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Post–harvest application of edible coatings to improve the shelf life of fruits

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Abstract
Countries that depend on crop production for their economies, fruit loss after harvest is a major concern for them. Fruit is being lost every year because of outdated conservation methods and ignorance regarding conservation practices. Globally, food of exceptional quality is in high demand, except for preservatives that has been used to longer the shelf life. Innovative technologies in food integration may be able to extend shelf life, reduce packaging layers, and improve food quality and safety. Edible coatings have been deemed one of the most effective and safest methods for preserving food due to their film-forming characteristics, antimicrobial properties, biodegradability, and biochemical properties. This also shields fruits and vegetables from deterioration since moisture and oxygen are not permitted inside. Edible coatings keep fruit fresh for a longer period of time by reducing respiration and preserving its quality. Edible coatings with antibacterial and antifungal properties provide protection against bacterial contamination. This review discusses several edible coatings and their potential uses in terms of improving postharvest quality and extending postharvest life. Fruits and vegetables are valued by consumers today because of their high nutritional value. Due to their perishable nature, fruits and vegetables have a short shelf life. Approximately 30% of fruits and vegetables are affected by insects, microorganisms, transport and storage conditions. Fruits and vegetables around the world are becoming increasingly difficult to preserve. Edible coatings can provide an effective solution to this problem. It provides a protective edible cover for fruit and vegetables. This not only benefits consumers, but it is also environmentally friendly. Nutraceuticals are foods that have health benefits for consumers and are considered edible herbs today. Coatings are available in a broad range of forms including hydrocolloids, lipids, and plasticizers. It has good barrier properties against moisture, oxygen, carbon dioxide, and water vapor.

Keywords: edible coating, fruits, vegetables, coating types, hydrocolloids & shelf life

Introduction
People have been linked to a wide range of health benefits by consuming vegetables and fruits. The cultivation and consumption of fresh and organic fruits have gained considerable popularity in recent years. As consumers opt for fresh and organic products, and as lifestyle modifications become increasingly reliable, chopped vegetables and fruits are becoming more popular. It is yet difficult for the food industry to keep cutting-edge food products in production for a long time. Fruits and vegetables are key components of a balanced diet. (Riva, *et al*., 2020) [42].

For plants, such as vegetables and fruits, cellular respiration involves constantly utilizing oxygen and releasing carbon dioxide. Metabolic process in the respiratory system involves breakdown of sugars, carbohydrates, proteins, and organic acids. The difficulty of replenishment follows the digestion of substrates and carbohydrates, since the plants are separated from the vegetables or fruit immediately afterwards (Yousuf *et al*., 2018) [54]. In terms of color, taste, weight, and nutritional value, maintaining quality has become increasingly challenging over time. Dehydration of fruits and vegetables can also lead to shriveling, wilting, flaccidity, and loss of nutritional value in addition to causing nutritional loss (El-Sayed *et al*., 2020) [16, 17].

Using other procedures to prevent spoilage due to weather conditions during production phase is important in order to avoid post-harvest degradation caused by microbiological degradation and reduce the biochemical and physiological changes that arise after harvest. A better understanding of packaging technology, for instance, the gas composition, will alter metabolic conditions and improve fruit shelf life and superiority (Arroyo *et al*., 2020 & El-Sayed *et al*., 2020) [7, 16, 17].

For food storage and packaging, edible coatings and biopolymer films have been extensively investigated. These films have taken packaging to a whole new level, narrowing the gap between packing, storage, and food storage (Umaraw *et al*., 2017 & Youssef *et al*., 2018) [50, 52]. It transfers the quality of fresh fruits and vegetables, enhances shelf life, reduces odors and stains, and prevents moisture loss. Researchers are currently developing edible and perishable films which combine the benefits of packaging, preservation, and food. (Youssef *et al*., 2019) [53]. Increasingly, consumer demands for healthy, organic, and nutrient-rich foods have led to the development of edible films based on ecological concerns, plastic waste and industrial food waste issues. There are biopolymers made by food industry wastes, as well as less commonly used polysaccharides, lipids, and proteins capable of being used as nutraceuticals, flavors, antioxidants, and antimicrobials (Umaraw *et al*., 2020 & Al-Tayyar *et al*., 2020) [51, 2, 3].

A layer of edible coating is applied to fruits and vegetables to prolong shelf life. In addition, they contribute no harmful substances to the diet, and they are safe to consume as part of the product. Fruits and vegetables are coated with edible films or coatings to prevent them from spoiling, and the coatings are environmentally friendly. In the last few years, new edible films and coatings have been developed as a result of the use of herbs and antimicrobial compounds to preserve fruits and vegetables. The edible coatings prevent moisture loss as well as enhance the taste and appearance of foods. In addition to controlling growth and maturation, they also control respiration (Dhall *et al*., 2013) [15]. Vegetables and fruits, such as tomatoes, cucumbers, and cherries, can be coated with edible coatings to prevent oxidative browning and to decrease the growth of microorganisms. Furthermore, edible films can be used to reduce disruption in the production process as well as improve shelf life by minimizing moisture loss through solute migration and gas exchange. Fruit and vegetables can be controlled and extended in shelf life by coating, which reduce browning, discoloration, taste, and bacterial growth.

Methodology

The present article describes various methods used to treat different types of edible coatings on fruits, including the outcome of the application. To prepare the revive paper, a number of articles were referenced in order to identify the findings of the research, as well as the methods used to apply a coating to fruits and vegetables in the research. A protective outer layer is applied to fruits and vegetables to prolong their shelf life. Physiological and chemical changes occur during the coating process, which affect fruit weight, freshness, color, and other factors that are important to fruit preservation. The references which were used to referred are from past 10 years Furthermore, edible coatings can significantly prolong the shelf life of fresh and minimally processed foods and protect them from being harmed by harmful environmental factors, such as preservation of oxygen, carbon dioxide, moisture, aroma, and taste compounds. Researchers concluded that edible coatings can prolong shelf life, prevent moisture loss, delay ripening, and even prevent microorganism growth on fresh fruits and vegetables. It is feasible to apply coatings in numerous ways, such as dipping, brushing, or spraying, to create the modified atmosphere. Applied edible coatings can be achieved by dipping the products into coating material and letting them dry. As a result, the addition of edible films and coatings to traditional packaging does not cause the fruit to lose its integrity, but rather provides extra levels of protection (Umaraw *et al*., 2020 & Al-Tayyar *et al*., 2020) [51, 2, 3]. Different types of fruits and vegetables are coated with edible coatings are:-

Fruits

Among the edible coated fruits are apple, peach, orange, grapefruit, banana, cherry, papaya, lemon, strawberry, and mangoes. Also included are fresh-cut apples, fresh-cut pears, fresh-cut peaches.

