www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(6): 71-77

www.thepharmajournal.com
Received: 18-04-2023
Accepted: 22-05-2023

Nanakpreet Kaur
Student, Department of Food Science and Technology, Lovely Professional University Phagwara, Punjab, India

Corresponding Author:
Nanakpreet Kaur
Student, Department of Food Science and Technology, Lovely Professional University Phagwara, Punjab, India

Utilization of fruits and vegetables by-products in the preparation of edible films

Nanakpreet Kaur

Abstract
In today's era with the advancement of technology in every sector, food industries are also seeking for new inventions in the packaging unit operations due to multiple ill effects of traditional version of packaging materials which are constantly giving rise to environmental pollution. Edible films are manufactured in order to enhance food product quality, shelf life extension, safeguarding food from numerous atmospheric conditions with additional benefits such as providing antioxidant, antimicrobial, and nutritional properties. By-products of fruits and vegetables are rich source of vitamins, minerals, dietary fibres, proteins and bioactive compounds which are discarded as waste and loss of nutrition in the form of peels, pomace and seeds ultimately leads to environmental hazards. Edible films production is the best alternative to prevent food waste and reduction in the use of plastic based packaging materials. The current review focuses on the edible films prepared using by-products of fruits and vegetables, components of edible films and application of edible films in the preservation of fruits and vegetables.

Keywords: Edible films, By-products utilization, food preservation, fruit and vegetable waste, biodegradable

Introduction

Fruits and vegetables are loaded with multiple nutrients and highly consumable foods amongst the horticulture crops. With the changing lifestyle and diet patterns of folks the production and processing of horticulture crops is rising due to its high demand. As the consumption of these food products is more thus huge of amounts of waste is generated from various fruits and vegetable processing industries and household kitchen waste which increase the environmental pollution when accumulated in open (Kumar *et al*., 2021) [16]. The food waste generated in the European Union is approximately 89 million tons and this is expected to grow more by 40-fold in upcoming years. Fruits and vegetable waste is indigestible components which are generally not consumed and thrown at various levels such as during collection, handling, transportation and processing (Plazzotta *et al*., 2017) [34]. There are numerous by-products obtained during processing of fruits and vegetables such peels, stones, pomace, seeds which are loaded with various bioactive compounds, dietary fibres, and phenolic compounds and these compounds can be utilized in production of edible films (Rasid, Nazmi, Isa, & Sarbon, 2018) [35]. The traditional food packaging materials are replaced with the new biodegradable edible films which are made up from various food waste materials such as fruit and vegetable peels, pomace and hence the food waste is converted into wealth. Nowadays due to emergence of new technologies namely extraction of biopolymers and bioactive compounds led to increase the production of edible films and bioplastics (Esparza *et al*., 2020) [8]. Packaging is necessary unit operation in the food industry which aids to keep the food product unaffected during storage, transportation, handling and distribution. Packaging is mainly done to preserve the food materials from various atmospheric and external effects such as biological, chemical and mechanical damage; for containment, preservation, reduction of quality deterioration also to attract the end users as well as showcase of product and nutritional information (Sarkar & Kuna 2020). Edible films are delicate layers of edible materials which are applied to the food products for the enhancement of shelf life as well as protect the food and its constituents from degradation (Ribeiro *et al*., 2021). Traditional food packaging materials for instance plastic, metal, paper and glass have had some constraints comparing with edible food packaging. For instance plastic packaging materials (polyethylene, polyethylene terephthalate and polypropylene are considered to be harmful for the environment (Sundqvist-Andberg and Akerman 2021) [44]. There is an alarming need to shift from conventional polymers to biopolymers as these are beneficial in number of ways such as biodegradable nature, sustainable, recyclable and these are starch, proteins and lipids which can used in the production of food packaging materials (Lisitsyn *et al*., 2021) [20]. To overcome the problems caused by traditional/conventional food packaging materials, researchers are focusing on conversion of food waste and by-products of various fruits and vegetables into more useful products such as edible films (Tumwesigye *et al*., 2016; Torres-Leon *et al*., 2018) [47, 26].

The review focuses on the utilization of fruits and vegetables waste products in the preparation of edible films. Brief about edible films and its components various types of by-products of fruits and vegetables. Different types of edible films from fruits and vegetables waste as well as applications of edible films in preservation of fruits and vegetables.

