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Significance of edible coating in mitigating postharvest losses of tomatoes in Pakistan: a review

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ABSTRACT

Purpose: Tomato, being a climacteric and soft textured fruit, faces many challenges in postharvest life, and many factors influence its quality during storage. It faces price fluctuation in Pakistan due to postharvest losses. This review focuses on intensive research in recent years regarding edible coatings and films to minimize crop losses, and to maintain tomatoes quality by giving structural integrity. F**indings:** Tomato is a highly demanded vegetable due to its extensive uses, but its postharvest losses are 33-46% in developing countries. The application of edible coating is one of many methods used to extend the shelf life of tomatoes. The edible coating acts as semipermeable barriers to gases and water vapors. It is not a new concept and dates back to the 12th century. Edible coatings are made from lipids, carbohydrates, or protein-based materials, with additional additives like emulsifiers, plasticizers, release agents, and lubricants. The use of edible coating with different formulations is an effective method for extending the shelf life of fresh produce and tomatoes. **Limitations:** Edible coating formulations should be wet and uniformly spread on fruit surfaces, as proper adhesion, cohesion, and durability matter. Significantly less eco-friendly coatings are available compared to chemically synthesized layers. **Directions for future research**: These days, many new materials are evolving as coating solutions based on their film-forming properties, and these materials can replace synthetic plastic-based films. Composite and multi-layer coatings should be developed and micro encapsulation techniques should be adopted for better results.

INTRODUCTION

Tomatoes have become one of the most popular and productive vegetables in the world. FAO listed 15 vegetables, and among them, tomato is placed sixth in terms of total annual world production (Ishtiaq et al., 2017). It is a vital vegetable due to its nutritional status and low price. It is consumed in every home in different modes, such as fresh, salad, ketchup, sauces, soups, and meat dishes. Pakistan did not export tomatoes significantly 15 years ago, but exports have increased since then. Tomato export can be increased by improving production technologies, entering the worldwide market, and enhancing preservation technologies. Tomato is an important agricultural commodity, so its production should be increased according to demand. The soft texture of tomatoes is the main reason for its low postharvest quality in markets (Kader, 2002). Some poor handling and postharvest storage conditions are also reasons for tomato's quality deterioration. Due to ripening, tomato quality can be changed by the softening process. Tomato color and firmness depend on packaging and temperature. It can also be concluded that changes in firmness are related to surface color, which affects consumer acceptability. A prevalent method for extending the shelf life of tomatoes is to keep tomatoes in refrigerated storage for domestic and export marketing. Packaging of tomatoes can also help to improve the shelf life of tomatoes by slowing the ripening process. The mechanism behind it is to maintain the level of carbon dioxide and oxygen inside the packages due to the respiration, and the permeability properties of the films. The rate of spoilage of the tomato crop depends on several factors, and to overcome postharvest losses, there is a need to develop cost-effective and technologically viable methods. Current farming practices, preservation methods, postharvest problems, and marketing methods were surveyed in a study that showed that growers of tomato crops are uneducated, and they are doing cultivation on rented plots with excessive use of agrochemicals (Sathiyabama et al., 2014). After harvesting, tomatoes are kept on the farm in storage rooms, as there are no purchase outlets, and prices also fluctuate through the year. The insufficient storage practices of tomatoes result in postharvest losses. A proper distribution system for fresh tomatoes is fundamental to deliver tomatoes to the final consumers and minimize losses. In this condition, an appropriate, cheap, and unadorned method of postharvest preservation is sufficient. With every passing year, consumer interest in the quality, safety, and longevity of fresh produce is increasing. Organoleptic properties of food can be increased by applying edible films. These coatings contain colorings, flavorings, sweeteners, and sometimes natural ingredients can also be used, like lipids, proteins, and polysaccharides, with added plasticizers and surfactants. These films can also act as carriers of antimicrobial and antioxidant agents, but their permeability and mechanical properties are poorer than synthetic films. The film composition and formation process determine its barrier, color and mechanical properties that affect its functionality. More research is needed to develop composite coatings to improve water barrier properties, solubility and adhesion cohesion properties and to commercialize this technology (Baldwin et al., 1998).

