Advances in Bioresearch
Adv. Biores., Vol 14 (2) March 2023: 172-180

Print ISSN 0976-4585; Online ISSN 2277-1573
Journal's URL:http://www.soeagra.com/abr.html
CODEN: ABRDC3
DOI: 10.15515/abr.0976-4585.14.2.172180

Advances in Bioresearch

REVIEW ARTICLE

Significance of edible fruit coatings for improving the socio-economic status of fruit growers: A review

Akshay Kumar, Vikram Singh*, Vishal Johar, Pankaj Kumar and Suprikesh Kumar Kadlag
Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India- 144411
* Corresponding author: vikram.26038@lpu.co.in

ABSTRACT
The aim of this work is impact of edible coating in fruits. The coating is becoming a chief catalyst in the preservation of fruit crops. Without any proper handling process, the fruit may not survive in the long term. There are an ample number of advantages of coatings. Every type of fruit is vulnerable due to improper postharvest handling, and thus to maintain shelf life of fruits coating may prove to be a pragmatic and effective panacea. The edible coating enhances the shelf life, quality, total soluble salt (TSS), and taste of various fruits. It is to be noted that different fruits with their unique storage requirements should be applied with edible coating according to their suitability. Furthermore, edible coating acts as a barrier to moisture and maintains the exchange of gases, it can be further implied that edible coating reduces the wastage of fruits as well as the wastage of farmer's income. Nations can certainly proper with proper utilization of edible coatings during the import or export of fruit items.
Keywords: *Edible fruit coatings, the shelf life, quality, total soluble salt (TSS), and taste of various fruits*

Received 25.12.2022 Revised 08.02.2023 Accepted 16.03.2023

How to cite this article:
A Kumar, V Singh, V Johar, P Kumar and S Kumar Kadlag. Significance of edible fruit coatings for improving the socio-economic status of fruit growers: A review. A Review. Adv. Biores. Vol 14 [1] March 2023; 172-180

INTRODUCTION

India's horticulture production has increase from the recent years. India holds second rank in the world after China. Out of 654 million tons fruit production in the world, India estimated 89 million tons and sharing about 13.6% of the world production. Cultivation of fruits and vegetables production has helped many states and agricultural across India to grow economically [34]. Agriculture sector plays a very important role to enhance the Gross domestic product (GDP) of the country this is first time in history where (GDP) has reached almost 20 percent for the first time in 17 years, according to economic survey 2020-2021. But the matter is deterioration of fruit is rapidly increased and due to this post harvest losses of fruit enhances and this is becoming the matter of concern in food security and global hunger in many countries. Approximately 20–35% of the production is being wasted due to a lack of proper postharvest management and the post-harvest losses and wastage, which is accounts for more than 6,720,000.00 US dollars). In the last few decades, the use of fruit coating is rapidly increased in food industry because it has the life saving properties of the products, it extends the storage and protect the food from external contamination, refuse its deterioration and enhance the shelf life of the fruit products because it forms a outer layer on fruits and acts as a supporting agents which don't allow the entry of gases and any kind of moisture loss as well as keep the fruit qualities, extend natural ageing, and maintaining the structure of coated fruits Coating does not have any harmful or substances which cause allergy. It is easily digestible and extends the market life of fruits. Edible Coatings have number of advantages viz, keep fruit moisture, have no affect on nutritional and functional characteristics of fruits, basically it is edible so have no antibacterial and antimicrobial properties [42]. There are 5 types of edible coatings. Lipid based, in this coating the vegetables oil, minerals oil and wax type of coatings is part of them. Protein derived from animal and plants, the example of this coating is casein and whey protein coating, collagen or gelatin, egg albumin, corn protein and corn protein and wheat gluten types of coating are involve. Waste from agriculture and industries, in this coating materials is derived from fruit residues, vegetables residues,

silk wastes, sugarcane bagasse and wine manufacture wastes. Polysaccharides in these coating materials derived from cellulose and its by-product, pectin, alginate and carrageenan, chitin and chitosan and starch and its by-product. Coating based on composite waste is derived from lipids and proteins, polysaccharides and protein and from lipids and polysaccharides [25].