Edible films

Edible films and coating are delicate layers of edible materials having thickness below 0.3 mm, which are generally utilized to safeguard food, enhances quality as well as eaten as essential component of the food product (Jeevahan and Chandrasekaran 2019; Parreidet *et al*., 2018) [11, 32]. Edible packaging is one of the essential alternative for the end users nowadays because of its ability to solve resolve the problems caused by plastic packaging materials, as these are biodegradable and do not cause harm to environment (Calva-Estrada *et al*., 2019; Hassan *et al*., 2018; Jeevahan and Chandrasekaran 2019; Mkandawire and Aryee 2018) [5, 11, 10]. Edible films prevents water and gas losses, mobility of solutes from the food, and allow some of the essential gas exchanges namely oxygen, carbon dioxide and ethylene which are necessary for respiration of foods (Dehghani *et al*., 2017) [7]. Edible films are synthesized by using edible materials, that can be kept in direct contact with food components (final food products) causes no harm to the food provides extra benefits such as edibility, biodegradability, reduction of waste as well as utilizes the industrial by-products (Hassan *et al*., 2018; Jeevahan and Chandrasekaran 2019; Murrieta-Martinez *et al*., 2018) [10, 11, 26].

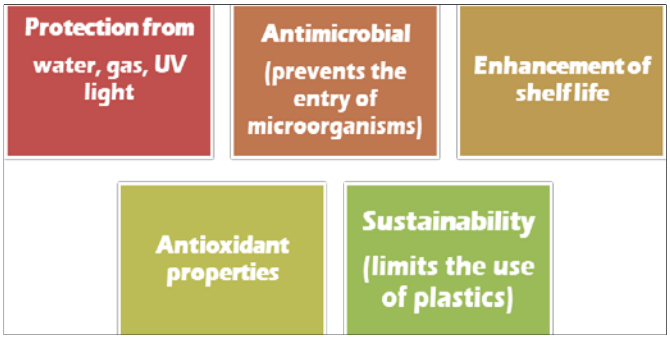


Fig 1: Various functional properties of edible films

Materials for edible films

Edible films are categorized into three main groups on the basis of materials used in their production: polysaccharides, proteins and lipids (Saklani *et al*., 2019) [40]. Edible films require edible materials for film preparation. Ample of edible materials could be taken from various animal, plant sources animal proteins, plant protein, polysaccharides, lipids. Milk, muscle protein, wool/feather egg white some of the animal protein sources whereas soybean, wheat gluten, corn zein and sunflower proteins are plant proteins. Polysaccharides include aliganate, chitosan, starches, cellulose derivatives, pullulan, gums and whole grain materials.Agro industrial residues are sugarcane bagasse, wine manufacture waste, fruit and vegetable residues such as pomace, peels and seeds (Galus *et al*., 2021) [9].

Table 1: Edible materials and their functions

Materials	Examples	Functions	References
polysaccharides	Starch Chitosan Methyl Cellulose Persian gum	Thickening agent Antimicrobial agent Excellent film forming ability Thickener	Jimnenez *et al*., (2014). (Singh *et al*., 2015) [43] (Khan *et al*., 2018) [13] (Pak *et al*., 2020) [30]
Proteins	Sesame Whey protein Wheat gluten films	Good nutritional, mechanical and barrier properties Preservation of foods loaded with polyunsaturated fatty acids Barrier to gases, excellent mechanical and nutritional properties	(Sharma *et al*., 2018) [42] (Oses *et al*., 2008) [28] (Mojumdar *et al*., 2011) [24]
Lipids	Palm fruit oil	Antimicrobial properties and excellent barrier to water due to hydrophobic nature Excellent barrier to water	(Hassan *et al*., 2018) [10].
Additives			
Plasticizer	Glycerol and Sorbitol	Provides flexibility, regidity	(Calva-Estrada *et al*., 2019) [5]

Basic components of edible films

Proteins

Proteins are important sustainable macromolecule or organic polymer in the manufacturing of edible films. These are polymers of amino acids which are different for different protein type. Proteins as a edible material in the film preparation helps in reducing wetness damage, slowdown movement of lipids, enhances mechanical properties as well as amplify the food quality and possesses the potential to transport anti-microbial materials, flavors and colors (Hashimi *et al*., 2019). Film forming abilities of ample of proteins, both plant (zein, gluten, soy protein) as well as animal (gelatin, casein, whey proteins) origin have been interestingly researched over past three decades (Durdica *et al*., 2014). Multiple researches have been conducted to manufacture bioplastics by using protein as a basic component as it possess ample of applications in food industries (Li *et al*., 2018).