ECONOMICAL AND NUTRITIONAL SIGNIFICANCE OF TOMATOES

Economic importance

Tomato is the 4th most important commercial vegetable crop globally (Ahmed et al., 2017). The production value of tomatoes is fifty billion dollars worldwide, which shows its economic importance among other vegetable crops. In terms of the universal production of tomatoes, it is ranked 2nd after potatoes. Tomatoes were originated from the tropical America region and then transferred to Africa. In the 16th century it was brought by Spanish people to Europe and from there, its popularity spread in Asia as well. Tomato can be called a luxury crop due to its consumption pattern as it is more widely consumed in developed countries than developing countries. Its production has increased up to 163 million tonnes, and the area under production is about 4.8 million hectares. The major tomato producing country is China, with 50 million tonnes followed by India with 17 million tonnes. Some other countries also grow tomatoes in substantial quantity, including the USA and Turkey. Leading growers in Africa are Nigeria, Egypt, Tunisia, and Morocco. Tomato production, consumption and popularity has increased over the years due to its economic and nutritional importance, and due to this, developing new storage and preservation techniques to extend its shelf life have significant value (Ochida et al., 2019).

The consumption of tomatoes varies among countries based on new VS processed tomatoes. In developed countries like the USA and Italy, 96% of tomatoes are processed while in India, only 1% of tomatoes are processed. The top five producers of tomatoes are the USA, China, Italy, Spain, and Turkey, and these are contributing a share of 85% in global tomato production. The largest consumers of tomatoes in the world are China, Europe, Africa, and North America. Fresh tomatoes trading is a paramount worldwide business, but its import and export only occur between neighboring countries due to its fragile and perishable nature (Costa & Huvelink, 2018).

The major tomato producing area in Pakistan is Danna Katchely, Azad Jammu and Kashmir where 30% of tomato growers are illiterate, and 50% have 20 years of experience (Chohan & Ahmad, 2008). A majority of farms in the region are small scale, of 5 Acre or less, as the farmers cannot follow advanced modern technology for cultivation and postharvest handling operations. The government of Pakistan needs policies that improve knowledge and farming practices to grow economically significant vegetables like tomatoes. Tomato is an economically attractive crop of Pakistan due to its short growing duration and high yield. All four provinces of Pakistan are producing tomatoes over an area of about 52,300 hectares. As the fast-food industry is flourishing in Pakistan, the demand for tomatoes is increasing. It is expected to grow shortly, soon (Agriculture Statistics of Pakistan, 2011-12 Government of Pakistan). Maximum tomato production occur in Balochistan, producing annually 205.6 thousand tonnes followed by KPK and Sindh with the output of 153.1 and 80.4 thousand tonnes, respectively. A study conducted by Tahir et al. (2012) highlighted tomato economy of Pakistan. Tomato yield depends upon the production strategies, especially energy inputs (Hatirli et al., 2006).

Nutritional importance of tomatoes

The tomatoes are enriched with micronutrients, carotenoids, and antioxidants. Tomatoes, due to their unique composition and lycopene content, can be taken to prevent cancer and cardiovascular diseases. Heat processed tomatoes have more bioavailable lycopene that can efficiently quench reactive oxygen species, and thus can help stop oxidative, destructive reactions. Some other forms of lycopene present in tomatoes are lycopene epoxide, alpha-carotene, and lutein. Alpha-carotene has significant pro-vitamin A activity and is effective against lung cancer (Kuti & Konuru, 2005). The nutritional composition of tomatoes is illustrated in Table 1. Helyes and Lugasi (2006) give an overall composition of tomato. They stated that tomatoes are very popular and play a key role in the human diet. The refraction value of tomato fruit is directly proportional to the quantity of valuable nutritive material and flavor, and inversely proportional to yield. Many studies revealed that daily consumption of tomato decreases the risk of cancer to the respiratory and digestive tract (Etminan et al., 2004; Giovannucci, 1999). Tomato is rich in lycopene, and some other antioxidants, such as ß-carotene, vitamins C and E, and polyphenols, such as kaempferol and quercetin.