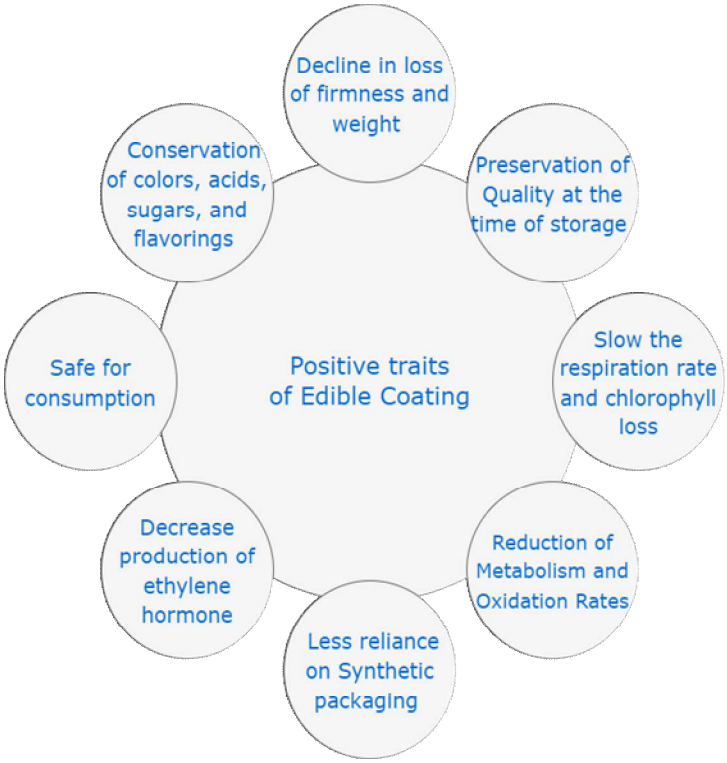

Fig.1. Beneficial effects of edible coating on fruit crops

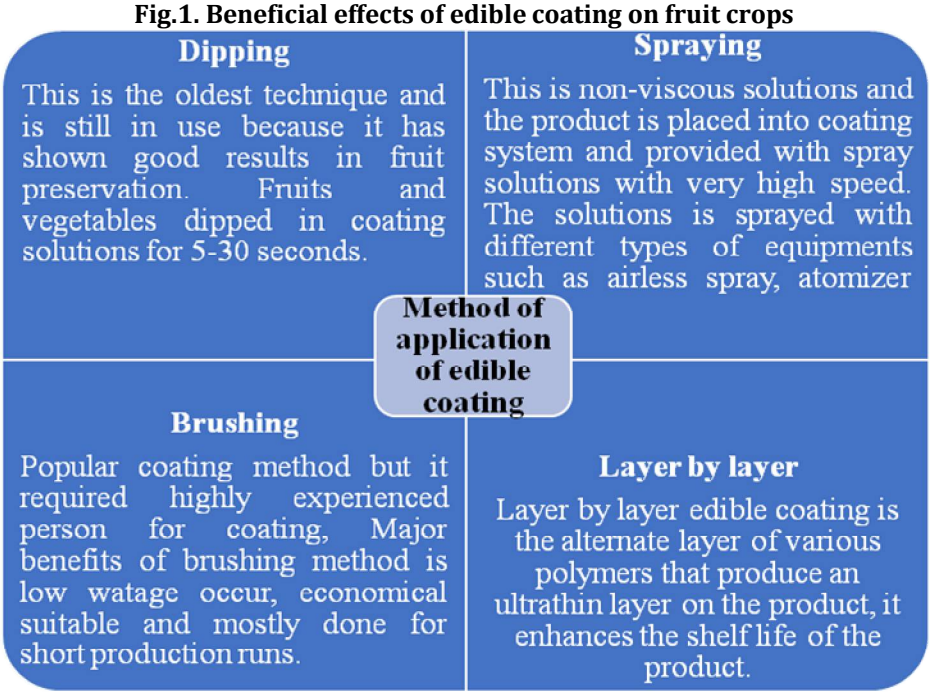

Fig. 2 Methods of fruit coating.