Lipids

Dietary fats constitute triacylglycerols, phospholipids and cholesterol. Lipids are basically water hating so these are not soluble in water and are not carried into blood, for this purpose nature has devised these to bind with proteins to make them soluble in blood stream (Bali and Utaal 2019) [3]. Lipids being insoluble in water possess some advantages such as these prevent moisture which results in the reduction of microbial and physiochemical destructions. Utilization of lipids in various product formation possess numerous benefits, for instance; edible films prepared using lipids as one of the constituent plays crucial role in good barrier properties, brittleness as well as water vapor transmission. Lipids utilized in biofilming are classified mainly into two groups and four subgroups. Lipids have generally two major groups which are polar and non polar. Waxes are the example of non polar group, they do not have any polar constituent hydrocarbon ultimately they do not possess any interaction with water which clearly states that these are insoluble in water thus waxes plays significant role in resisting the water vapour transmission in edible films. Triglycerides belong to class I of polar lipids. Moisture resistance quality of edible films increases with addition of certain lipids such as stearic, lauric, palmitic acids and stearyl alcohol. Depending on chain length the monoglycerides belongs to class II or III (Aydin *et al*., 2017) [1]. Fats are constituted of triglycerides which are generally derived from plants sources. Edible palm fruit oil also used to prepare films possesses ample of advantages such increased elongation, and enhanced resistance to water. Edible oils have numerous benefits such as enhanced antimicrobial properties, excellent resistance to water vapour transmission, insolubility in water, for instance clove oil, thyme oil, lemon peel oil are some of the essential oils which aids in enhancement of antimicrobial properties in various edible films for packaging purpose (Hassan *et al*., 2018) [10].

Polysaccharides

Polysaccharides belong to the third important class of biopolymers (carbohydrates) which provides structure, protection, adhesion, stimuli responsiveness as well as play essential role in the immunity enhancement, clotting of blood, fertilization and protection from various diseases as well as these possess certain antimicrobial, anticancer, antioxidant properties which enables them to be useful in various sectors such as food, pharmaceuticals and medical fields. These are plentiful macromolecules which occur in nature gathered from renewable sources namely plants, fungi, bacteria and algae (Mohammed *et al*., 2021) [23]. Despite of ample of benefits in pharmaceuticals, polysaccharides have gained essential properties in food applications namely least toxic, biodegradability, biocompatibility, easily processed and mouldability. Edible films prepared from polysaccharides have multiple advantages such as extension of shelf life, stability, biodegradable ultimately environment friendly. For instance chitosan, cellulose, pectin, carrageenan, gums, pullulan as well as starch are the major polysaccharides utilized in the edible film preparation (Kong *et al*., 2022) [14].

Composite materials

In order to enhance the functional properties of edible films, composite materials are made by intermixing different materials which are edible in nature. For instance combination of proteins and polysaccharides possesses excellent resistance to gas, and less resistance to water vapour transmission. Hybrid of two or more edible materials increases the complete strength of the packaging, for example composite edible films manufactured by adding fats and oil into the protein and polysaccharides films. Barrier to water vapours and oxygen increases by the incorporation of fats and oils in the composite edible films (Kumar *et al*., 2021) [16].

By- products of fruits and vegetables

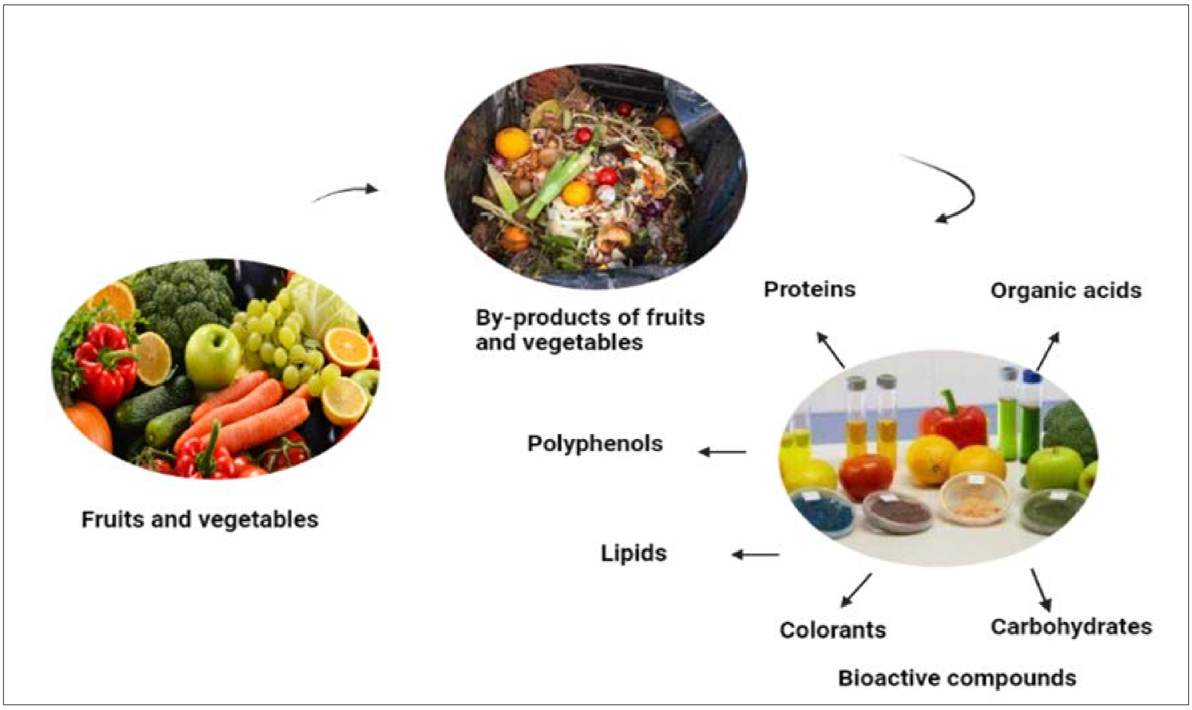
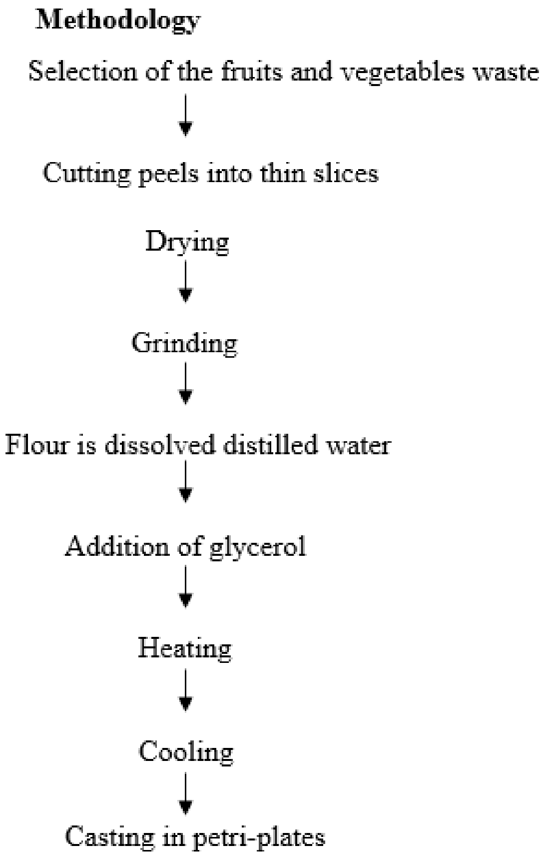