Technological, sensory attributes and levels of different antioxidant compounds in tomato fruits can be influenced by environmental factors such as temperature, light, and growing practices and conditions. Carotenoids derived from tomatoes can inhibit the oxidation of human plasma low- density lipoproteins (LDL) initiated by singlet oxygen species, and in this way, the risk of cardiovascular diseases is decreased. The vitamin C concentration in tomatoes is between 14.6 mg.100 g^{-1} fresh weight and 21.7 mg.100 g^{-1} fresh weight (Abushita et al., 1997). Total sugar contents, total volatile compounds, and organic acids are critical in evaluating sensory characteristics and consumer acceptance for tomatoes (Azodanlou et al., 2003). Some epidemiological studies, as done by Giovannelli et al. (1999) showed that the consumption of tomato-based products is effective against certain types of cancer due to its high antioxidant potential. The antioxidant potential of different tomato varieties was studied, and it was found that antioxidant compounds concentrations were different in different varieties (George et al., 2004). To adopt good dietary habits and healthy lifestyles, the consumption of tomatoes and its products is recommended. The effect of tomato extract on blood pressure was evaluated, and it was concluded that tomato extract helps to reduce blood pressure in hypertension patients (Engelhard et al., 2006). Flavonoids are considered as efficient antioxidants, and tomatoes are enriched with quercetin, flavonols, and flavones (Kaur & Kapoor, 2001). A leading source of phenolic compounds is tomatoes in Indian and American diets. Processed tomatoes have a higher concentration of lycopene than raw tomatoes (Weisburger, 2002). Lycopene contents of tomatoes remain unchanged even after multiple-step processing. No change was observed in concentrations of lycopene even after 12 months of storage (Agarwal et al., 2001). The reason is that, at high temperatures, the Trans form is converted to the cis form, which is more bioavailable. Different in vivo studies show that tomato lycopene, when fed to selected human population for 1 week, resulting in the presence of carotenoids in blood serum (Cohen, 2002; Paetau et al., 1998; Rao & Rao, 2007). Dietary supplementation with lycopene resulted in a significant increase in serum lycopene level and diminished amounts of serum thiobarbituric acid-reactive substances. These results indicate that lycopene can be absorbed from tomato products and may act, as an in vivo antioxidant, and can play an important role in preventing cancer (Rao & Agarwal, 1998). A diet plan with sufficient servings of tomatoes can be a good choice to reduce the risk of cardiovascular diseases and prostate cancer (Canene et al., 2005). The risk of chronic diseases like cancer and cardiovascular diseases decreased when consumption of tomatoes and tomato-based products, increased due to the lycopene contents of these products, which have cardio protective effects (Agarwal & Rao, 2000). Giovannucci (1999) reviewed tomato as a functional food. Intake of tomato and tomato based products, or the plasma level of lycopene is associated with a lower risk of various cancers. The benefits of tomatoes and tomato-based products are due to the carotenoid content of tomato, but more definitive data are required in this context. Among all the carotenoids present in nature, lycopene is the most important for its bioavailability as it is not converted to vitamin A and thus available all the time as an antioxidant to quench free radicals that can initiate deteriorative chain reactions leading to mutations. Tomatoes are also rich in ascorbic acid, which can also inhibit reactive oxygen species.

Table 1. Nutritional composition of one tomato (127g)

Component	Amount in grams	Minerals	Amount in milligrams
Water	120	Sodium	5
Carbohydrate	3.4	Potassium	337
Protein	1.1	Iron	0.2
Fat	0.3	Zinc	0.1
Fiber	1.5	Calcium	14
Sugar	3.4	Selenium	0.1 microgram
Starch	0.1		
Vitamins			
Vitamin C	30.1 mg	Vitamin B12	0 mg
Vitamin A	117 mg	Riboflavin	0.01 mg
Vitamin B6	0.01 mg	Niacin	0.8 mg
Folate	18 microgram	Thyamine	0.03 mg
Beta carotene	697 mg		

Source: (Rao & Rao, 2007).

