulsi like Eugenol, Linalool, camphor, etc are important constituents of Tulsi oil which were seen to be of great importance for fruits in increasing their period of storage.

Different characteristics possessed by edible coatings are as follows:

Coatings should be water resistant, and it should be applied evenly on the fruits and should remain intact.

It should act as a barrier for water vapour.

Main characteristic of edible coating is that it should enhance the appearance of the commodity, maintain the structure, and retain the flavouring compounds.

It should be non-sticky and should dry properly within a considerable amount of time.

They contain components such as vitamins, antioxidants, etc. They improve the nutritional aspects of the commodities and to ensure that the quality does not get affected.

Effects of chitosan

In carbohydrates, chitosan is the most popular biopolymer derived from chitin which acts as a good preservative for food. There are many sources from where it can be obtained, but its main source is marine crustacean shells (Arbia *et al.,* 2013). Chitosan application in fruits is possible due to its antimicrobial and other activities which helps in the protection of commodities. It has been discovered that chitosan could be prepared by various methods like with the help of essential oils like lemon oil, cinnamon oil, and rosemary oil etc. Chitosan films which are edible are beneficial for oxygen transmission and has low water vapour barrier characteristics and the retaining of moisture content in the fruits. Chitosan coatings have proved to be very strong and difficult to break, the presence of hydrogen bonds makes it sensitive to environmental humidity. It has good film forming properties that makes it the best coating material for fruits. This treatment has proved to be very efficient in upgrading of storage period for many fruits which helps in decreasing the respiration rate, transpiration rate, controlling fruit decay, reducing nutrient loss, weight loss and for maintaining the aroma in fruits.

Jiang and Li (2001) displayed consequence of chitosan treated longan fruits which depicted a positive effect as it helped in reducing the respiration rate, increasing ascorbic acid content, controlling weight loss, inhibiting decay of fruits, and improving the storage life of this fruit. Some fruits like strawberry are known to be highly perishable in nature. It has been observed that 1.5% chitosan coating on strawberry was able to inhibit the fungal growth in strawberry fruit, thereby preventing its microbial delay (Munoz *et al.,* 2008). It has found to be capable to prevent fungal diseases which degrades the overall parameters of fruits like quality etc, when it is kept for storage (Romanazzi *et al.,* 2013). We must ensure that to maintain its colour, texture, and freshness etc, we must ensure its proper preservation. This is done by incorporating various coatings such as chitosan and many others. In guava fruit, the weight loss was prevented to some extent by applying chitosan coating at 2% concentration. During storage, a decline was seen in the Vitamin C content of guava. But when guava was applied with 1% and 2% chitosan coating, the Vitamin C loss in guava was delayed which was not seen in control (Hong *et al.,* 2012). Litchi possesses good commercial value in the market but its short storage period is a major constraint for this fruit because once it is plucked from the tree, it must be consumed as soon as possible. However, litchi which was given chitosan treatment improved the storage life and decreased the loss of sensory quality. It was observed that after storing for 6 days, litchi fruits which were not coated with chitosan had rotten completely which ultimately were of no use to the market but litchi which were coated with chitosan of 1% and 2% still had better quality. The TSS, titratable acidity and ascorbic acid was higher when treated by chitosan which was not in the case of control (Dong *et al.*, 2004). Rate of respiration in litchi was lower which was coated by chitosan as compared to control because chitosan coated fruit has good moisture absorption capacity thereby preventing heat transfer.

Similarly, in sapota, chitosan coating helped in delaying the weight loss. The weight loss in uncoated fruits was 17% after 35 days storage as compared to coated fruit which was 13% after storing for 35 days. The maximum acceleration in TSS was observed in chitosan 1.5% coated fruit which was around 23° Brix after storing for a month in comparison to uncoated fruit which had TSS of 20°, 21° Brix of the same time period. Even the total and reducing sugars were at its peak with fruit treated with chitosan 1.5% (Deb and Gautam, 2018). In pistachio fruit, the weight loss was comparatively high in uncoated samples (0.42%) as compared to the samples treated with chitosan (0.27%) and salicylic acid (0.24%).

Lower respiration rate was seen in mango cv. Tainong with chitosan 2% thereby retaining the firmness of fruit (Zhu *et al.*, 2008). On the final day of storage, it was seen that the weight loss was 25% higher in the fruits which were not given any coating in comparison to the fruits which were treated with 1% chitosan. After storing the fruits for about a month, maximum firmness was recorded by fruits treated by chitosan 1% (7.40 N). The least firmness was recorded in uncoated fruits (4.18 N) (Sinha *et* *al.,* 2021). The weight loss in pineapple fruits which were coated by chitosan was around 25% as compared to the pineapples which were not given any coating. Weight loss in control fruit was around 33%. Similarly, the firmness of pineapple coated with chitosan was far better (36 N) whereas in control, it was (23 N) after 12 days storage interval. After 15 days, it was seen that 35% of the pineapple fruit has started browning which were not administered by any coating. In contrast, all pineapples on which coating was applied, hardly any browning was observed even after 20 days (Basumatary *et al.,* 2022).