Fig 2: By-products of fruits and vegetables

Production of fruits and vegetables has been increased tremendously due to rising population and to meet the required demand. Fruits production in years 2017 increased approximately 0.9 million tons and vegetables more than 1 billion tons (Bayram *et al*., 2021). Vegetables with largest production are onions, potatoes, tomatoes, cucumbers and cabbages. Waste generated from fruits and vegetables is also increasing for instance mango (60%), passion fruit (45%), peas (40%), pineapple (33%), citrus fruits (50%), pomegranate (40%). By-products generated from fruit and vegetables are peels, pomace and seeds which are essential sources of bioactive compounds namely proteins, dietary fibres, lipids colorants and certain phytochemicals (Sagar *et al*., 2018; Trigo *et al*., 2019) [39, 46]. Essential bioactive compounds extracted from the by-products of fruits and vegetables posses ample of health benefits namely antioxidants, anti-diabetic, anticarcinogenic, cardioprotective, as well as antimicrobial effects (Baiano 2014; Sagar *et al*., 2018) [2, 39].

Edible films from fruits and vegetable by-products:
Fruits and vegetables are natural sources of many macro as well as micronutrients such as proteins, carbohydrates, lipids, vitamins and minerals. So research on the by-products of fruits and vegetables which are rich in certain bioactive compounds is increasing day by day to utilize the waste by preparing ample of value added products. Saberi *et al*., (2017) [38] stated that ample of polyphenols such as flavonoids and proanthocyanidins are isolated from vegetables and fruits and important sources of bioactive compounds. These compounds are utilized in human diet as effective antioxidants which provide prevention against fatal diseases such as cancer, cardiovascular diseases, obesity and diabetes. The banana peels are also natural source of antioxidants and phytochemicals such as catecholamines. Otoni *et al*., (2017) [29] stated that fruits and vegetables by products are underutilized such as purees, pomaces, due to low market value. For instance apple processing industry generates 9000 tons of apple peels waste each year, the waste generated from fruit juice industry is loaded with certain bioactive compounds such as pectin, dietary fibres and phytochemicals.



Mango peel based edible films
Rojas-Bravo *et al*., (2019) [37] prepared edible films from Mango (Mangifera indica L. cv Manila) Peel Powder to enhance the total phenolic compounds and antioxidant property of films. Mango is excellent source of polyphenolic compounds having antioxidant property which safeguards the human body from oxidative stress. Mango peel is also loaded with ample of bioactive compounds such flavonoids (mangiferin, quercetin, and anthocyanins), phenolic acids (gallic acid and hydroxybenzoic acid) and carotenoids. Results indicated that the antioxidant value increased by increasing the concentration of mango peel powder. Leon *et al*., *(*2018) developed the biodegradable edible films formulated with mango peel which is fruit waste and converted into useful active packaging materials with certain additional properties such as optical, barrier, also antioxidant properties, and a green packaging. The edible films were evaluated on the basis of antioxidant, barrier, mechanical as well water vapour transmission rate. The results revealed that the films prepared from mango waste showed excellent barrier properties, water vapor permeability varies from from 0.88 × 10−10 - 1.00 × 10−10 g m−1 s−1 Pa−1. The scavenging activity of the films and the polyphenol content was increased by 18% and 60%.