Vegetables

There is lettuce, tomato slices, cucumber, capsicum, cantaloupe, fresh potatoes, fresh-cut cabbage, and minimally processed carrots.

Properties of Edible Coating

These coatings provide excellent protection against oxygen, moisture, carbon dioxide, and ethylene. Fruit and Vegetables are able to maintain shape and color as well as improve their appearance. In addition to antioxidants and vitamins, fruits and vegetables have edible coatings that enhance their nutritional profile without altering their composition. A fruit or vegetable coated with a coating can be protected and has an extended shelf life.

Classification of Edible Coatings

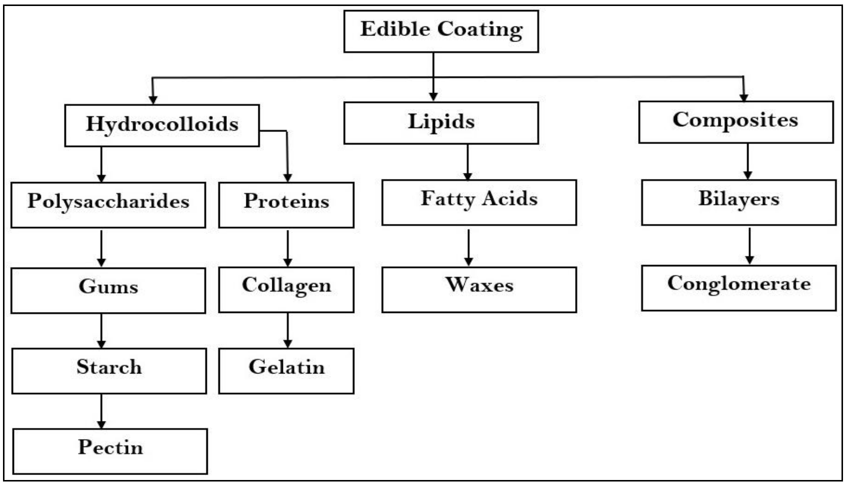

Fig 1

Applying methods of Edible Coatings

Edible coatings can be applied to fruits and vegetables using a variety of methods. They include the following

A. Dipping Method

Despite being one of the oldest commercial methods, it is still in use today. Fresh fruits are dipped in coating solutions to cover their surfaces thoroughly. Once the coating solution has been drained from the food surface, any remaining coating is removed. A strong bond forms between the fruit and the outer surface after it has been dried. Various adhesive coating mixtures can be coated with this method (Atieno *et al*., 2019 & Modesti *et al*., 2019) [8, 30].

B. Layer by Layer Method

Layer-by-layer approaches control coating characteristics and functionality more precisely by layering polyelectrolytes that have opposite charges. This process produces multilayer films that can help enhance the effectiveness of edible coatings (Brazil *et al*., 2012 & Modesti *et al*., 2019) [30].

C. Vacuum Impregnation Method

As opposed to dipping, vacuum impregnation offers more benefits. Having a vacuum environment makes a difference when fruit is dipped. Rather than dipping the fresh foods in a traditional dip tank, fresh foods are submerged in an airtight vacuum chamber. As a result of immersion in an atmospheric pressure solution, the food material is restored to its normal atmospheric pressure (Nandane *et al*., 2016) [32].

D. Spraying Method

The spraying method is recommended for coating solutions that have a low viscosity and can be sprayed under high pressure. As drying times and temperatures affect polymeric coatings sprayed via a spraying system, they have an impact on polymeric coatings applied manually. As a result of forming droplets and spreading them across the fruit's surface, the spraying method increases the amount of liquid coating on the surface (Yousuf *et al*., 2018) [54].

E. Foaming and Dripping Method

The foaming and dripping techniques for coating application are considered classics. Scientists and professionals in the fruit industry are now reluctant to accept these strategies. With the dripping technique, brushes are used to coat the fruit surface directly with the coating. In order to apply foamed coatings, a foaming agent must be added. Several tumbling activities are used to dissolve the foam, ensuring consistent dispersion (Atieno *et al*., 2019) [8].

Herbal Edible Coating: A new concept

Herbal coatings are a new food industry coating method made from herbs. A combination of herbs and food are usually used to make these, and the most common herbal ingredients are Aloe vera gel, Neem, Lemon grass, Rosemary, Tulsi, and Turmeric. Being antimicrobial and vitamin-rich, herbs also contain important minerals and antioxidants. (Chauhan *et al*., 2014) [13]. Increasingly, aloe vera gel has been used in fruit and vegetable supplements because of its antibacterial properties as well as the fact it reduces moisture loss. In addition to ginger, clove bud, turmeric, neem, and mint, herbal edible coatings for fruits and vegetables contain essential oils and extracts. (Nasution *et al*., 2015).

Discussion

Recent years have seen the exploration of edible coatings as a way to prolong the shelf life of fresh fruits and improve their quality, since they are biodegradable and environmentally friendly. The outer films of fruits and vegetables can provide additional physiochemical, morphological, and physiological control mechanisms. (Yousuf *et al*., 2018) [54]. Coating materials are characterized by their physicochemical properties and barriers, which in many cases are highly determined by their molecular structure and structure of component molecules, or by their microstructure. Surface coatings often appear on fruit, and the properties of the coating are eventually associated with those of the fruit. The properties of the fruit can, however, affect its properties during its application. (Nandane *et al*., 2016) [32].

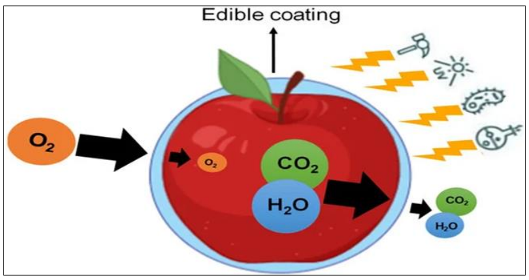

Fig 1: Edible coating on fruit. There is a complete barrier to gas and water at the coated area.