Sources of edible coating materials and use in food industry

Based on Polysaccharides

The polysaccharides-based coating is obtained from sources such as plants, microorganisms and crustaceans. They are natural bonded together widely used to create coating. These are some polysaccharides used in the formation of these films, alginates, starch, chitosan, pullulan, Pectin and

cellulose [46]. However, polysaccharides create a poor fence against water vapor because of their hydrophilic nature because hydrophilic substances are poorly soluble in water, and they are usually used to enhance the shelf life of meat products, vegetables, and fruits [23]. Starch is a polysaccharide made up of two distinct molecules the one is amylose and amylose is a linear polymer and the second one is amylopectin is a water-insoluble polysaccharide that is highly branched polymer. Starch is used in large amounts in the coating of food materials because it is found in ample amounts in nature at a low cost. Coatings based on starch are colorless and have oil-free appearance. They decline the rate of respiration of vegetables and fruits. The source from where starch is extracted for the edible coating is corn, potato and cassava etc. [41]. Chitosan is found in the exo-skeleton of the invertebrates and is derived from chitin and for the formation of chitosan it is going through a phase namely as deacetylation this process helps in the formation of Chitosan, it is a polysaccharide used in the edible coating of food products. From the hidden traits of chitosan which is antimicrobial and antioxidative properties it is widely used in coating materials for fruits and vegetables. Chitosan-based films are highly sensitive to moisture but also show good resistance to oxygen, fat, and oil. Chitosan is the perfect coatings for fresh produce of fruits and vegetables, because of its outstanding film-forming properties and it also has good compatibility with antimicrobial agents, vitamins and minerals [1].

Alginates are obtained from seaweed and have film forming properties. It controls respiration and enhances the mechanical properties of the food Alginate is a naturally occurring polysaccharide specifically used in the bio-industry. It is made up of the sodium salt of alginic acid that comes from some brown algae species [38]. The source of gellan gum is Sphingomonas elodea (Majorly named Pseudomonas elodea) found growing on the elodea plant consists of repeated units of tetrasaccharides, and is made up of a fermentation process and it is a well known biopolymer because of unique it's properties and which is easily converted into a transparent gel that is resistant to heat, e.g., high transparency, good hardness, smooth surfaces, and decline water vapor permeability, The application of gellan gum with including pulsed light use may extend the shelf life of the fresh-cut apple and keep the antioxidant values of the fruit [28].

Edible coating based on Pullulan

Pullulan is a bio polysaccharide that is usually thick and formed effective film, and obtained from starch by the fungus which is namely as *Aureobasidium pullulans*. Pullulan is different characters from other polysaccharides because it gets soluble in water easily, basically pullulan-based edible coating is widely used to enhance the life of fruits which is harvested climacteric and non-climacteric fruits crops. This is a effective way to increasing the shelf life of various food products [14]. Cellulose is a main part of plant cell wall which has more hydrogen bonds which cause insolubility in water. The cellulose has very less soluble in water. Some chemical modified form of cellulose is hydroxypropyl methylcellulose, methylcellulose, hydroxypropyl cellulose and carboxymethyl cellulose, which having positive result in film and coating application [40]. Carboxymethyl cellulose is polysaccharide which is soluble in with biodegradable characteristics and film-forming properties produced at low cost with various resources. It is an long-chain compound that consists of glucopyranose with high molecular weight, which giving strength and structural unity in edible coatings. They show excellent oxygen, aroma, oil barrier, and anti-senescence qualities. [36]. Pectin is extracted from different plants and usually from plant-based by-products sources, Pectin is the composite of plant cell wall present in the middle lamella of plant cells they are basically known as heteropolymers and polysaccharides made up of acid name as galacturonic units that may present in structure, molecular composition, and molecular weight and pectin is used as a gelling and stabilizing agent [45].