In pear, chitosan coating along with salicylic acid showed a considerable effect in various quality parameters. Pear coated with chitosan 2% and salicylic acid 2mM showed minimum evaporation of CO_2 (1800 μmol kg/ h) thus preventing respiration as compared to control. Combination of chitosan 2% and salicylic acid 2mM showed high phenolic content 650 mg/kg while control fruit showed low phenolic content. The ascorbic acid content of fruit treated with chitosan 2% and salicylic acid 2mM was 55 mg/kg which is high as compared to chitosan 1% which is 43 mg/kg and control which is 35 mg/kg. Even internal browning was suppressed by chitosan 2% and salicylic acid 2mM in 67 days of storage as compared to control (Sinha *et al.,* 2021). Similarly, other works were done on pear cv. 'Patharnakh' coated with chitosan in different concentrations to increase the storage life and maintain post-harvest quality. Coatings of 0.5%, 1% and 2% were given on pear fruit. After applying these coatings, it was seen that chitosan 2% gave the best results in controlling weight loss by 18%, maintaining fruit firmness by 17%, reduced respiration by 42% as compared to control. Apart from this, chitosan 2% treatment reduced enzymatic activity of fruits and prevented internal browning thus maintaining post-harvest life (Adhikary *et al.,* 2022).

Even chitosan in lower proportion can be used for the natural preservation of fruits (Sakif *et al.,* 2016). Chitosan treatment deaccelerated weight loss in stored apples and if heat treatment is given along with this, low pH and respiration rates were observed (Shao *et al.,* 2012). Reduced weight loss was seen in pears treated by chitosan (Zhou *et al.,* 2008). In Banana, one methyl cyclo propane and edible coating of chitosan helped in increasing storage time of banana by 4 days (Baez Sanudo *et al.,* 2009). It has been observed that after applying chitosan, coated fruits showed no signs of fungus while on the other hand uncoated fruits showed some signs of fungal infection. Uncoated fruits lose their firmness in their storage period. In mango fruits, the decline in the firmness was prevented by chitosan coating of 1% and 2%. Firmness with 1% and 2% chitosan coating was 43.6 and 26.1% as compared to the control after storing for 16 days. The ascorbic acid content of mango fruits which were coated with 1% and 2% chitosan was 47.7% and 82.3% higher than control after storing for 16 days. The weight loss in fruits treated with 1% and 2% chitosan was 19.2 and 37% lower than control after keeping for 15 days.

In pistachio fruit, chitosan 2% and salicylic acid 2 mmol/l showed positive results in maintaining their quality attributes. In comparison to control, fruits treated with chitosan and salicylic acid depicted higher sensory scores in terms of color and texture. Weight loss was very less in treated pistachio fruits (0.20%) as compared to control which depicted weight loss of 0.40%. Enzymatic activities of catalase and peroxidase enzymes were far better in the treated pistachio fruits in comparison to control. Highest phenolic content was observed in chitosan and salicylic acid treated samples (20.90 GAE/g) throughout the storage period whereas control samples showed a rapid decline in phenolic content during the storage period. Combination of chitosan and salicylic acid proved to be quite effective in maintaining the storage life (Molamohammadi *et al.,* 2019).

In figure 2, the consequence of chitosan coatings is depicted for various fruits. This coating is known to retain freshness of fruit for a comparatively longer time. It is very important to better the other textural properties of fruit such as size, color retention etc. The sensory quality of the fruits is much better in fruits which are given coatings.

Effects of *Aloe vera*

Aloe vera is a plant that has various medicinal properties. It is known as "plant of immortality" by the Egyptians. It has proved to be a boon for humans in many ways. Currently, it is largely spread among the tropics and sub-tropics. *Aloe vera* is a perennial plant. It is said to have thick, thorn-edged leaves, its colour ranging from grey to bright green. It looks like a cactus, which comes under Liliaceae family. *Aloe vera* gel is known to be odourless and tasteless. One of the coating products is *Aloe vera* which is becoming evident in maintaining the colour, textural property, and storage life of fruits. Since ancient times, people of various traditions and cultures have used *Aloe vera* for medicinal purposes. This gel is known to prevent the acceleration of different fungal organisms that cause spoilage consisting of *Staphylococcus aureus*, *Salmonella*, *Streptococcus*, *Escherichia coli*, *Aspergillus niger*, *Candida* and many others (Ullah *et al.,* 2016). It is a very environment friendly natural product and possess no risk on human health. To lessen the anaerobic conditions, the coatings of *Aloe vera* gel declined consumption of O_2 and production of CO_2. A very popular method which is of large-scale application in fresh commodities. It has been found that *Aloe vera* gel coating has proved to be the best edible coating for preservation of different commodities specially fruits and thereby preventing the loss of moisture and firmness, controlling the respiration rate, and preventing microbial decay in fruits (Hazarika *et al.,* 2021). The coating of *Aloe vera* gel maintains the sugar to acid ratio at a higher level. Various studies have proved that *Aloe vera* is edible and odourless and does not have any negative impact on human health. *Aloe vera* gel has proved to be beneficial for various fruits such as papaya, sweet cherry, guava, and many other fruits.