The fruit response should also be evaluated after dressing has been applied, so that the characteristics of the bound fruit can be taken into consideration-

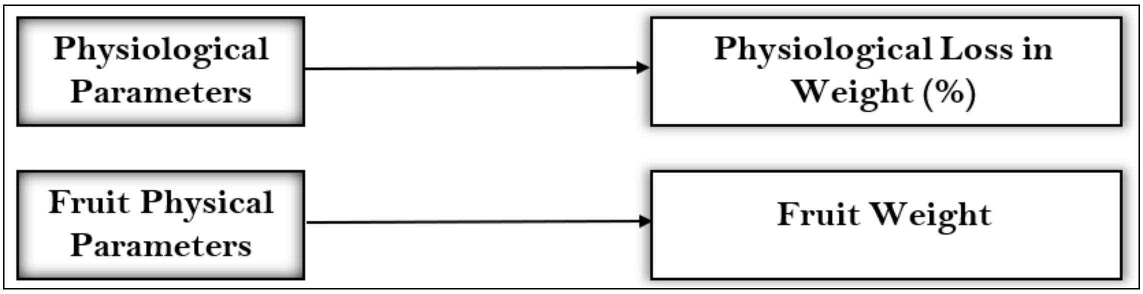

Fig 2

In order to characterize the properties of a coating, these following aspects matter most-