EDIBLE COATING BASED ON PROTEIN

Proteins normally occur in two types, one is fibrous form and another is globular proteins. Fibrous proteins are not dissolves in water name as keratins, collagens, fibrin and elastin, and globular proteins transport the molecules and side chain of amino acids, example of protein comes under globular are whey protein, wheat gluten, corn zein and soy protein are found in edible coatings. These coatings are good oxygen blockers and thus help preserve the food products with less deterioration rate. Proteins having good mechanical properties, covering the outer surface of fruits which act as a barrier block the harmful gases affect on fruits [11].

Edible coating based on Corn zein and films

Edible coating made from zein shows very good film properties. They are more moisture blockers than other films, corn coatings are a main source of zein which is having prolamin protein that can be dissolved in 70–80% ethanol and is hydrophobic, and has high proline amino acid content found in plants, mainly in seeds cereals grains such as Gliadin (Wheat), rye (secalin), avenin (oats), Zein (Corn) and Kafirin (Sorghum) Hordein (Barley) [9].

Edible coating based on Gelatin and films

The nature of gluten has a significant impact on its filming properties; gelatin is a hydrophobic protein normally present in wheat and also a globular protein, used in some edible coatings/films because of its low cost and easily availability. Gelatin coatings usually known for it's good transparency, mechanical and barrier properties and manufactured via an extrusion or casting process [15].

Edible coating based on Lipid and films

Lipids are naturally hydrophobic and used in edible coating from past because they resolve moisture entry into the fresh food product which can cause some significant deteriorative changes in the food material. Examples of lipids used in edible coatings include wax and paraffin [8].

Impact of edible coating after their application on fruits

Table 1. Types of edible coating used in different fruit crops to enhance their shelf life

S.N.	Fruit	Used Edible coating	Benefits	References
1	Apple	Gellan and alginate	This coating maintains the quality of fresh-cut Fuji apples and reduces ethylene production.	[27] [31]
	Fresh cut apple	Oil from neem, marigold, aloe Vera and guar gum.	They retard the repining process and increase TSS and TPC rates.	[10]
	Apple (Anna Apple)	Arabic and Soybean gum, Paraffin wax and Jojoba oil	Maintaining the quality of apple (Anna apple) at the time of storage also delays the weight loss change, overall beneficial for apple storage.	[2]
	Apple	WPC, SPI, Alginate, Carrageenan.	Plummet the Delaying of color changes at the time of storage.	[20]
	Cut apples	Conservation of fresh-cut apple with gellangum-based prebiotic edible coatings	Pulsed light along with fiber coating disapprove any apprehensions about microbial action on fresh-cut apples.	[28]
	Apple (Golden delicious)	Edible Candelilla wax coating and also using tarbush.	It gave positive effects on fruit by decline weight loss and maintaining the level of water activity in Golden delicious.	[35]
	Apple	Whey protein concentrate, WPC & APE.	Using whey protein concentrate and apple pomance extract.	[22]
2	Pear (Bartlett)	Jojoba oil, candelilla wax, gum Arabic, and pomegranate polyphenols.	These coatings enhance the water vapor resistance and keep the fruit for up to four weeks.	[47] [48]
	Pear (Babughosha)	Soy protein isolate (SPI) added the ingredient hydroxypropyl methylcellulose (HPMC) and also used Olive oil concentration.	This technique is effective in improving the post-harvest quality of pear fruit.	[4]
	Fresh cut pear	Whey protein coating and also using lemon and lemongrass essential oil.	Whey protein coating shows better results, like it declines the browning of pear at the time of storage. It also maintains fruit taste, color, and smell.	[19]
	Le conte pear	Chitosan and beeswax edible coating	Chitosan and beeswax pollen grains coatings are the safe and best coating for the preservation and safe for human health too	[43]
3	Peach	Sodium alginate and chitosan coating	Chitosan coating controlled the growth of microorganisms and enhance fruit quality and shelf life of fruit	[12]
		Nano-Chitosan coating	It enhances the shelf life of vegetables and fruits high amount decline the fruit weight losses and maintained the hardness of the fruit.	[18]
		Beeswax Coating	Beeswax-coated fruit extends the shelf life of peach fruit for up to 50 days and also improves the quality of the fruit.	[6]
4	Plum	Lac based coating	This study shows the different results on the storage life of Plum and elongate the shelf life of fruit and maintains the nutritional quality of the fruit.	[24]
		Carboxymethylcellulose-based (CMC) Edible Coating	This coating maintains the antioxidant properties of the fruit and enhances the shelf life of the fruit.	[37]
		Polysaccharide edible coatings	Fruit coatings maintain the life of fruits, by delaying the repining process, and slow down the physical changes at the time of storage	[16]