POSTHARVEST QUALITY AND LOSSES IN TOMATOES

Generally, the method adopted for the ripening of tomatoes is ethylene treatment, which allows the picking of tomatoes at the green stage. Deterioration can be controlled in this way, but the quality of vine ripe tomatoes is better than ethylene-treated ones, in terms of flavor, texture, and overall quality characteristics (Kader et al., 1978). Tomato quality can be improved by adopting suitable preservation practices that involve delaying the ripening process (Mutschler et al., 1992). The composition of tomatoes was also influenced by some postharvest techniques, and shelf life was extended up to 17 days compared to 7 days for control treatments. Some postharvest treatments involving temperature modifications can alter the amount of antioxidant activity of tomatoes. Storage of tomatoes at 5℃ can result in less enhancement of lycopene content and reduction of antioxidant activity, but weight loss was minimized (Javanmardi & Kubota, 2006). Chilling injury is a problem in tomato if kept at low temperature, so it is ruled out for long-term storage. Controlled atmosphere (CA) and modified atmosphere packaging (MAP) are relatively costly techniques, so the best preservation technique when these technologies are not possible is the use of edible coatings. There are some factors which can ultimately extend shelf life and minimize perishability of tomatoes for example desiccation reduction, delayed processes of maturation and senescence and microbial barrier properties. The edible coating can be used in combination with other preservation techniques, like the low temperature and modified atmosphere packaging, to increase the effectiveness of preservation and minimize postharvest losses. Tomatoes have a soft texture and perishable nature and can only stay fresh up to 2-3 days after harvest. Many postharvest techniques and advanced handling practices can influence postharvest quality of tomatoes and extend shelf life. Developing countries bear more postharvest losses due to lack of infrastructure, proper handling practice, and advanced postharvest preservation techniques (Ochida et al., 2019)

EDIBLE COATINGS APPLICATION ON TOMATOES

Maximum losses occur between harvest and consumption in the case of tomatoes (Brooks et al., 2008). Some such factors are transpiration, increased ripening, respiration, senescence and postharvest diseases (Zapata et al., 2008). The most commonly used preservation methods for tomatoes are based on the control of atmosphere, temperature, and humidity. By applying edible coatings, the internal atmosphere of fruits can be changed by controlling the transfer of respiratory gases, moisture, and aroma compounds. In this way, texture and flavor can be preserved. Given the perishability of tomato and its importance in world agricultural trade, many studies of edible coatings have been conducted in previous years. An edible coating will create a modified atmosphere by creating a semi-permeable barrier against CO_2, O_2, moisture, and solute movement. Many types of edible coatings are in use, but keeping in mind the environment and biodegradability, we prefer natural over synthetic materials (Bailén et al., 2006). There is an immense need to develop an environmentally friendly and innovative technique like edible coating, that can change the internal environment of fruits and vegetables, and that can ultimately retard water loss, ripening and decay (Park et al., 1994). Edible coatings can also impart some textural and sensory attributes to fruits and vegetables demanded and liked by customers. Some commercially available coating materials are chemical-based, but now there is a preference to shift from chemical to natural ingredients (Troy & Kerry, 2010). Gum Arabic was replaced with natural gums, such as almond gum, and was used at a 10% concentration to maintain the quality of tomatoes (Mahfoudhi & Hamdi, 2015). The overall quality of tomatoes was preserved during 20 days of storage. Alginates and zein were used to maintain the quality of tomatoes during postharvest storage. Respiration rate and ethylene production were lower in coated tomatoes than uncoated control, so overall, ripening processes were delayed and consumer acceptability was increased in markets.

The effect of carnauba and mineral oil coatings on the postharvest quality of tomato fruits was evaluated. These coatings were effective in delaying color losses and minimizing weight loss. The use of a mineral oil treatment preserved the quality of tomato fruit to the greatest extent. The effect of carnauba and mineral oil coatings on the bioactive compounds and antioxidant capacity of tomato fruits was evaluated (Davila-Avina et al., 2014). It was concluded that edible coatings preserve the overall quality of tomatoes during storage without affecting the nutritional quality of fruit.

El Ghaouth and colleagues investigated the effect of chitosan on respiration, ethylene production and quality parameters of tomato stored at 20℃ and coated with chitosan (El Ghaouth et al., 1992). Chitosan coating reduced the respiration rate, and ethylene production of tomatoes, and results were that chitosan-coated tomato was firmer and decay was less than uncoated tomatoes. Significant postharvest losses of tomatoes are due to fungal infection, and physical injuries. In this study, chitosan coating proved to be the best preservation technique as well as safe. It also controlled *Botrytis cinerea*, so this study demonstrates the potential of using chitosan derived coating to delay ripening and reduce decay.