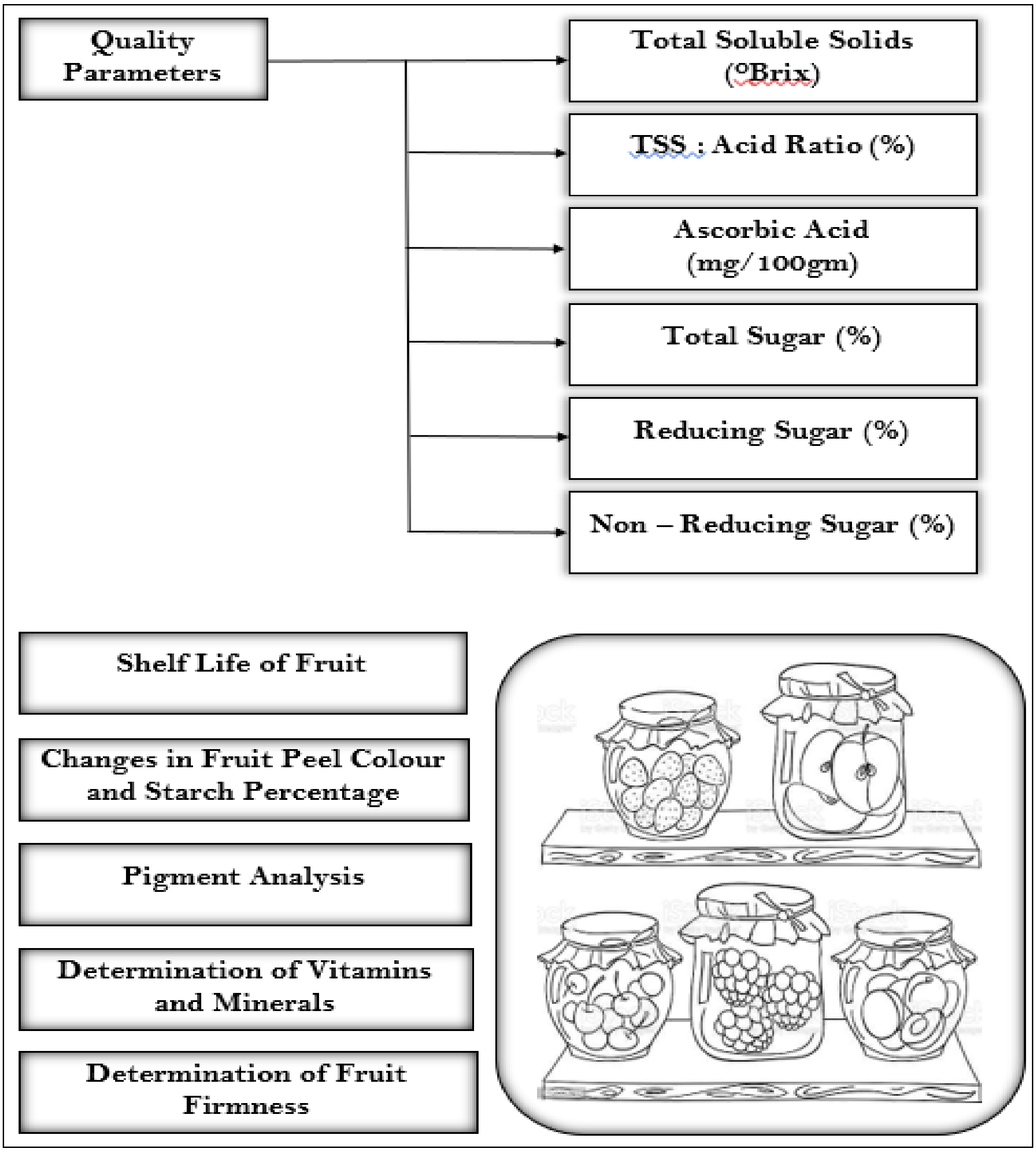

Fig 3

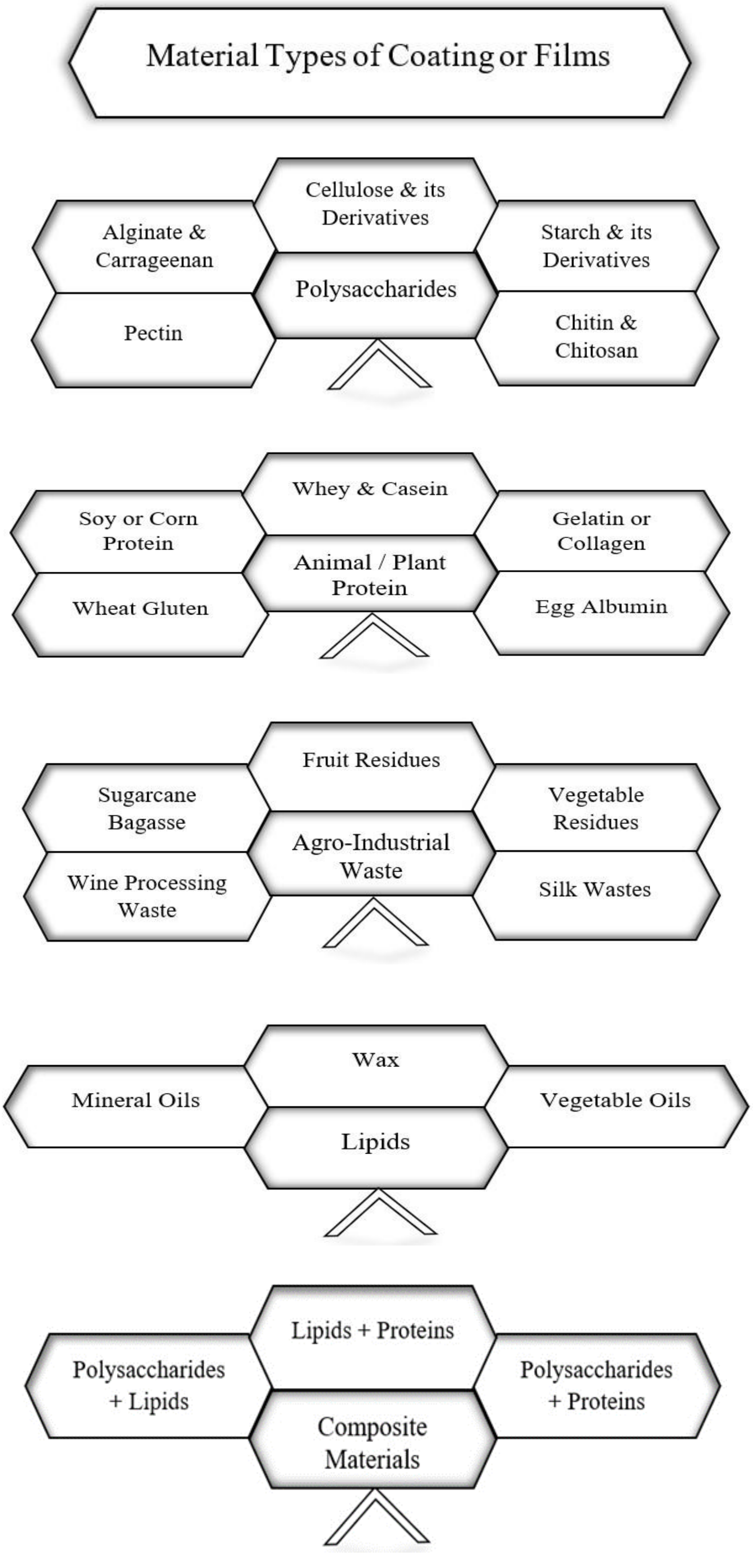

Fig 4

Application of Edible Coating / films on fruits

1. Guava

Guava is a fruit that originates in America, and it is very sweet and delicious. In addition to the high ethylene content, the fruit has a significant respiratory activity. It is coated with edible gelatin, triacetin, and lauric acid, chitosan, cashew, mesquite, arabic, and caribbean gums, different waxes (candelilla and carnauba), cellulose, and CMC for improved quality and shelf life. It has been demonstrated that natural gums coatings can be quite useful in coating functions of foods. The edible coatings delayed colour changes on surfaces, reduced mass loss, and protected hardness (Forato *et al*., 2015, García-Betanzos *et al*., 2017 & Murmu and Mishra 2017, 2018) [19, 22, 31].

2. Banana

Banana companies suffer substantial losses due to anthracnose during transportation and storage. Anthracnose is prevented from spreading on bananas by forming a thick film on their surface and altering the atmosphere around them. As a result, their cells become stronger and delay ripening. The use of arabic gum alone did not demonstrate any fungicidal effects, however, when combined with chitosan, all of the arabic gum solutions showed fungicidal effects.

3. Citrus

There were 18.9 million tonnes of citrus produced worldwide in the year 2017, making it the most important crop. Citrus supply chains suffer from postharvest losses just like any other fresh crop supply chain. Arnon *et al*., (2015) [5] developed the coating consists of a Mandarin-based polysaccharide interior layer and chitosan exterior layer made from polysaccharides. As a result of the research results, quality indicators such as glossiness gradients and peel colours improved uniformly across citrus fruits. Saberi *et al*., (2018) [43] examined the effects of edible coatings made with guar gum and pea starch on the storage, storage life, and shelf life of oranges. Hydrophobic chemicals were incorporated into this composite coating in order to decrease fruit respiration, ethylene production, weight loss, peel pitting, stiffness loss, and fruit decay rate.

4. Papaya

This fruit contains a variety of bioactive chemicals which are strong antioxidants. Ripe papayas are sliced into wedges, peeled, seeded, and served. Papaya's freshness is quickly deteriorated. The use of edible coatings can prolong papaya's shelf life, improve its appearance, and reduce microorganism growth and decay after harvesting, improving its postharvest quality. (Ali *et al*., 2011, Brasil *et al*., 2012 & Yousuf and Srivastava, 2015) [1, 11,55]. (Brasil *et al*., 2012) [11] enhanced the quality of the fruit by immobilizing the fresh-cut papaya in multilayered antimicrobial coatings (chitosan and pectin). In coated papaya, carotene concentrations were higher, juice leakage rate was lower, and organoleptic profile was better.

5. Blueberry

Almost every human being consumes blueberries in both their fresh and processed forms, as well as other berry fruits. A blueberry is a berry rich in antioxidants. Research on the effectiveness of coating strawberry fruits with curcumin and limonene liposomes integrated with methyl cellulose has shown that the coating inhibits fungal growth on the fruits. (Nora *et al*., 2020) [34].

6. Mango

During extreme weather, mangoes mature fast due to their climacteric nature. Due to their soft texture, mango fruits have a limited postharvest life and are more vulnerable to pathogenic diseases. In order to improve mango fruit quality, shelf life, and quality of storage, several strategies have been used, including controlled and modified environments, edible coatings and films, low temperatures, and ionizing radiation. (Khaliq *et al*., 2015, Singh *et al*., 2013) [24] Researchers combined arabic gum (10%) with calcium chloride (3%) coatings to study physical and chemical properties of mangoes stored at low temperatures (Khaliq *et al*., 2015) [24].