	Japanese Plum (Prunus salicina Lindl.)	Rice starch-based edible coatings	This study has revealed that rice starch-based edible coating slows down the respiration rate and restrains the ethylene productions	[44]
5	Table Grape (Thompson Seedless)	The composite edible coating includes Xantham gum and some quantity of olive oil	The application of Xantham gum and olive oil concentration improves the quality and extends the shelf life of the fruit for up to 24 days.	[7]
	Grape	Chitosan edible coating Chitosan and gum ghatti	Coating enhances the shelf life of fruit, but it is more beneficial when used in the form of nanoparticles. In this study nanoparticles of chitosan coating were used and it slows down the ripening process, overall, it enhanced the post-harvest life of fruit. Fruits are treated with different Concentrations of gum ghatti and chitosan , various results are obtained like enlarge berry size, slow down the weight loss, having suitable effects on the antioxidant activities, this coating gives superior result on the all getting parameters.	[29] [42]
6	Strawberry	The impact of polysaccharide-based edible coating improves the enzyme activity.	(Chitosan, pullulan and alginate) and give a positive result on fruit-like polysaccharides coating extend the fruit softening and other properties of the fruit	[26]
	Strawberry (Fragaria spp)	Coating extracted from Cajanus cajan seeds applied on fresh strawberry fruit for preservation	The extracted material from Cajanus cajan is applied to the strawberry such as protein isolate and gum from the seeds. Applied at the different concentrations on the fruit shows good results.	[21]
		Use of starch extracted from banana and chitosan aloe vera gel as an edible coating	The use of compound films which are made up of banana starch chitosan and add distinct aloe vera gel quantities, which shows better results on strawberry fruit and extends the shelf life for up to 15 days.	[32]
	Strawberry	Use of Chitosan and extract of apple peel polyphenols as an edible coating	The strawberry is coated with different concentrations of chitosan and apple peel polyphenols, having a positive effect on the life of the strawberry. It enhances the storage life and delays fruit senescence, and also maintains the quality of fruit during storage.	[3]
7	Cavendish Banana	Carrageenan edible coating	Carrageenan can be used as edible coating to extend the shelf life of banana fruits (*Musa acuminata* AAA group).	[17]
8	Guava	Lipids and polysaccharides	Fruit coated with vegetables wax and sodium alginate delaying the yellowing of skin and reduce respiration rate.	[33]

In table 1 the different types of edible coating may apply to fruit crops which shows a favorable result in the conservation of the fruit crops and may lead to enhancing the shelf life of the fruit crops, number of edible coating are derived from a natural process that does not have any harmful effect on fruits as well as on human life too. Figure 2 indicating types of benefits in the flow chart after the application of different edible coatings in fruit crops overall they enhance the product life and their value too.