Pumpkin by-products based edible films
Lalnunthari *et al*., (2019) [18] studied the extraction of protein and pectin from pumpkin by-products and utilized in development of edible films. Pectin was extracted from pumpkin peel powder, protein was extracted from pumpkin seeds, and mixed in different ratios such as 100:0 (F1), 50:50 (F2), 0:100 (F3) and then 5g/100 ml dissolved in distilled water heated and mixed at 90°C for 1 hr. 40% glycerol was added as a plasticizer. The film forming solution was poured into petri plates and kept in tray drier for (50 ± 2 _C, 8 h). 2% solution of calcium chloride was poured on the films followed by drying and then finally peeled off for further analysis. Results indicated that the films barrier and mechanical properties were of acceptable range (Tensile strength: 2.04–5.28 MPa; elongation: 13.13–14.37%; water vapour permeability: 3.24 9 10-6– 6.24 9 10-6 g/Pa m h).

Apple peel edible films
Brakut *et al*., (2021) [4] developed edible films based on apple peel. Films were prepared using apple peels, which were washed properly and sun dried and grinded into fine powder by electric blender, 3 g of peel powder was dissolved in 100 ml distilled water by constant stirring using magnetic stirrer for 5 min, followed by heating at 80 °C for 30 minutes and glycerol was added as plasticizer for enhanced flexibility. The film forming solution was poured into petri plates and air dried for 24 hr at room temperature. Calcium chloride 2% was added as cross linking agent and films were dried again and finally peeled off for further analysis.

Banana peel flour based edible films
Salazar *et al*., (2021) [41] prepared edible films based on Green Banana (Musa acuminata AAA) Wastes for food applications. Green bananas which were not utilized for consumption or export were selected, washed and sliced. Two types of slices were taken, one was whole banana slice which includes peel and pulp another was only banana peel slices. The slices were dried using convective oven dryer at 60 °C for 6 hr and ground to fine powder. The edible films were prepared using casting methodology. The banana flours were added in 100 ml distilled water and dissolved until complete dissolution followed by addition of glycerol and the solution was heated at 90-95 °C for 5 min and cooled for 50 °C and finally 25 g of film forming solution was casted over Petri plates, followed by drying at 60 °C for 8 hr. films were used as wrap for chicken breast and grilled chicken and a green banana flour proved to be a worthy material to develop edible films for food applications.

Blue berry residue-extract films

During the processing of blue berries, huge amount of by-products are generated in the form of seeds, peels and stems which are the essential source of bioactive compounds such as polyphenols and anthocyanins. Blue berry extracts were isolated by using ultrasound extraction method. The extract was further analyzed for total antioxidant and phenolic content. Glycerol was used as plasticizer and corn starch was used to bind the films. The results showed that, grammage of films was ranging from 0.0131 to 0.0143 g/cm², range of moisture content was 17.19-1800 %, thickness was 0.15- 0.23 mm and total antioxidant activity of the blue berry extract ranged between 52.65-76.02% (Griep *et al*., 2023).

Persimmon fruit based films

Persimmon fruit showed carbohydrate profile suitable for acquire biopolymer-based films (Matheus *et al*., 2021) [22]. It is a fruit with ample of bioactive compounds having antimicrobial and antioxidant properties, such as carotenoids, tannins, phenolic compounds and others (Persic *et al*., 2018) [33]. Edible films were prepared using different concentrations of persimmon fruit puree, glycerol and pectin per kilogram of puree. The film forming solutions were homogenized for 3 min commercial blender and casted on polystyrene plates dried in a ventilated oven for 55 °C for 20 hr and peeled off for further analysis. Results showed that the films were orange in color, malleable, with minor pores on the surface, with no cracks (Matheus *et al*., 2021) [22]. Films showed high thickness, as the viscous solution formed thicker films (Arquelau *et al*., 2019).