In guava fruit, it was seen that *Aloe vera* gel treatment on fruits in proportion of 60% and 80%, the TSS accelerated gradually by 12 days which depicted that the fruits treated with *Aloe vera* gel slowed down the respiration rate. Guava fruits treated with *Aloe vera* gel declined weight loss in coated fruits as compared to the uncoated fruits. Guava fruits treated with *Aloe vera* gel in concentration of 40% and 60% showed a slight decline in chlorophyll content as compared to the control, with chlorophyll ranging from 8.1 to 3.5 µg/g and 8.1 to 4 µg/g during the period for which it was stored (Asi *et al.,* 2020).

In strawberry, *Aloe vera* coating was effective in controlling weight loss as compared to uncoated fruits. In control, TSS of strawberry had reached 9.4^0 brix after 6 days storage whereas TSS of coated fruits after 6 days had reached 8.2^0 brix. Titratable acidity declined rapidly in control fruits as compared to the fruits coated with *Aloe vera* gel. After 16 days, titratable acidity was 0.85% in control but in coated fruits, it was around 1.50%. *Aloe vera* coating has a positive effect on maintaining its flavour, quality of strawberries and hence maintaining its shelf-life (Singh *et al.,* 2011). Pomegranate fruits kept under ambient conditions and coated with *Aloe vera* had a positive effect on reducing its weight loss. On 12^{th} day of storage, there was 6.50% reduction in weight loss of fruit coated with 100% *Aloe vera* coating whereas in uncoated fruit, weight loss after 12 days was 12.70%. Juice content of fruit coated with *Aloe vera* 100% helped in retaining juice by 48.15% whereas in control, juice content was 45%. Even ascorbic acid content of coated fruits was higher than uncoated fruits.

In papaya, it has been observed that fruits coated with *Aloe vera* has a bright green colour for a longer duration which means the ripening and decaying of fruits is delayed which was not seen in uncoated fruits. Even the ascorbic acid content was higher in papaya (coated) as compared to the uncoated papaya (Sharmin *et al.,* 2015). The weight loss in papaya (coated) showed to be very less in comparison to the uncoated papaya throughout the period for which it was kept when *Aloe vera* (100%) coating was applied at temperature 25-29^{0}C. It was found that treated papaya had mild loss of weight i.e 7.93% whereas uncoated papaya depicted 22.5% loss in weight (Brishti *et al.,* 2013). In sapota, the weight loss was around 17% in case of control but in contrast it was quite less in fruits coated with *Aloe vera* gel. The firmness level in control was around 0.03 kg which was quite low but the fruits treated with *Aloe vera* gel coating had a better firmness. The ascorbic acid content of control sapota declined from 13 to 5 while this decrease was also there in case of coated fruit but the rate of decrease in ascorbic acid content was less in coated fruit as compared to control.

In Ber fruit, during 15 days storage interval, it was seen that the physiological weight loss was maximum for fruits which were untreated as compared to treated fruits. Coated fruits after 15 days saw loss in weight of about 9.75% and in uncoated fruits, it was 22.65%. There was negligible difference in the pH value for fruits which were coated and which were not. pH value of Ber treated with *Aloe vera* gel was 5.53 and pH value of uncoated fruit was 5.83 after keeping for 15 days. Decline in Titratable Acidity (TA) showed to be less for treated fruits after 15 days storage. Ber coated with *Aloe vera* gel exhibited TA of 7.21 as compared to control which showed TA of 3.92 after 15 days. The decline of TSS is slower in coated fruit is lower as compared to the untreated fruit. In coated fruit, after 15 days, TSS is 6.10^0 Brix as compared to untreated fruit which is 3.80^0 Brix (Mani *et al.,* 2017).