EFFECT OF EDIBLE COATING ON PHYSICO-CHEMICAL PROPERTIES OF FRUITS

Effect on weight loss and the shelf life of fruits

Edible coating have affect on loss in weight, titratable acidity, ph, firmness, shelf life, color, respiration rate and microbial load in fresh cut fruits. Shelf life of all fruits was increased by edible coating. Insulin coated fresh cut apple and rich in fructose alginate solution which is great prebiotic alginate solution, and used in development of newly non-dairy functional food products. Apple slices are treated with prebiotic-alginate forms a novel environment for probiotic bacteria which mixed with apples and reach in human small intestine and having several health benefits (30). Ferulic acid incorporated with SPI compositions give the better result like it extends the shelf life, quality, preventing their firmness and loss of weight in fresh cut apples [5]. For long term storage, during the handling of fruit crops the destruction of natural layer get affect and which causes the loss in the quality of the fruits and for that the edible coating plays chief role because it create the

external barrier or layer in between the fruit crops and the environment, which protect the fruits at the time of handling like transportation and which maintain the quality of the fruit crops [39].

The impact of gellan and alginate edible coating over the shelf life of Fuji apple during storage time, alginate 2 g and in powder form gellan 0.5 g added to distilled water (100 ml) and provide heat to the solutions at 700 C and stir the solutions until it becomes clear these both coatings have a very good impact on the shelf life of fuji apple it declines the ethylene production and coated fruits keep the firmness of fruit and maintained the respiration rate of the fruit [27] [30] [31]. The use of whey protein concentrates as an edible coating and also extract of apple pomace as a coating to enhance the shelf life of the fresh-cut apple, The slices of the apple are coated with an adequate composition of (WPC and APE) and at the value of 0.5, 1.0, and 1.5 percentage and stored at 50 C for twelve days. Coated fruit showed good results such as a decline the weight loss the coated fruit is less brown as compared to uncoated ones, and WPC and APE also maintain the microbial activity of the fruit [22].

Banana is a very important fruit crop with having ample amount of nutritional values but it has short shelf life which increases post harvest losses rate, but to increase the shelf life of this fruit, the use of carrageenan edible coating applied at different treatments and out of these the fruit is treated with 1.5%, carrageenan coating store at twenty degree Celsius room temperature showed the best results, and maintain the quality, extend the shelf life for up to six days and have no any effect on the fruit weight [17].

The use of vegetables wax and sodium alginate coating which comes under lipid and polysaccharides coating used at 1.4 and 2 %, for 14 days of trial and vegetable wax coating gave better result it enhance the shelf life and reduce the physiological loss weight, keep the fruit color, retain higher firmness and ascorbic acid content of the fruit and keep the quality of the fruit for up to 8 days [33].

Effect of natural extract with addition of edible coating in fruit quality and TSS

Use of natural extracts material derived from plants which are used as an neem, aloe vera, and marigold oil edible coating,, different concentrations of these three natural based coatings are applied on the apple i.e., 1, 1.5, and 2 percent value of neam oil and aloe vera oil are applied on apple surface and 10, 15, and 20 percent of marigold oil used as a natural coating they maintain the quality of the product such as TSS and enhance titratable acidity and impede the ripening process [9]. In this study the use of (WPC), Soy protein isolate, Carrageenan & alginates were used as an edible coating, three distinct concentrations of edible coating are applied on fruit crops for the preservations of apple fruit i.e., 5 percent (WPC), 5g Soy protein isolate, Carrageenan 0.5g, and alginate 2 percent and including glycerol 1.5 percent is applied on the apple, and it gave a beneficial result it improves the shelf life of apple slices which reduce the change in color at the time of storage and maintained the quality of fruit during storage [20].