Potato peel based edible films

Gebrechristos *et al*., (2019) prepared the edible films based on the potato peel extract as an antimicrobial and potential antioxidant value. The study showed that the potato peel is a phenolic-rich plant by product that has the ample of biological functions. The results explored the antimicrobial efficiency of the peel and its scavenging properties incorporated with potato starch edible films. Antimicrobial test showed the positive response in *Escherichia coli*, *Salmonella enterica*, and *Staphylococcus aureus* with minimum inhibitory concentration of 7.5±2, 5.8±2, and 4.7±1 mg/ml, respectively. For *Klebsiella pneumoniae* and *Listeria monocytogenes* there was a negative response. The HPLC test results showed that the *caffeic, chlorogenic,* and *neochlorogeni* acids were the main compounds which showed antimicrobial property. The antioxidant activity and the phenolic content in the active films was from 10 to 22 mg GAE/g of the dried film with 24%–55% of inhibition, respectively. The structure of the films was scanned by scanning electron microscope which was ordered and some of the cracks and pores were visible in the active film. The active edible films based on the potato peel can used as a active food packaging material in the food industry.

Application of edible films in preservation of fruits and vegetables

Nowadays, folks are aware about healthy diet and consuming more of fruits and vegetables as these are loaded with essential vitamins and minerals as well as antioxidants and fibers. Masses showed more interest in foods which are healthy as well as consume less time in preparation (Hassan *et al*., 2018; Parreidt *et al*., 2018) [32, 10]. Fruits and vegetables are perishable in nature thus are more prone to be attacked by microorganisms. Some of the factors which are responsible for quality deterioration of fruits and vegetable are respiration, ethylene synthesis, reduction of moisture with time, urges the food industries to increase their shelf life by using some alternatives (Kumar *et al*., 2021c; Olivas and Barbosa-Canovas 2009) [16]. Edible films and coatings are suitable for preservation of fruits and vegetable by providing them a thin delicate layer to protect them from external factors for instance, Aloe vera gel acts as a semipermeable membrane and aids in reduction of respiration, excellent antioxidant, antimicrobial, properties, reduces the aging and can be eaten by humans without affecting their health as a coating over the fruits and vegetables and enhances the shelf life of the foods (Nicolau-Lapena *et al*., 2021) [27]. Sodium alginate is also one such example of polysaccharides isolated from brown algae. Being water soluble it exhibits excellent film forming potential. It possesses desirable oxygen barrier properties, thus helps in controlling respiration rates of fruits and vegetables (Kontominas 2022) [15].

Edible films made using apple peel using glycerol as plasticizer utilized in enhancement of fresh cut apple slices which provides 100% inhibition to browning reactions for 10 days (Brakut *et al*., 2021) [4]. Edible films prepared from papaya incorporated with ascorbic acid and Moringa oleifera to preserve minimally processed pears provides excellent sensory acceptance and good antioxidant properties (Rodriguez *et al*., 2020). Edible composite films made using combination of chitosan and gelatin used as packaging materials provides excellent barrier, mechanical, and antimicrobial properties, cherry tomatoes were coated with gelatin and chitosan incorporated with grapefruit seed extract and stored for 7 days. The results revealed that in cherry tomatoes there was no change in the hardness, colour and weight (Choi *et al*., 2023) [6].

Conclusion

Edible packaging is nowadays becoming widespread in food sector due to its numerous benefits such as biodegradability, biocompatibility, edibility as well as sustainability and changed the old version of packaging technique into advanced active edible packaging for food applications. The materials used in the preparation of edible films/edible packaging are food grade and do not cause any harm to human health as well as the surrounding environment. The approval to use these materials is provided by Food and Drug Administration USA and European Food Safety Authority. Edible films made from fruits and vegetable waste possess ample of functional properties such as high nutritional content, antimicrobial, antioxidant, properties. These films as packaging materials are not completely eliminating the traditional packaging but possess certain extra benefits. Food Scientists has reviewed edible films, its preparation as well as application of edible films in the food industries. Researchers are nowadays giving attention towards the development and improvement in the functional properties of edible films so that these can be commercialized.

References

1. Aydin F, Kahve HI, Ardic M. Lipid-based edible films. The Journal of Scientific and Engineering Research. 2017;4(9):86-92.
2. Baiano A. Recovery of biomolecules from food wastes—A Review. Molecules. 2014;19:14821–14842.
3. Bali S, Utaal M. Serum lipids and lipoproteins: a brief review of the composition, transport and physiological