All mango fruit varieties which were coated with *Aloe vera* at 50 - 75% at 13^{0}C depicted least loss of weight, reduced the loss of firmness and apart from that maintained the pH of the fruit during storage. (Sophia *et al.,* 2015). In mango fruits cv. 'Dusheri,' *Aloe vera* gel coatings of 100% successfully delayed the increase in pulp a*(70.15%) and in pulp b*(40.50%) values in comparison to fruits not treated with Aloe vera gel. Lower pulp C* values were shown by *Aloe vera* gel coatings of 100% (3.5%) and 50% (1.5%) which were not seen in control fruits. There was a 7.5% decline in B carotene pigment in comparison to control (Mshora *et al.,* 2021). In peach, this treatment resulted in less firmness loss in peach fruit. Further, *Aloe vera* gel coated fruits had less water loss which helped in maintaining the turgor pressure of cell wall resulting in good quality fruits. The TSS of peach fruits coated with *Aloe vera* gel decreased slightly as compared to the control fruits. TSS had 9% increase for untreated fruits but not in the case of coated fruits. High amount of TSS indicated that water content had depleted in the fruit (Hazrati *et al.,* 2017). In peach, weight loss was around 6% for control which was skyrocketing in comparison to the fruits treated with *Aloe vera* gel coating. The titratable acidity in control fruits decreased from 0.70 to 0.60 g/100g. Treated fruits also showed a decrease in titratable acidity, but the decrease rate was slower in treated fruit in comparison to control.

In Banana, coatings of *Aloe vera* gel showed some difference in weight loss percentage of banana. *Aloe vera* gel coated bananas showed a decline in weight loss from 3-20% while that of control bananas, weight loss ranged from 5-25%. After 5 days, it was seen that the reducing sugar content of banana in uncoated fruit was around 19%. Reducing sugars indicate the presence of starch in the fruit. In treated fruit, reducing sugar ranged from 9-15% only. The firmness of coated banana sample has always shown to be high as compared to the control (Quoc, 2021).

Effects of Sodium Alginate

It is naturally derived from brown algae. Alginate coatings have been found to be extremely beneficial for increasing the shelf and the storage period of fruits (Reddy and Singh, 2020). It possesses unique colloidal properties and can be used in gels, emulsions, and a thickening agent. The coating materials used for making alginate are calcium, magnesium, and aluminium etc. It reduces moisture/water loss in fruits preventing transpiration thus controlling the rate of respiration. Sodium alginate can also be incorporated with other substances like essential oils, calcium, pectin etc which prevents the spoilage/decay of fruits. It was observed that 'William pears' treated with 2% sodium alginate coating kept at a temperature of 25°C for 15 days displayed very less weight loss. This coating of 2% had lesser permeability of water vapour and good elasticity; so it could be very beneficial for fruit preservation. Alginate coating on jujube could delay the release of ethylene and thereby delaying respiration and the TSS of the fruit was increased.

It was concluded that alginate coating of 2% was good enough to maintain the quality of jujube (Wang *et al.,* 2020). Alginate coating showed a significant difference in various parameters of plum during storage. The weight loss in cv. 'Golden Globe' was approximately 5% after 30 days storage period in control. When it was treated with alginate, the weight loss was quite low. The firmness at the time of harvesting was 9.7 N after storing for a few days, firmness level has reached up to 5.3 N. When alginate coatings were applied, their firmness levels were retained thus it prevented the softening of the fruit (Valero *et al.,* 2013). In sweet cherry, alginate coating of 1% was very effective in maintaining the textural property in comparison to the other treatments. Hardly any difference was recorded in the weight loss in control and fruits which were given alginate coatings.

In Nanfeng mandarins, the decay rate of coated fruits was lesser than that of coated fruits. After storing for 30 days, 17% control fruits had decayed completely whereas 1.5% alginate coated fruits had seen a decay of 10% in 30 days storage interval. Weight loss of control fruits was two to three times higher than coated fruits.

The loss of titratable acidity in 10 days was 0.095% in 1.5% alginate coated fruits which was less than control fruits. In pear cv. 'Punjab Beauty,' sodium alginate coatings of 1 and 2% in combination with pomegranate peel extract was effective in maintaining various quality parameters like antioxidant activities, total phenolics, titratable acidity etc. After 45 days, it was observed that polyphenol oxidase (PPO) activity was 35% lower in sodium alginate 2% and pomegranate peel extract coated fruit as compared to control fruit. These coatings suppressed internal browning of fruits during the storage period and lowered the PPO activity (Megha *et al.,* 2023).

Just like other edible coatings, sodium alginate has proved to be advantageous in reducing the weight loss in fruits and helpful in sustaining the antioxidant activity. In mango fruits, coating of sodium alginate at 2-3% for 2 weeks storage period reduced weight loss in comparison to the control fruits. In coated mango fruits, antioxidant activity was greater as compared to control. Alginate coating maintained the phenolic compounds in mango fruits. Fruits treated with high phenol will have higher quality but not in the case of control fruits (Rastegar *et al.,* 2019).