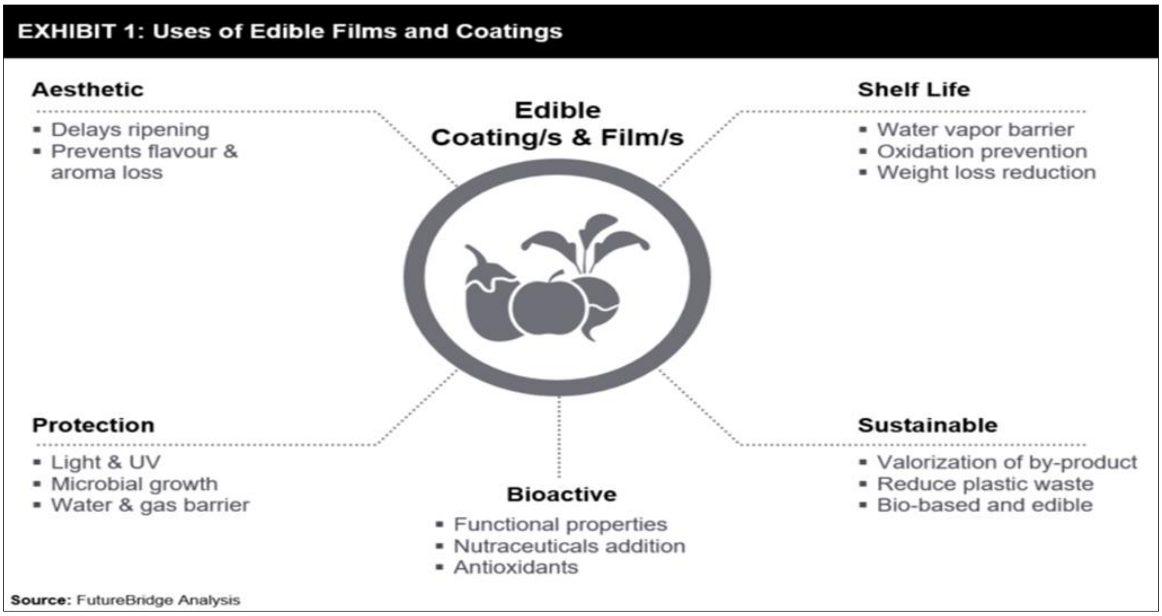

Fig 5

Table 1: Utilization of different coatings for shelf life extension in various fresh fruits Tropical and Sub-tropical Fruits

Fruit	Coating	Result	Reference
Guava	Guar gum	The infestation was eradicated by the presence of guar gum in water. This treatment eliminates fruit flies and prolongs shelf life.	Esameldin *et al*., 2018
	Chitosan cassava starch blended with Lippiagracilis and Schauer genotype starches	Chitosan with a 2.0% concentration of sodium and Lippiagracilis Schauer strain with a 1.0%, 2.0%, or 3.0% concentration of cassava starch with a 2.0% concentration controlled both Gram - negative bacteria and Gram positive bacteria *in vitro* and suspended ripening.	Aquino *et al*., 2015
	Pomegranate peel extract with chitosan and alginate	Combined with pomegranate peel extract (PPE; 1% w/v), pomegranate peel extract and coating improved the quality of guava when stored at low temperatures, according to experiments utilizing alginate and PPE.	Sneha *et al*., 2018
Banana	Coatings made with nanocellulose emulsion	In an emulsion varnish containing cellulose nanofibers, the angle of interaction was low, the spacing coefficient maximum, a lower surface tension than the critical surface tension of banana peels, and an excellent wettability. The increase in storage will also be achieved by deferring ethylene biosynthesis.	Deng, 2017
Kinnow Mandarin	Cinnamaldehyde based coatings made from chitosan	A lower fruit decay rate and an improved fruit quality were achieved with CI-CH.	Gao *et al*., 2018
	Surface coating with hydroxypropyl-methylcellulose, calcium chloride, and magnesium oxide	In addition to improving acidity and vitamin C content, treating kinnow fruits with sodium chloride, magnesium sulfate, and hydrophosphate water also reduced weight loss, preserved skin elasticity, and prevented ethylene production. Additionally, the TSS is low, so the shelf life is extended even further.	Randhawa *et al*., 2018
	A polysaccharide coating of opuntia in Kinnow	Coating the fruit with cactus polysaccharides retains about 2% moisture and pH. Fruit retains 3.19 % of its weight and is therefore shelf-stable for a longer period of time.	Riaz *et al*., 2018
Persian Lime	Coatings that contain antimicrobial compounds derived from soybean proteins	As a result, blue mould is prevented, water loss is reduced, and color remains vibrant.	González-Estrada *et al*., 2017
Orange	Additionally, salac, gelatin, and Persian gum may be used for coating	Results were satisfactory when Persian gum was used at 3, 4, and 5%; gelatin was used at 5, 6 and 7%; and shellac was used at 9, 10 and 11%.	Khorram *et al*., 2017
Strawberry	Cassava starch and sodium alginate along with lemon peel essential oil	As a result, the degradation process could be seen. There was an antimicrobial effect of lemon peel essential oil (0.6%) against many species of bacteria, including Bacillus. Although lemon peel essential oil inhibited pathogens such as Botrytis spp. and Rhizopus stolonifera, it did not have much effect on other pathogens.	Rahmawati *et al*., 2017
	Coating with banana starch, chitosan and aloe vera gel	Aloe vera 20%, when used as a coat, increases the physiochemical properties of the skin, such as color, firmness, and skin elasticity, as well as reducing weight loss.	Pinzon *et al*., 2020
	Coatings based on polysaccharides (alginate, chitosan, and pullulan)	Additionally, polysaccharide-coated fruits had higher ascorbic acid levels, reducing fruit decay and enhancing antioxidant enzyme activity.	Li *et al*., 2017
Blueberry	It's best to use Sodium alginate, Pectin, or both alginates and pectin	Reduces yeast growth, including that of aerobic bacteria, and increases fruit firmness.	Mannozzi *et al*., 2017
Papaya	Aloe Vera gel	During storage, the product's color and physical properties were improved by adding aloe vera (1.5% in this case). Therefore, papaya's shelf life could be extended by up to 15 days.	Sharmin *et al*., 20160
	An essential oil and	CMC in combination with L. sidoides EO preserves	Zillo *et al*.,