For the Preservation of peach fruit the use of chitosan and sodium alginate edible coating at the time of post-harvest storage. Distinct values of coating applied on fruit crop i.e., two percent acid-soluble chitosan, one point five percent sodium alginate, and including three percent chitosan and two percent sodium alginate solution were used, and polythene bags are tightly closed and kept in storage at four-degree Celsius temperature with ninety-five percent relative humidity for up to nine days, the following result may come after the nine days the chitosan coating may decline the metabolic activity at the time of storage without any change in fruit quality, color, TSS content of the fruit, it also stops of growth of microorganism and overall chitosan coating is the best method of preservation and enhances the quality and life of the fruit [11]. To enhance the post-harvest quality and shelf life of pear fruit with soy protein isolate at five percent concentration, some amount of (HPMC) hydroxypropyl methylcellulose at 0.40 percent and olive oil at one percent and potassium sorbate 0.22 percent values applied on the pear fruit and it enhances the shelf life and keep the pear fruit quality [4].

Edible coating declines the browning appearance

The application of (WPI) at the amount of eight percent, lemon oil at one percent, and lemongrass oil at 0.5 percent as an edible coating used on Pear fruit gives better results by improving or keeping the quality of the fruit. The main impact of whey protein coating is it declines the browning appearance of pear fruit at the time of storage, and with the use of whey protein edible coating it maintained the fruit taste, smell, color, and hardness of the fruit [19].

Use of Candelilla wax, gum arabic, jojoba oil, and Pomegranate natural organic compounds used as an edible coating which preserves the shelf life of the fruit, the amount of candelilla wax is three percent, gum arabic four percent, jojoba oil 0.15 percent and organic compounds extracted from pomegranate is 0.15 percent all replications are upgrading the shelf life of pear and maintained pH, decline weight loss, and keep the overall quality of the pear crop up to four weeks [47]. The use of chitosan and beeswax pollen grains in preservations of pear fruit out of every concentration applied on the fruit the Chitosan

BW/PG showed result and keep the quality of the Le Conte pear at the time of storage, this knows to be a safe method of preservation [43].

Edible coating maintaining the firmness of the fruits

The paltry thin layer of jojoba wax, soy gum, glycerol, and Arabic gum was applied to the apple fruit and the coating is stored at (0^0 C, 90-95% Relative Humidity), coatings in apple fruit showed better results, it extends the weight loss period, and keep the firmness of fruit and also keep the quality of apple fruit [2]. The use of Candelilla wax edible coating in three treatments i.e. AWOC, AWC, and AWCE for up to eight weeks of storage, these treatments gave better results decline weight loss, balance the water level, and improving the softness of the apple, on the other hand, AWC coating application enhances the shelf life and quality of the apple [35]. Enhancing the shelf life of peach fruit by applying beeswax edible coating at cold storage preservation, in this the amount of one hundred twenty-gram wax add in two hundred ml of distilled water and giving heat around eighty-to-ninety-degree Celsius temperature after the mixing of solutions add in hot water and add one hundred ml of edible oil in wax. And the result showed that the fruit treated with beeswax coating and stored at a specific temperature from (one to six-degree Celsius) has enhanced the shelf life of fruit up to fifty days and kept the fruit quality at best and this is becoming a great way to decline the post-harvest losses and enhance the income of small and marginal farmers [5].

Coating enhance the antioxidant activity of the fruit and their shelf life

Three polysaccharides-based edible coatings were applied on strawberries at the time of storage these coatings are (Chitosan, pullulan and alginate) and give a positive result on fruit-like polysaccharides coating extend the fruit softening and did not Change the ascorbic acid and phenolics value of the fruit overall all three coatings have a positive result on fruit are beneficial for the preservation of strawberries during cold storage conditions [26].

CONCLUSION

Edible coatings are used for decades for the storage of fruits and vegetable crops in the food industry for the longer shelf life of the product. There are various coating materials applied to fruit crops such as polysaccharides, hydrocolloids and wax, they enhance the outer and inner quality of the product. Providing safety to the fruits by its environmentally friendly character, the main key point of the coating is it maintains the nutritional value of the product, coating declines water loss and retard the ripening process of the fruit. According to review edible coating is beneficial for fruit crops to store the product for the long term, it also declines the overall wastage of the fruits, in the food industry it acts as saviors, because it saves fruits and also saves the income of farmer's and nation incomes too.

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