In strawberry fruits, it was observed that the fruit coated with sodium alginate in combination with ascorbic acid had lower weight loss, lower respiration, and transpiration. Alginate treatment delayed the acceleration in PPO activity and firmness was maintained in comparison to the untreated fruits. Water loss was also reduced in strawberry which helped in increasing the storage period of strawberry (Nazoori *et al.,* 2020).

In grapefruit, coatings of sodium alginate helped in controlling weight loss, maintaining the firmness, and helped in the delay of ripening process during the time period for which the fruit is kept (Aloui *et al.,* 2014).

Apart from that, various polysaccharide based edible coatings classified in to the following:
Pectin
Cellulose
CMC (Carboxy Methyl Cellulose)
HPC (Hydroxy Propyl Cellulose)
HPMC (Hydroxy Propyl Methyl Cellulose)
MC (Methyl Cellulose)
Starch
Gums such as Arabic, Guar, Xanthan, etc.

Pectin

The middle lamella of plant cell wall contains a compound known as pectin which is also a polysaccharide. These coatings are safe, biodegradable, non-toxic, oil and fat resistant.

They are available easily and can be used for application on various commodities for their preservation. Pectin is a white and colloidal carbohydrate and many fruits such as apples, papaya, guava etc when fully ripened have a large amount of pectin in them (Mohnen, 2008).

Mainly, pectin is seen in peels of fruits such as citrus, apples, mangoes etc. Hydrochloric acid (HCL) is the most popular chemical for pectin extraction from various fruits. It is naturally consumed through human diet and is an important source of dietary fibre. Its role is not only limited to food processing industry, but has proved to be of great use in the medical field.

Applications of Pectin on fruits

They are of great use for application as a stabilizer, gelling and a thickening agent. They are also known to produce packaging materials especially in the food industry. Pectin extracted from fruits can be utilized as a gelling agent for preparation of fruit jams, jellies etc.

As we see in the environment, food packaging is responsible for causing environmental degradation and to limit this, edible coatings from pectin can be used. They help in maintaining the oxygen levels in the fruit, modify its composition, and quality is also maintained by delaying ripening as much as possible. It also prevents fungal growth on commodities.

In mango cv. 'Ataulfo,' pectin coating showed positive effects on different quality parameters of fruit. On applying coating, it was seen that only 4.5% loss of weight was recorded in coated mangoes whereas 6.5% decline in weight was seen in control. The firmness of pectin coated mangoes were better than that of control. The rate of increase in TSS was slow in coated fruits (4%) in 10 days interval whereas sharp increase in TSS was recorded for control fruits (20%) in just 6 days storage interval. Coated fruits showed less titratable acidity in contrast to control fruits (Moalemiyan *et al.,* 2011).

In sapota, pectin coating of 2.5% showed 18% loss in weight after storing for 10 days whereas for coated fruits, weight loss was about 30%. TSS of coated fruits was 28^{0} brix on 10^{th} day of storage which was higher than that of control.

The firmness reduction was higher for uncoated fruits as compared to coated fruits. The ascorbic acid content showed a decline of 10% on 9^{th} day of storage for pectin coated fruits (Menezes and Athmaselvi, 2016).

Pectin with high degree of methyl esterification (DM) are used as a gel in bakeries for making jams, fruit preservatives, milk products, soft drinks etc. Pectin with low DM is obtained by de esterification of HM pectin only under the condition that temperature, time, and pH are monitored properly. It can be used in the canning industry for fruits and vegetables and could be of great deal as a coating substance.

Cellulose

It is renewable and biodegradable in nature. It is the main source of higher plants being wood and cotton. In aqueous solutions, cellulose is not soluble because of its hydrophilic nature. Cellulose and the materials that are made from it can also be used for applying coatings on fruits as well as for food packaging.

They prevent the attack of bacteria and fungi on eatables and so they can be stored safely for a large amount of time. Cellulose has various derivatives such as Carboxy Methyl Cellulose (CMC), Methyl Cellulose (MC), Hydroxy Propyl Methyl Cellulose (HPMC) etc.