	carboxymethylcellulose coating	postharvest qualities in papayas.	2018
	Chitosan plus extract of propolis	A combination of chitosan (1%) and propolisethanolic extract (5%) improved postharvest handling of fruit.	Barrera *et al*., 2015
Mango	Chitosan plus Calcium Chloride	The storage of mango fruit was extended by calcium chloride and chitosan, which worked as preservatives.	Shweta *et al*., 2014
	A coating containing Chitosan as well as cassava and starch	The fruits were improved by the addition of cassava starch, chitosan, and cassava starch/chitosan (2%) to the starches.	Oliveira *et al*., 2018
	Calcium chloride combined with gum arabic	Guar gum (10%) along with calcium chloride (3%), worked effectively to preserve fruit quality.	Khaliq *et al*., 2015
Ber	Guar gum together with aloe Vera	The coating retained the firmness, colour, and acidity of fruit when stored at ambient temperatures.	Arghya M *et al*., 2018
	Tragacanth gum, Chitosan, and Guar gum used as a coating	Fruits have a longer shelf life.	Nilesh Bhowmick *et al*., 2015
Grapes	Coatings containing octenyl succinic anhydride made from modified wheat starch	This preserves the quality of the fruit and maximizes shelf life. Starch-based coating also improves the shelf life as well as the quality of the fruit while preserving the total amount of carotenoids.	Punia *et al*., 2019
	Chitosan nanoparticles coatings	Chitosan-containing edible nanoparticles can greatly enhance the flavor of grapes.	Castelo *et al*., 2018
	A combination of shrimp chitosan and Mentha essential oil	Aspergillus niger and Penicillium expansum fungi reduced the incidence of fungi infections in grapes when Shrimp chitosan was combined with MPEO or MVEO.	Guerra *et al*., 2016
Guava, Mango and Papaya	A combination of chitosan and lemongrass oil	During postharvest handling, anthracnose is controlled.	Lima *et al*., 2018
Different Fruits	Coatings based on Chitosan Mono-Bilayer	Chitosan coatings are effective in reducing oxidative stress after harvest by enhancing fruit quality.	Modesti *et al*., 2019

Summary

Food technology has been using edible films for a long time. Natural polymers and wax are the most commonly used materials in the production process. A team of scientists is working on making edible coatings stronger, safer, and more efficient. A wide range of research results have shown that edible coverings can be used to extend the shelf life of food commodities, control the exchange of material, enhance the sensory properties, as well as boost the nutritional and aesthetic qualities of food commodities (Modesti *et al*., 2019) [30]. It is common to use edible coverings to extend the ripening time of fruits and vegetables while they are stored, as well as meat products, nuts, almonds and other foods. Edible coating has additional applications in active packaging. It is beneficial to extend the shelf life of foods by extending their shelf life with substances that inhibit microbial growth, release components, or adjust their pH. Various types of food can be packaged with edible coatings to control the vapors generated by water vapor, and edible coatings can also serve as water vapor barriers (Silvia *et al*., 2011) [46].

Produced fruits are increasingly being kept as fresh as possible by avoiding chemical fumigation with sulfur dioxide, in part to prevent browning. Furthermore, edible coatings have the potential to protect fresh fruits from quality changes and quantity losses. Those coatings serve several purposes including reducing quantity losses and quality changes. (Deng *et al*., 2017) [14].

Table 2: Result of Edible coating on certain fruits

Crop	Coating	Result	Reference
Apple	Coatings consisting of Aloe Vera, Neem oil, and marigold flower extracts	These coatings ensure a high level of storage quality.	Shweta *et al*., 2014
Peach	An alginate-based coating based on rhubarb extract	In addition to improving postharvest qualities, they extend shelf life.	Xiao-yu *et al*., 2019
	An extract of the mango seed kernel and mango peel	It was found that mango peels coated with glycerol and/or extracted from mango kernels reduced ethylene and CO_2 levels.	Cristian *et al*., 2018
Pear	In the formulation of edible coatings, evaluation of hydroxypropyl methylcellulose and olive oil	Weight loss is lessened, pH values are improved, and TSS and TA values improve.	Nandane *et al*., 2016
Bartlett	A mixture of sempfresh and 1-methylcyclopropene coupled with	CA+1-MCP + SF provide highest storage quality. It improves colour and firmness, as	Zhi *et al*., 2018

	controlled atmospheric conditions	well as reducing ethylene production.	
Plum (Santa Rose)	Lac-based coatings, Semeperfresh coatings, and Niprofresh coatings	The coating retained nearly five times as much firmness and two times as much antioxidant activity as a cellulose coating.	Kumar *et al*., 2018

Conclusion

Fruits and vegetables have been coated with edible coatings as a food preservation method for several years. In addition to hydrocolloids, waxes, and proteins, various coating materials are also used. Scientists have created new edible films that can be eaten with fruits and vegetables, and are also safe and environmentally friendly. The present review demonstrates the extensibility of edible coatings, the inhibition of water release, the retardation of maturation, and the prevention of bacteria growth, particularly on fruit and vegetables. A new concept known as Herbal Edible Coating has recently emerged in the field of edible coatings. It is more effective and provides better health outcomes. As well as being nutrient-rich, these fruits and vegetables also served as medicine.

A food packaging innovation that is highly innovative is edible coating. Edible coatings are a good way to reduce packaging waste. These coatings are not only edible, but they can also be made with natural or synthetic materials. Typically, these structures contain starches, proteins, fats, waxes, and oils, which make them excellent gelators. In addition to improving their gelation properties, plasticizers have other properties such as air permeability and water resistance. Nutritional products should be plasticized with glycerol, mannitol, sorbitol, and sucrose for better efficiency. Edible coating helps preserve the nutritional characteristics of produce and also gives them a longer shelf life. Edible films can be applied to fruits and vegetables in a variety of ways, including dipping, spraying, brushing, and filming. In the packaging industry, film / coating composition is primarily geared toward packing. The component films and coatings of composite films and coatings carry more performance than do single films alone. By including antioxidants and active constituents in herbal extracts, food commodities gain nutritive properties. The end result is improved as well as the benefits to health.