functions. International Journal of Scientific Reports. 2019;5(10):309-314.
4. Brakut N, Hirye P, Dhaye K, Pawar V, Vaibhav P, Acharya S. Edible films made from apple peel. International Journal of Food Sciences and Nutrition, 2021;6(2):91-94.
5. Calva-Estrada SJ, Jimenez-Fernandez M, Lugo-Cervantes E. Protein-Based Films: Advances in the Development of Biomaterials Applicable to Food Packaging. Food Engineering Reviews. 2019;11:78-92.
6. Choi I, Lee BY, Kim S, Imm S, Chang Y, Han J. Comparison of chitosan and gelatin-based films and applicationto antimicrobial coatings enriched with grapefruit seed extract for cherry tomato preservation. Food Science and Biotechnology. 2023.
7. Dehghani S, Hosseini SV, Regenstein JM. Edible films and coatings in seafood preservation: A review. Food Chemistry. 2018;l240:505–513.
8. Esparza I, Jiménez-Moreno N, Bimbela F, Ancín-Azpilicueta C, Gandía LM. Fruit and vegetable waste management: conventional and emerging approaches. J Environ Manag. 2020;265:110510.
9. Galus S, Arik Kibar EA, Gniewosz M, Krasniewska K. Novel Materials in the Preparation of Edible Films and Coatings—A Review. Coatings. 2020;10(7):674.
10. Hassan B, Chatha SAS, Hussain AI, Zia KM, Akhtar N. Recent advances on polysaccharides, lipids and protein based edible films and coatings: A review. Int J Biol Macromol. 2018;109:1095–1107.
11. Jeya Jeevahan J, Chandrasekaran M, Venkatesan SP, Sriram V, Britto Joseph G, Mageshwaran G. Scaling up difficulties and commercial aspects of edible films for food packaging: A review. Trends Food Sci Technol. 2020;100:210–222.
12. Jimenez A, Fabra MJ, Talens P, Chiralt A. Edible and Biodegradable Starch Films: A Review. Food Bioprocess Technol. 2012;5:2058-2076.
13. Khan A, Niazi MBK, Naqvi SR, Farooq W. Influence of Plasticizers on Mechanical and Thermal Properties of Methyl Cellulose-Based Edible Films. J Polym Environ, 2018;26:291-300.
14. Kong I, Degraeve P, Pui LP. Polysaccharide-Based Edible Films Incorporated with Essential Oil Nanoemulsions: Physico-Chemical, Mechanical Properties and Its Application in Food Preservation—A Review. Foods. 2020;11(4):555.
15. Kontominas MG. Use of alginates as food packaging materials. Foods. 2020.
16. Kumar A, Gupta V, Singh S, Saini S, Gaikwad KK. Pine needles lignocellulosic ethylene scavenging paper impregnated with nanozeolite for active packaging applications. Ind Crops Prod. 2021c;170:113752.
17. Kumar L, Ramakanth D, Akhila K, Gaikwad KK. Edible films and coatings for food packaging applications: A review. Environmental Chemistry Letters. 2022;20:875-900.
18. Lalnunthari C, Devi LM, Badwaik LS. Extraction of protein and pectin from pumpkin industry byproducts and their utilization for developing edible film. J Food Science Technol. 2020;57(5):1807-1816.
19. Li M, Zhang F, Liu Z, Guo X, Wu Q, Qiao L. Controlled release system by active gelatin film incorporated with β-cyclodextrin-thymol inclusion complexes. Food and Bioprocess Technology. 2018;11(9):1695–1702.
20. Lisitsyn A, Semenova A, Nasonova V, Polishchuk E, Revutskaya N, Kozyrev I. Approaches in Animal Proteins and Natural Polysaccharides Application for Food Packaging: Edible Film Production and Quality Estimation. Polymers. 2021;13(10):1592.
21. Matheus JRV, de Andrade CJ, Miyahira RF, Fai AEC. Persimmon (Diospyros Kaki L.): chemical properties, bioactive compounds and potential use in the development of new products – A review. Food Reviews International. 2020, 1–18.
22. Matheus JRV, de Assis RM, Correia TR, da Costa Marques MR, Leite MCAM, Pelissari FM. Biodegradable and Edible Film Based on Persimmon (Diospyros kaki L.) Used as a Lid for Minimally Processed Vegetables Packaging. Food and Bioprocess Technology. 2021;14:765-779.
23. Mohammed A, Naveed M, Jost N. Polysaccharides; Classification, Chemical Properties, and Future Perspective Applications in Fields of Pharmacology and Biological Medicine (A Review of Current Applications and Upcoming Potentialities). Journal of Polymers and the Environment; c2021.
24. Mojumdar SC, Moresoli C, Simon LC, Legge RL. Edible wheat gluten (WG) protein films. J Therm Anal Calorim, 2011;104:929-936.
25. Murrieta-Martínez CL, Soto-Valdez H, Pacheco-Aguilar R, Torres- Arreola W, Rodríguez-Felix F, Márquez-Ríos E. Edible protein films: sources and behavior. Packaging Technology and Science. 2018;31:113–122.
26. Murrieta-Martínez CL, Soto-Valdez H, Pacheco-Aguilar R. Torres- Arreola, W., Rodríguez-Felix, F., & Márquez-Ríos, E. Edible protein films: sources and behavior. Packaging Technology and Science. 2018;31:113–122.
27. Nicolau-Lapeña I, Colàs-Medà P, Alegre I, et al. Aloe vera gel: An update on its use as a functional edible coating to preserve fruits and vegetables. Prog Org Coatings. 2021.
28. Oses J, Fernandez- Pan I, Ziani K, Mate JI. Use of edible Wlms based on whey protein isolate to protect foods rich in polyunsaturated fatty acids. Eur Food Res Technol, 2008;227:623-628.
29. Otoni CG, Avena-Bustillos RJ. Azeredo HMC, Lorevice MV, Moura MR, Mattoso LHC. Recent Advances on Edible Films Based on Fruits and Vegetables—A Review. Comprehensive Reviews in Food Science and Food Safety. 2017;16:1151-1169.
30. Pak ES, Ghaghelestani SN, Najafi MA. Preparation and characterization of a new edible film based on Persian gum with glycerol plasticizer. J Food Sci Technol. 2020;57(9):3284-3294.
31. Parreidt TS, Lindner M, Rothkopf I, Schmid M, Müller K. The development of a uniform alginate-based coating for cantaloupe and strawberries and the characterization of water barrier properties. Foods. 2019;8:1–21.
32. Parreidt TS, Muller K, Schmid M. Alginate-based edible films and coatings for food packaging applications. Foods, 2018;7:1–38.
33. Persic M, Jakopic J, Hudina M. The effect of post-harvest technologies on selected metabolites in persimmon (Diospyros Kaki Thunb.) fruit. Journal of the Science of Food and Agriculture. 2018;99(2):854–860.
34. Plazzotta S, Manzocco L, Nicoli MC. Fruit and vegetable waste management and the challenge of fresh-cut salad.