Ali et al. (2010) used gum arabic as a coating material for preservation and enhancing the shelf life of tomatoes. Gum arabic was used in different concentrations, and tomatoes were stored at 20℃ for 20 days with RH 80-90%. Fruits coated with a 10% gum Arabic solution showed a delay in changes in firmness, weight, and overall quality characteristics. Results show that by adding 10% gum arabic in the coating solution, the ripening process can be delayed, and storage life can be increased while retaining quality attributes required by consumers.

Gum acacia is a dried gummy exudate from the stems of acacia species. It is less viscous than a highly soluble hydrocolloid used extensively in industrial sectors because of its emulsification, film-forming, and encapsulation properties (Motlagh et al., 2006). It was used for coating pecans to give them a better shiny look. El-Anany et al. (2009) used it as a coating material for apples and, found that it improves the overall quality of apples.

Tomatoes were subjected to cellulose-based edible coating made of hydroxypropyl methylcellulose (HPMC), and different analyses were conducted during a storage period of 18 days at 20℃ (Zhuang & Huang, 2003). During storage, softening occurred, but after applying an HPMC-based coating, softening was delayed, and retention of color was observed. Overall, ripening processes were delayed, which can reduce economic losses from mechanical injury during transportation and handling of tomatoes. The exocarp of tomato is a fragile cellular layer easily injured during transport after harvest. The HPMC edible coating for tomatoes can provide an additional protective layer and reduce quality degradation and quantity losses by modifying the internal atmosphere of fresh tomatoes. Since HPMC has low oxygen and carbon dioxide permeability, it could prevent oxygen from entering the tissue of the constantly respiring tomato; during which oxygen is consumed inside the tissue and CO_2 is released, CO_2 is expected to accumulate inside the packaging during the storage of the tomato. This accumulation would decrease ethylene synthesis and reduce the respiration rate, which would, in turn delay ripening as evidenced by slower changes in firmness and color. A reduced rate of loss of firmness can minimize the economic loss that would result from spoilage from mechanical injury during the transportation of tomatoes. Also, the HPMC edible coating did not adversely affect the flavor of the stored tomatoes.

Semper fresh TM edible fruit coating was applied to tomatoes at the pink stage (Tasdelen & Bayindirli, 1998). This coating formulation includes sucrose esters of fatty acids, sodium carboxymethyl cellulose, and mono-diglycerides of fatty acids. Firmness, weight loss, titratable acidity, pH, soluble solids, sugars, ascorbic acid, and lycopene were measured to examine changes in quality during storage with or without the coating. The coating was significantly more effective in delaying changes in firmness, titratable acidity, pH, soluble solids, sugars, ascorbic acid, and lycopene compared to uncoated control.

Some antimicrobials, specifically antifungal agents that are generally recognized as safe (GRAS), can be used in edible coating formulation to avoid postharvest fungal losses. Their effectiveness was determined with cherry tomatoes artificially inoculated with fungal strains of *Botrytis cinerea* and *Alternaria alternate* (Fagundes et al., 2013). Different parameters, like the incidence of disease, lesion diameter, and area, were determined to evaluate the effectiveness of the antifungal agents, and it was concluded that antifungal agents could control the incidence of fungal decay. *Rhizopus stolonifer* rapidly spreads towards adjacent fruits, causing severe economic losses during the storage of tomatoes, while *Escherichia coli* may cause serious, even life threatening diseases. Chitosan-based materials can be used as the edible films or coatings to avoid water loss and microbial spoilage. Waxes and essential oils may also be considered for use as antimicrobial agents in chitosan coatings and were tested in combinations on tomatoes of three different maturity stages (Ramos-García et al., 2012). The protective effect of coating applications was better against *E. coli* than *R. stolonifer*. Pathogenic microorganisms were also controlled by applying chitosan based edible coating added with beeswax and lime essential oil.