References

1. Ali A, Mahmud TMM, Kamaruzaman S, Siddiqui Y. Effect of chitosan coatings on the physicochemical characteristics of Eksotika II papaya (Carica papaya L.) fruit during cold storage. Food Chem,2011:124(2):620-626. doi: 10.1016/j.foodchem.2010.06.085.
2. Al-Tayyar NA, Youssef AM, Al-hindi R. Antimicrobial food packaging based on sustainable bio-based materials for reducing foodborne pathogens: A review, Food Chem, 2020, 125915.
3. Al-Tayyar NA, Youssef AM, Al-Hindi R. Antimicrobial packaging efficiency of ZnO-SiO2 nanocomposites infused into PVA/CS films for enhancing the shelf life of food products, Food Packag. Self-life,2020:25:100523.
4. Aquino DAB, Blank AF, L de Aquino Santana LC. Impact of edible chitosan–cassava starch coatings enriched with Lippiagracilis Schauer genotype mixtures on the shelf life of guavas (Psidium guajava L.) during storage at room temperature. Food Chem,2015:171:108-116.
5. Arnon H, Granit R, Porat R, Poverenov E. Development of polysaccharides based edible coatings for citrus fruits: A layer-by-layer approach. Food Chemistry,2015:166:465-472.
6. Arghya M, Prasanna VSSV, Shuvadeep H, Praveena J. Efficacy of edible coatings blended with aloe Vera in retaining post-harvest quality and improving storage attributes in Ber (Ziziphus mauritiana Lamk.). IJCS,2018:6(6):1727-1733.
7. Arroyo BJ, Bezerra AC, Oliveira LL, Arroyo SJ, de Melo EA, Santos AMP. Antimicrobial active edible coating of alginate and chitosan add ZnO nanoparticles applied in guavas (Psidium guajava L.), Food Chem,2020:309:125566.
8. Atieno L, Owino W, Ateka EM, Ambuko J. Influence of Coating Application Methods on the Postharvest Quality of Cassava, IJFS,2019, 1-16. doi:10.1155/2019/2148914
9. Barrera E, Gil J, Restrepo A, Mosquera K, Durango D. A coating of chitosan and propolis extract for the postharvest treatment of papaya (Carica papaya L. cv. Hawaiiana). Rev.Fac.Nal.,,Agr,2015:68(2):7667-7678.
10. Bhowmick Nilesh, Ghosh A, Du P, Dey K. Efficacy of edible coatings on the shelf life of ber (Zizyphus mauritiana Lamk.) fruits at ambient condition. IJAEB,2015:8(3):601-608.
11. Brasil IM, Gomes C, Puerta-Gomez A, Castell-Perez ME, Moreira RG. Polysaccharide-based multilayered antimicrobial edible coating enhances quality of fresh-cut papaya. LWT - Food Sci. Technol,2012:47(1):39-45. doi: 10.1016/j.lwt.2012.01.005.
12. Castelo BMNF, de Mendonçasoares BL, Marques DK, Ferreira CL, Canto D, Flores MAP *et al*. Effects of fungal chitosan nanoparticles as ecofriendly edible coatings on the quality of postharvest table grapes. J. Postharvest Bio and Tech,2018:139:56-66.
13. Chauhan S, Gupta KC, Agrawal M. Development of A. vera gel to control postharvest decay and longer shelf life of Grapes, Int. J. Curr. Microbio. App. Sc,2014:3(3):632-642.
14. Deng Z, Jung J, Simonsen J, Zhao Y. Cellulose nanomaterials emulsion coatings for controlling physiological activity, modifying surface morphology, and enhancing storability of postharvest bananas (Musa acuminate). Food Chem,2017:232:359-368.

15. Dhall RK. Advance in edible coating for fresh fruits and vegetables: A review, Critical Reviews in Food Science and Nutrition,2013:53(5):435-450.
16. El-Sayed SM, Ibrahim OA, Kholif AM. Characterization of novel ras cheese supplemented with jalapeno red pepper, J. Food Process. Preserv, 2020, e14535.
17. El-Sayed SM, El-Sayed HS. Production of UF-soft cheese using probiotic bacteria and Aloe vera pulp as a good source of nutrients, Ann. Agric. Sci,2020:65(1):13-20.
18. Esameldin BM, Kabbashi GHA, Abdlerahman NA. Guava (Psidium guajava L.) fruit coating with gum Arabic for quality and fruit fly control. J. Exp Sci,2018:9:01-04.
19. Forato LA, de Britto D, de Rizzo JS, Gastaldi TA, Assis OBG. Effect of cashew gum-carboxymethylcellulose edible coatings in extending the shelf-life of fresh and cut guavas. Food Packag. Shelf Life,2015:5:68-74. doi: 10.1016/j.fpsl.2015.06.001.
20. Gao Y, Kan C, Chen M, Chen C, Chen Y, Fu Y *et al*. Effects of Chitosan Based Coatings Enriched with Cinnamaldehyde on Mandarin Fruit cv. Ponkan during Room-Temperature Storage. Coatings,2018:8:372.
21. González-Estrada RR, Chalier P, Ragazzo-Sánchez JA, Konuk D, Calderón-Santoyo M. Antimicrobial soy protein based coatings: Application to Persian lime (Citrus latifolia Tanaka) for protection and preservation. J. Postharvest Bio and Tech,2017:132:138-144.
22. García-Betanzos, Hernández-Sánchez CIH, Bernal-Couoh TF, Quintanar-Guerrero D, Zambrano-Zaragoza MDLL. Physicochemical, total phenols and pectin methylesterase changes on quality maintenance on guava fruit (Psidium guajava L.) coated with candeuba wax solid lipid nanoparticles-xanthan gum. Food Res. Int, 2017:101:218-227. doi: 10.1016/j.foodres.2017.08.065.
23. Guerra ICD, de Oliveira PDL, Santos MMF, Lúcio ASSC, Tavares JF, Barbosa-Filho JM *et al*. The effects of composite coatings containing chitosan and Mentha (piperita L. or x villosaHuds) essential oil on postharvest mold occurrence and quality of table grape cv. Isabella. J. IFSET,2016:34:112-121.
24. Khaliq G, Mohamed MTM, Ali A, Ding P, Ghazali HM. Effect of gum arabic coating combined with calcium chloride on physico-chemical and qualitative properties of mango (Mangifera indica L.) fruit during low temperature storage. Scientia Hort,2015:190:187-194.
25. Khorram F, Ramezanian A, Hosseini SMH. Shellac, gelatin and Persian gum as alternative coating for orange fruit. Scientia Hort,2017:225:22-28.
26. Kumar P, Sethi S, Sharma RR, Srivastav M, Singh D, Varghese E. Edible coatings influence the cold-storage life and quality of ―Santa Rosa‖ plum (Prunus salicina Lindell). J. Food Sci. and Tech,2018:55(6):2344-2350.
27. Li L, Sun J, Gao H, Shen Y, Li C, Yi P *et al*. Effects of Polysaccharide-Based Edible Coatings on Quality and Antioxidant Enzyme System of Strawberry during Cold Storage. IJPS,2017, 1-8. doi:10.1155/2017/9746174
28. Xiao-yu Li, Xiao-long D, Ying L, Lin-jing T, Qian W, Jian-long L. Rhubarb extract incorporated into an alginate-based edible coating for peach preservation. Scientia Hort,2019:257:108685.
29. Mannozzi C, Cecchini JP, Tylewicz U, Siroli L, Patrignani F, Lanciotti R *et al*. Study on the efficacy of edible coatings on quality of blueberry fruits during shelf-life. LWT - Food Science and Tech,2017:85:440-444
30. Modesti M, Zampella L, Petriccione M. Chitosan Mono- and Bilayer Edible Coatings for Preserving Postharvest Quality of Fresh Fruit. Polymers for Agri-Food Appli, 2019, 465-486. Springer, doi: 10.1007/978-3-030-19416-1_23
31. Murmu SB, Mishra HN. The effect of edible coating based on Arabic gum, sodium caseinate and essential oil of cinnamon and lemon grass on guava. Food Chem,2018:245:820-828. doi: 10.1016/j.foodchem.2017.11.104.
32. Nandane AS, Dave RK, Rao TVR. Optimization of edible coating formulations for improving postharvest quality and shelf life of pear fruit using response surface methodology. J. Food Sci. and Tech,2016:54(1):1-8.
33. Nasution Z, Wei JN, Hamzah Y. Characteristics of fresh cut Guava coated with Aloe vera gel as affected by different additives. Kas. J. (Nat. Sc.),2016:49:111-121.
34. Nora SM, Dinga P. Trends and advances in edible biopolymer coating for tropical fruit: A review. Food Research International,2020:134:109208.
35. Oliveira Lima, de Oliveira PDKÁR, dos WA, Vieira S, Câmara MPS, de Souza EL. Control of anthracnose caused by Colletotrichum species in guava, mango and papaya using synergistic combinations of chitosan and Cymbopogon citratus (D.C. ex Nees) Stapf. essential oil. Int J Food Microbiol,2018:266:87-94.
36. Oliveira TA, Paiva CA, Silva AC, Nascimento LV, Leite RHL, Aroucha EMM. Postharvest Quality of Tommy Atkins Mangoes Coated with Cassava Starch and Chitosan-Based Coatings. JAS,2018:10(11):2018. ISSN 1916-9752 E-ISSN 1916-9760
37. Pinzon MI, Sanchez LT, Garcia OR, Gutierrez R, Luna JC, Villa CC. Increasing shelf life of strawberries (Fragaria ssp) by using a banana starch- chitosan- Aloe vera gel composite edible coating. IJFS,2020:55(1):92-98.
38. Punia S, Sandhu KS, Dhall SB, Kaur M. Dynamic, shear and pasting behaviour of native and octenyl succinic anhydride (OSA) modified wheat starch and their utilization in preparation of edible films. Int. Jour. Of Biologic Macromole,2019:133:110-116.