Trends Food Sci. Technol. 2017;63:51–59.
35. Rasid NAM, Nazmi NNM, Isa MIN, Sarbon NM. Rheological, functional and antioxidant properties of films forming solution and active gelatin films incorporated with Centella asiatica (L.) urban extract. Food Packaging and Shelf Life. 2018;18:115–124.
36. Rodríguez GM, Sibaja JC, Espitia PJP, Otoni CG. Antioxidant active packaging based on papaya edible films incorporated with Moringa oleifera and ascorbic acid for food preservation. Food Hydrocolloids, 2019, 105630.
37. Rojas-Bravo M, Rojas-Zenteno EG, Hernandez-Carranza P, Avila-Sosa R, Aguilar-Sanchez R, Ruiz-Lopez II. A Potential Application of Mango (Mangifera indica L. cv Manila) Peel Powder to Increase the Total Phenolic Compounds and Antioxidant Capacity of Edible Films and Coatings. Food and Bioprocess Technology. 2019;12:1584-1592.
38. Saberi B, Vuong QV, Chockchaisawasdee S, Golding JB, Scarlett CJ, Stathopoulos CE. Physical, Barrier, and Antioxidant Properties of Pea Starch-Guar Gum Biocomposite Edible Films by Incorporation of Natural Plant Extracts. Food Bioprocess Technol. 2017;10:2240-2250.
39. Sagar NA, Pareek S, Sharma S, Yahia EM, Lobo MG. Fruit and vegetable waste: Bioactive compounds, their extraction, and possible utilization. Compr. Rev. Food Sci. Food Saf. 2018;17:512–531.
40. Saklani PS, Nath S, Kishor Das S, Singh SM. A review of edible packaging for foods. Int J Curr Microbiol Appl Sci. 2019.
41. Salazar D, Arancibia M, Casado S, Viteri A, Lopez-Caballero ME, Montero MP. Green Banana (Musa acuminata AAA) Wastes to Develop an Edible Film for Food Applications. Polymers. 2021;13:3183.
42. Sharma L, Sharma HK, Saini CS. Edible films developed from carboxylic acid cross linked sesame protein isolate: barrier, mechanical, thermal, crystalline and morphological properties. J Food Sci Technol. 2018;55:532-539.
43. Singh TP, Chatli MK, Sahoo J. Development of chitosan based edible films: Process optimization using response surface methodology. J Food Sci Technol. 2015;52:2530-2543.
44. Sundqvist-Andberg H, Åkerman M. Sustainability governance and contested plastic food packaging – An integrative review. J Clean Prod. 2021;306:127111.
45. Torres-León C, Ramírez-Guzman N, Londoño-Hernandez L, Martinez-Medina GA, Díaz-Herrera R, Navarro-Macias V. Food Waste and Byproducts: An Opportunity to Minimize Malnutrition and Hunger in Developing Countries. Front. Sustain. Food Syst, 2:52.
46. Trigo JP, Alexandre EMC, Saraiva JA, Pintado ME. High value-added compounds from fruit and vegetable by-products— Characterization, bioactivities, and application in the development of novel food products. Crit. Rev. Food Sci. Nutr. 2019.
47. Tumwesigye KS, Oliveira JC, Sousa-Gallagher MJ. New sustainable approach to reduce cassava borne environmental waste and develop biodegradable materials for food packaging applications. Food Packag. Shelf Life. 2016;7:8–19.