A unique formulation of edible coating was developed using different percentages of pure aloe vera gel with some additives to extend postharvest life of important crops like tomatoes. Aloe vera gel concentration was used from 0-80% in different treatments, and after the application of edible coating by dipping method, various quality and safety parameters of stored tomatoes were evaluated. Treatments with aloe vera gel coating of lower percentage deteriorate rapidly compared to treatments with a higher percentage of aloe vera gel. The findings of this work supported use of aloevera gel as an excellent, effective, and technologically viable edible coating material. This can be concluded from the above mentioned study that tomatoes with an edible coating having 80% aloe vera gel retained quality during 30 days of storage, and their shelf life was extended up to 35 days. A higher concentration of aloe vera gel is suitable for extending the shelf life of fresh produce (Firdous et al., 2020).

Chitosan is a cheap material that can control many pre and postharvest diseases caused by several microbial agents, including bacteria, viruses, and fungi, by affecting tomato morphology and initiating specific enzyme-based defense mechanisms against pathogenic agents. It is a natural, biodegradable compound with a polycationic nature, and is a deacetylated form of chitin derived from the exoskeleton of crustaceous animals. Chitosan act as a miracle ingredient for extending the shelf life of fresh produce by different mechanisms of action, like increasing production of phenolic compounds, glucanohydrolases, and phytoalexins that act as antifungal agents. It can decrease the activity of macerating pectin degrading enzymes. It initiates the synthesis of structural lignin-like materials and increases yield as well. It is suitable as an edible coating material due to its semipermeable film-forming properties. Sustainable agriculture can be achieved by using and exploring this kind of biodegradable, plant preservative, natural ingredient (Bautista Banos et al., 2006).

Badawy and Rabea (2009) used biopolymer chitosan to control the development of postharvest grey mold in tomatoes. Tomatoes were kept at different storage conditions, and chitosan having different molecular weights were used. In vitro analysis revealed that fungicidal activity increased with low molecular weight chitosan and high doses of chitosan ensured the fungal safety of tomatoes. Chitosan is not only antifungal, but is also involved in decreasing polyphenol oxidase activity, and enhances total protein and phenolic compound levels in bruised tomatoes. Hence, chitosan has not only fungi toxic properties, but also promotes biochemical defense responses.

Reddy et al. (2000) inoculated tomatoes with black mold (*Alternaria alternata*) and then compared activities of different maceration enzymes in chitosan-coated and control tomatoes. Chitosan acted as an antifungal agent due to its ability to inhibit the production of chelating agents, like oxalic and fumaric acids, and some toxins, like alternariol monomethyl ether. Control fruits showed a decrease in pH to 4, while chitosan treated tomatoes had an average pH of 4.6. A phytoalexin, rishitin, was also produced in tomato tissue due to chitosan treatment. Rishitin acts as an antifungal agent, so by applying chitosan, postharvest losses can be controlled.

An edible coating formulation was prepared using rice starch and coconut oil with tea leaf extract and coated on tomatoes (Das et al., 2013). Its effect on tomatoes was evaluated during 20 days of storage. The addition of lipids in coconut oil and tea leaf extract improves the surface integrity, solubility, and stability of coating solutions. A significant effect was observed in weight loss values and delayed ripening. Tea leaf extract and coconut oil also exhibit antimicrobial potential. In providing rigidity and continuity on fruit surfaces, they also offer microbial barrier properties. The effect of chitosan coatings combined with zeolite was evaluated on tomato, and quality attributes were tested during refrigerated storage. The addition of zeolite (3% $w.w^{-1}$ based on chitosan) and Tween 80 (0.1% $v.v^{-1}$) in a solution at (1.5% $w.v^{-1}$) and lactic acid (1% $v.v^{-1}$) improved its coating properties. It delayed the ripening of the tomatoes (García et al., 2014). The summary of recent works on edible coating application on tomatoes is narrated in Table 2. Fresh tomatoes were coated with a novel edible coating composed of lactobacillus supernatant, glycerol, gelatin, and starch. This special coating has antimicrobial properties against pathogenic bacteria. Tomato decay percentage was decreased with both treatments as compared to control, and pathogenic bacterial loads were also lower down. Antimicrobial activity of lactobacillus was increased at 3.5 KGy irradiation dose (Khalil et al., 2020).