39. Rahmawati D, Chandra M, Santoso S, Puteri MG. Application of lemon peel essential oil with edible coating agent to prolong shelf life of tofu and strawberry. ISAC,2017:1803(1):020037.
40. Randhawa MA, Arfan M, Pasha I, Nadeem M, Ahmad N. Synergistic Effect of Salts and Cellulose Based Coating on Shelf Life of Kinnow (Citrus reticulata Blanco). The J. Anim. Plant Sci,2018:28(2):520-526.
41. Riaz SS, Tauseef MSA, Imran MA, Shabir Rabia *et al*. Extraction of Polysaccharides from Opuntia Cactus for Its Potential Application in Edible Coating to Improve the Shelf Life Of Citrus (Kinnow Mandarin) Fruit. J Microbiol Biotech Food Sci,2018:8(1):745-750.
42. Riva SC, Opara UO, Fawole OA. Recent developments on postharvest application of edible coatings on stone fruit: A review, Sci. Hortic,2020:262:109074.
43. Saberi BJB, Golding JR, Marques Pristijono P, Chockchaisawasdee S, Scarlett CJ, Stathopoulos CE. Application of biocomposite edible coatings based on pea starch and guar gum on quality, storability and shelf life of 'Valencia' oranges. Postharvest Biol. Technol,2018:137:9-20. doi: 10.1016/j.postharvbio.2017.11.003.
44. Sharmin M, Islam M, Alim M. Shelf life enhancement of papaya with aloe vera gel coating at ambient temperature. J. Ban Agril. Univ,2016:13(1):131.
45. Shweta C, Gupta KC, Agrawal M. Efficacy of Chitosan and Calcium chloride on Post harvest storage period of Mango with the application of hurdle technology. IJCMAS,2014:3(5):731-740.
46. Silvia AVC, Luis P, Miguel A, Del R, Maria B, Perez-Gago. Antimicrobial edible films and coatings for fresh and minimally processed fruits and vegetables: A review, 2011.
47. Singh Z, Singh RK, Sane VA, Nath P. Mango - Postharvest biology and biotechnology. Crit. Rev. Plant Sci,2013:32(4):217-236. doi: 10.1080/07352689.2012.743399.
48. Sneha N, Saxenaa MA, Kaur C. Effect of chitosan and alginate-based coatings enriched with pomegranate peel extract to extend the postharvest quality of guava (Psidium guajava L.). Food chem,2018:240:245-252.
49. Torres-Leóna Cristian, Vicenteb AA, María L, Flores-Lópezb, Romeo R, Serna-Cockd L *et al*. Edible films and coatings based on mango (var. Ataulfo) by-products to improve gas transfer rate of peach. LWT - Food Sci. and Tech,2018:97:624-631.
50. Umaraw P, Verma AK. Comprehensive review on application of edible film on meat and meat products: An eco-friendly approach, Crit. Rev. Food Sci. Nutr,2017:57(6):1270-1279.
51. Umaraw P, Munekata PE, Verma AK, Barba FJ, Singh VP, Kumar P *et al*. Edible films/coating with tailored properties for active packaging of meat, fish and derived products, Trends Food Sci. Technol,2020:98:10-24.
52. Youssef AM, El-Sayed SM. Bionanocomposites materials for food packaging applications: Concepts and future outlook, Carbohydr. Polym,2018:193:19-27.
53. Youssef AM, Assem FM, Abdel-Aziz ME, Elaaser M, Ibrahim OA, Mahmoud M *et al*. Development of bionanocomposite materials and its use in coating of Ras cheese, Food Chem,2019:270:467-475.
54. Yousuf B, Qadri OS, Srivastava AK. Recent developments in shelf-life extension of fresh-cut fruits and vegetables by application of different edible coatings: A review, LWT,2018:89:198-209.
55. Yousuf B, Srivastava AK. Psyllium (Plantago) gum as an effective edible coating to improve quality and shelf life of fresh-cut papaya (Carica papaya). International Journal of Bioengineering and Life Sciences,2015:9(7):765-770.
56. Zhi H, Dong Y, Wang Y. Effects of controlled atmosphere, edible coating, and 1-methylcyclopropene on improving storage quality of — "Bartlett" pears after long-term storage. J. of Horti. Sci and Biotech, 2018. DOI: 10.1080/14620316.2018.1450098
57. Zillo RR, da Silva PPM, de Oliveira J, da Glória EM, Spoto MHF. Carboxymethylcellulose coating associated with essential oil can increase papaya shelf life. Scientia Hort,2018:239:70-77.