Table.1 Various components of *Aloe vera* gel shown in table 1 divided into the following: (Serrano *et al.*, 2006)

Class	Compounds
Anthraquinones	Isobarba-aloin, Aloe-emodin, Emodin, Aloetic acid, Ester of cinnamic acid, Anthranol, Chrysophanic acid, Resistanol etc
Vitamins	B1, B2, B6, A-Tocopherol, β–Carotene, Choline, Folic acid, Ascorbic acid
Enzymes	Cyclo-oxygenase, Oxidase, Amylase, Catalase, Lipase, Alkaline- phosphatase
Miscellaneous	Cholesterol, Steroids, Tricylglycerides, β – Sitosterol, Lignins, Uric Acid, Gibberellin
Saccharides	Mannose, Glucose, L-Rhamnose, Aldo-pentose
Carbohydrates	Cellulose, acetylated mannan, Arabinogalactan, Xylene, Pure mannan, pectic substance, Galactan
Inorganic compounds	Calcium, Sodium, Chlorine, Manganese, Zinc etc
Non-essential amino acids	Arginine, Aspartic acid, Glutamic acid, Proline, Glycine
Essential amino acids acids	Lysine, Valine, Leucine etc

Table.2 Coatings containing alginate for applying on various fruits depicted in table 2

Fruits	Coatings	Physico chemical quality	References
Grapes	Galactomannans, cashew gum, gelatin, and alginate	Alginate(2.0%)/galactomannans (0.5%)/cashew gum (0.5%)/ gelatin (2.0%) edible coating delayed the loss in weight and maintained the crispiness and colour of the grapes.	De Souza *et al.*, 2021
Peach	Rhubarb extract and alginate	weight loss rate, respiration rate, PPO activity of rhubarb-SA coated samples were quite lower than those of 1% alginate coated samples and the control group, while the firmness and soluble solid content were significantly higher than those of the control group.	Li *et al.*, 2019
Blackberries	Limonene and alginate	Prevents increase of respiration.	Joshi *et al.*, 2021
Rose apple	$Cacl_2$ and alginate	40% alginate coating reduced respiration rate and weight loss.	Duong *et al.*, 2022
Strawberry	Alginate	Maintains the colour and firmness and did not increase antioxidant activity	Peretto *et al.*, 2017

Table.3 Depicts percentage of pectin extracted from fruit wastes: (Panchami and Gunasekaran, 2017)

Source	Calcium pectate (%)	Pectin (%)
Citrus peel	24.5	25.5
Mango peel	7.5	8.6
Banana peel	2.5	2.7
Apple pomace	10.6	12.5

Fig.1 (Sapper and Chiralt, 2018)depicts the relationship of various coating properties of fruits and various quality parameters lie firmness, appearance, preventing microbial attack, etc that are maintained in the commodities. The relation between coating forming agents and the surface energy in the commodity determines how effective any coating treatment on the product will prove to be.

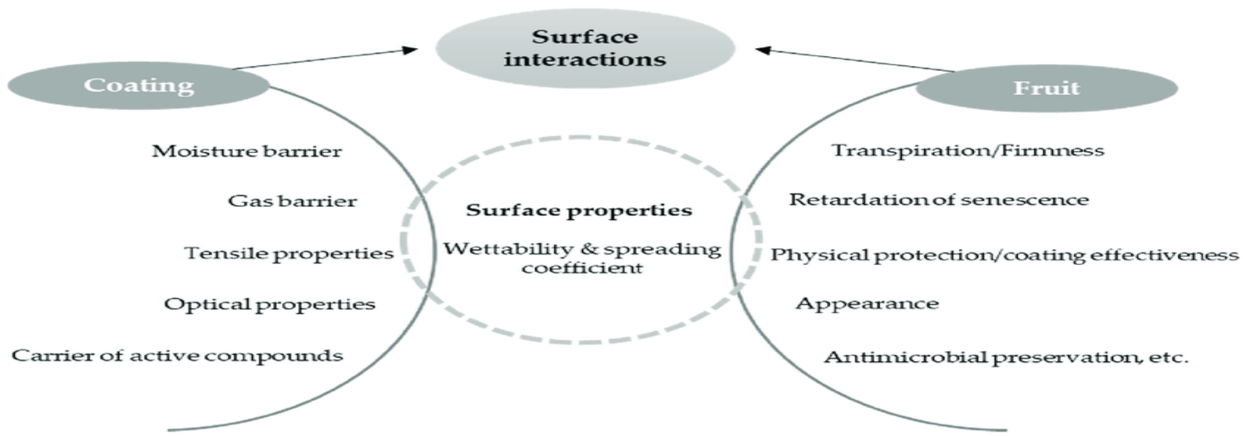
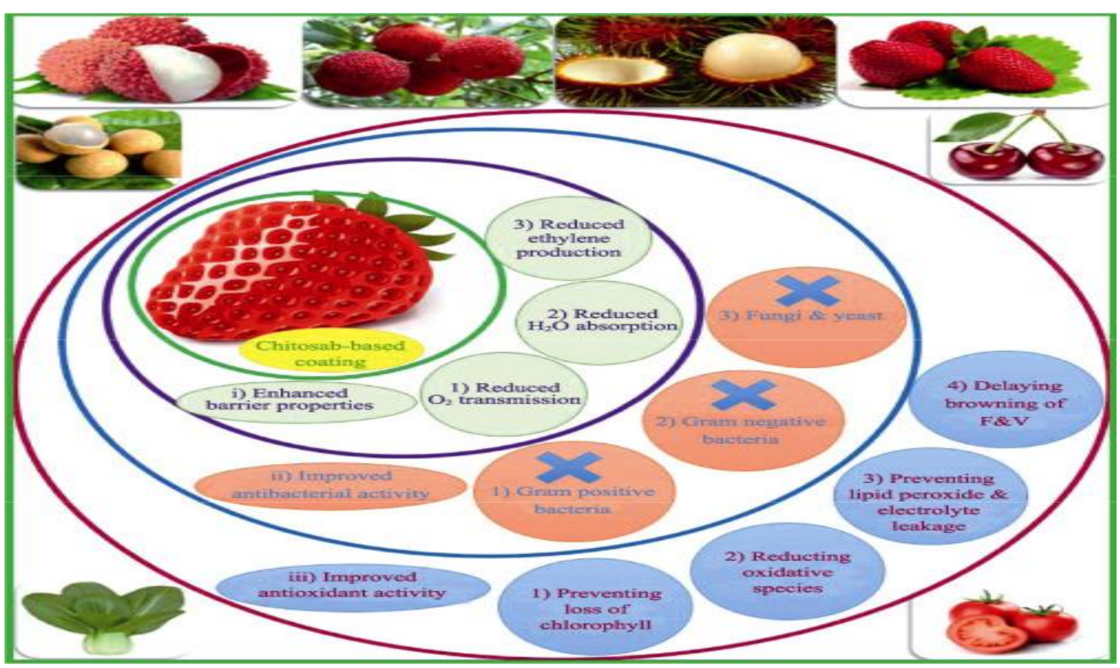