Table 2. Edible coatings application on whole and fresh-cut of tomatoes

Sr.#	Tomato type	Method and material used	Storage and observation	Reference
1	Green tomato	Gum arabic nano formulations (1-2%)	- 32 °C temperature, 35- 42 % RH for 28 days - With 1.5% conc. ripening process was delayed and overall quality was maintained and shelf life was extended	(Paladugu & Gunasekaran, 2017)
2	Tomatoes	Two factors were studied together, edible coating (pectin and chitosan) and harvesting ripening stages (mature green, turning and light red stages)	- 22°C±1 and RH of 74.5%±1 - Coating delayed ripening and improves functional component profile, - In combination any coating at turning stage gives best result	(Abebe et al., 2018)
3	Fresh-cut Cherry tomatoes	Chitosan as gel and as solid against three strains of fungi were tested. Tomato slices were immersed in solutions Chitosan, commercial chitosan and acetic acid and compared afterwards.	- In gel form it was effective against penicillium strain in 0.2-0.6 g/l while stable films were formed by commercial chitosan	(Leandro et al., 2018)
4	Cherry tomatoes	Grapefruit seed extract (GSE)-containing chitosan-based coating to inhibit salmonella invasion and improve storability	- This coating does not affect sensory properties or lycopene concentration but provides microbiological safety - Stored at 25 ºC	(Won et al., 2018)
5	Fresh tomatoes	Cassava starch based coating compared with commercial coating Semperfresh^{TM}	- Changes in firmness was delayed and overall acceptability was improved - Stored at 20°C for 4 weeks	(Adjouman et al., 2018)
6	Fresh tomatoes	Lactobacillus supernatant (irradiated and unirradiated) with glycerol, gelatin and starch. This special coating has antimicrobial properties against pathogenic bacteria.	- Tomato decay percentage was decreased with both treatments as compared to control and pathogenic bacterial loads were also lower down. antimicrobial activity of lactobacillus was increased at 3.5 KGy irradiation dose	(Khalil et al., 2020)
7	Fresh tomatoes	Aloe vera gel based edible coating from 0-20%	- 14 days storage at 11ºC and 90% RH - Ethylene production and ripening index was reduced - With 20% aloevera gel lycopene and beta carotene were reduced but phenolic contents were increased. The best results were achieved from 10% aloevera gel coating	(Chrysargyris et al., 2016)

Table 2 (Continued).

8	Fresh tomatoes	Chitosan based coating with pequi peel extract	- 22ºC for 16 days - Weight loss was reduced up to 22% while color variation was reduced up to 50%. Overall microbiological quality was improved due to PPE antifungal properties.	(Breda et al., 2017)
9	Fresh tomatoes	An innovative bacteriophage carrier edible coating to control bacterial growth. Bacteriophages were isolated to test against various E coli strains. The base material was chitosan and phages were isolated from beef meat and goat stool	- Chitosan based coating was suitable to stabilize phages by keeping its lytic activity intact. This whole functional coating idea with antimicrobial properties enhances the microbial safety of tomatoes during storage. This antimicrobial coating is useful against pathogenic strains due to its slow and steady release in medium.	(Amarillas et al., 2018)
10	Fresh tomatoes	Mango kernel starch (MKS) with additives like plasticizers (Sorbitol and glycerol)	- Stored at room temperature - Ripening was delayed in coated fruits up to 20 days. The better results were obtained with sorbitol. Overall quality was maintained and shelf life was prolonged	(Nawab et al., 2017)

CONCLUSION

Tomatoes being the fragile fresh produce with soft texture, are more prone to mechanical injuries, and bruises during postharvest handling, storage and transportation. Tomato is economically and nutritionally significant food commodity with a higher percentage of postharvest losses. These losses can be prevented by adopting lightly processed and technologically viable techniques like the application of an edible coating. The literature review above shows numerous studies validating the point that edible coatings with different formulations can improve the quality and safety aspects of tomatoes and can also extend the shelf life of tomatoes. There are many new techniques that should be adopted like micro-encapsulation and nano-laminates. Composite and multi-layer coatings result in an even more extended shelf life. Extensive research is needed to know which stage of tomato maturity is appropriate for applying edible coating so that we can reap the maximum benefit from this technique.

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