Fig.2 (Duan *et al*., 2019)



Effects of CMC (Carboxy Methyl Cellulose)

It is a water- soluble cellulose derivative which can be used as an edible coating in many fruits. It has a high solubility in hot and cold water and commonly used as packaging material. It is cheap and has good biodegradability. For food application, it has been found to be the most important derivative of cellulose. CMC-based coatings have water binding and moisture sorption characteristics because there are large number of hydroxyl and carboxylic groups in CMC structure. Apart from this, the amount of water in CMC hydrogel is high and could be used as a filler owing to its polymeric structure and high molecular weight (Tongdeesoontorn *et al.,* 2011).

CMC coatings have been found to be odourless, tasteless, non-toxic, water soluble and having good antioxidant activity. CMC contains high water content thereby showing excellent aroma and acts as an oil barrier in commodities. From CMC, MC, HPC and HPMC, numerous edible coatings have been made and can be used as a coating on some fruit and vegetables for preventing the transfer of oxygen, oil, or moisture transfer.

CMC edible coatings show anti senescence properties, delayed ripening in fruits like banana, mango, etc. Coatings can also be applied to harvested fruits to prevent the gas exchange between fruit and environment (Panahirad *et al.,* 2021). It is known to retain the flavour of many eatable products. The application of CMC in many fruits like Rambutan, Guava, etc have been found to be beneficial. In plums, 1% CMC coating was highly efficient in maintaining titratable acidity. 1% CMC had a good effect in retaining fruit firmness (9N) as compared to control. There was less decline in ascorbic acid content of plums coated with 1% CMC as compared to control. Weight loss in uncoated plum was seen to be high as compared to coated plum. In coated plum, weight loss was 10% with 1% CMC coating but in control, it was 16%. There was not much difference in the TSS of coated and uncoated plum. TSS of coated plum was 10.50 while in control, it was 11.15 (Panahirad *et al.,* 2019).

CMC coatings showed significant effects on various quality parameters of 'kinnow' mandarin fruits. After storing for 30 days, weight loss in 'kinnow' mandarin fruits coated with CMC was 2.80% whereas in control, weight loss was 7.50%.

The ascorbic acid content of coated fruits was 2% higher than control fruits after 30 days of storage. It is seen that total phenolics declines in fresh fruits during storage. CMC coatings showed that total phenolics was 1.50% higher than that of control fruits.

In Rambutan fruits, it was seen that the fruits which were treated with CMC had higher Vitamin C concentrations than the fruits which were stored under ambient conditions (Saowakon *et al.,* 2017).

CMC being a water-soluble compound could not prevent water loss. In guava fruit, weight loss was lower compared to the non-coated fruit after coating with CMC. It was found that decay was lower (8.33%) in coated fruit while in control fruit, it was higher (29.17%). CMC coating resulted in the higher ascorbic acid content in coated fruit as compared to the uncoated fruit.

In guava cv. 'Allahabad Safeda,' different concentrations of CMC 1%, 1.5% and 2% were used for evaluating various parameters like weight loss, decay, firmness, phenolic content etc. CMC coated fruits of 1.5 g/l showed considerable loss in weight by 4% and decay rate of 8.50% as compared to uncoated fruit. CMC coating of 1.5g/l on fruits showed positive results in maintaining high firmness, titratable acidity (0.40%) and better taste as compared to control. Overall, CMC coatings of 1.5 g/l on guava fruits helped in maintaining the shelf-life in ambient conditions (Kumar *et al.,* 2021). Other derivatives of cellulose like HPC, HPMC and MC when immersed in cold water get dissolved easily. HPMC is edible in nature which is odourless, oil resistant and non-toxic. The water absorption capacity of coated paper can be improved by 25% in comparison to the uncoated paper (Nechita and Roman, 2020).

Starch

It is the most common polysaccharide composed of amylose and amylopectin. Preference is given to high amylose content in starch for preparation of edible coatings. They are found to be environment friendly due to their low cost, easy availability.

Starch is derived from different sources like cereals, legumes and even unripe mango and banana. Starch based coatings are odourless and tasteless, but the quality and its value in the market is not affected by its coating.

Coating of starch on fruits helps to prevent oxygen transmission and hence maintains the firmness of fruits. Starch can also be used as a composite coating with other types of coatings which can improve the various properties of fruits and better the postharvest life of fruit (Oyom *et al.,* 2022).

Starch had considerable effects on the post-harvest life of various fruits. Nawab *et al.,* (2017) observed that mango kernel starch improved the storage life of tomato which decreased respiration, transpiration, maintaining firmness, increasing ascorbic acid content etc. In strawberry, starch coating enhanced skin colour, prevented water loss which helped in maintaining firmness and various quality parameters fruit. Even avocado fruits coated with starch had similar effects as that of strawberry.

Edible coatings made from gum have proven to be helpful in increasing the shelf-life of various commodities. Gums are known to be environment friendly, so researchers are focussing more on gums. Gums can be of various types but the major source of gums are plants.

Xanthan gum is a polysaccharide and the process involved in its making is fermentation. (Katzbauer, 1998). The biochemical properties of xanthan gum depend on the type of microbes used in the fermentation process. Low concentration of xanthan gum produces a highly viscous solution and stable in wide ranges of pH and temperature (Garcia-ochoa *et al.,* 2000). Xanthan gum unlike other gums is obtained from fruits and derived from microorganisms.

Guar gum is a galactomannan rich flour that ranges from yellow to white in colour water soluble polysaccharide obtained from the leguminous Indian guar bean. Guar gum is one of the most important thickeners and is a versatile material for many food applications due to its different physicochemical properties as well as its high availability, low cost, and biodegradability. It has helped in maintaining quality of products as well as retaining their storage life. Guar gum is available at a much lower cost than other edible coatings.

Almond gum has been derived from almond tree and belongs to family Rosaceae. It is used as a foaming agent, emulsifier and gellan agent. There are various other gums like Psyllium seed gum, Tragacanth gum, Tara gum, Quince gum, Peach gum etc (Tahir *et al.,* 2019).

Future Prospects

Due to improper postharvest handling of commodities, most of the fruits get damaged after harvest. There is a demand for commodities throughout the world without the use of chemicals and which have a good postharvest shelf-life. Although application of edible coatings on commodities is limited as of now, in the coming years, there is possibility that it will spread to different kinds of products and will replace the old methods of packaging. In the future, there are high chances that edible coatings will be the most preferred methods for improving the storage life of fruits. Various studies are being done keeping in mind for development of environment friendly edible coatings. These are at the primary stage of development before they are made fully safe for large scale application in industries. For this, edible coatings have found to be essential. Edible coatings alone or in combinations can be used for many products such as gums, aloe vera gel, sodium alginate and chitosan etc. These coatings are very environment friendly and does not cause damage to the commodities. The use of novel edible coatings should be promoted and made aware to the public as much as possible. Soon, edible coatings can prove to be a promising method that can help to increase bioavailability. These coatings prevent nutrient loss, weight loss and various other losses from the commodities thus making them fit for consumption. Future betterment is required with respect to what materials we use for coating especially in terms of the migration of minerals, the nutritional value and how efficient it will prove to be, the cost-effective criteria and latest technological methods to guarantee and promote the shelf life and maintain the quality of the newly coated fruits. From this review, it can be said that edible coating technology can prove to be a blessing for various horticultural commodities like fruits not only for extending their storage life but also prevent the use of chemical additives which has become prevalent in the present era.

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