Research, Society and Development, v. 9, n. 8, e756986018, 2020
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i8.6018

Revestimentos comestíveis usados para conservação de vegetais minimamente processados: uma revisão

Edible coatings used for conservation of minimally processed vegetables: a review

Recubrimientos comestibles utilizados para la conservación de verduras mínimamente procesadas: una revisión

Recebido: 25/06/2020 | Revisado: 09/07/2020 | Aceito: 14/07/2020 | Publicado: 19/07/2020

Maria Clara Guimarães
ORCID: https://orcid.org/0000-0002-5512-1163
Universidade Federal Rural do Rio de Janeiro, Brasil
E-mail: mcguimaraes@id.uff.br
Joyce Fagundes Gomes Motta
ORCID: https://orcid.org/0000-0001-8591-7472
Universidade Federal Rural do Rio de Janeiro, Brasil
E-mail: joycefgmotta@hotmail.com
Dayana Ketrin Silva Francisco Madella
ORCID: https://orcid.org/0000-0002-2677-7120
Universidade Federal Rural do Rio de Janeiro, Brasil
E-mail: dayanaketrin@hotmail.com
Lívia de Aquino Garcia Moura
ORCID: https://orcid.org/0000-0001-9905-1059
Universidade Federal Rural do Rio de Janeiro, Brasil
Universidade Federal Fluminense, Brasil
E-mail: livia.lag@gmail.com
Carlos Eduardo de Souza Teodoro
ORCID: https://orcid.org/0000-0001-8591-0502
Universidade Federal Fluminense, Brasil
E-mail: carlosteodoro@id.uff.br
Nathália Ramos de Melo
ORCID: https://orcid.org/0000-0002-9533-506X
Universidade Federal Rural do Rio de Janeiro, Brasil
Universidade Federal Fluminense, Brasil
E-mail: nathaliarm@id.uff.br

Resumo

O mercado de vegetais minimamente processados (VMP) vem crescendo nas últimas décadas. Esse crescimento está relacionado com a mudança no estilo de vida e hábitos alimentares dos consumidores, que buscam alimentos práticos e saudáveis para consumo. Manter as características e qualidade dos VMP é um dos principais desafios dos produtores e comerciantes. Etapas do processamento mínimo aumentam a perecibilidade desses VMP, aumentando reações oxidativas e elevando da sua taxa metabólica. Pesquisas voltadas para desenvolvimento de tecnologias que reduzam essas reações ganharam destaque. Filmes e revestimentos comestíveis produzidos de fontes naturais surgiram como embalagens alternativas para aplicações em alimentos e receberam atenção devido às suas vantagens como natureza biodegradável e renovável, disponibilidade e custo. O uso de revestimentos comestíveis na conservação de vegetais na condição pós-colheita, sejam intactos ou minimamente processados, têm sido apontados como uma tecnologia emergente e de grande potencial, visto que conseguem controlar a atmosfera interna dos VMP. Biopolímeros como polissacarídeos, lipídeos e proteínas têm sido avaliados na formulação desses revestimentos. A escolha do material apropriado dependerá das características do vegetal, do biopolímero e dos objetivos almejados para o revestimento. Esta revisão, tem por objetivo apresentar alguns exemplos de aplicação, os principais tipos de coberturas comestíveis e técnicas de aplicação utilizadas em VMP com base na literatura, com o intuito de auxiliar uma escolha que possa gerar uma maior eficiência da cobertura.

Palavras-chave: Embalagem ativa; Biopolímeros; Vida útil.

Abstract

The minimally processed vegetable (MPV) market has been growing in recent decades. This growth is related to the change in lifestyle and eating habits of consumers who seek practical and healthy food for consumption. Maintaining the characteristics and quality of MPVs is a significant challenge for producers and traders. Minimal processing steps increase the perishability of these MPVs, thus increasing oxidative reactions and their metabolic rate. The research focused on the development of technologies that reduce these reactions gained prominence. Edible films and coatings produced from natural sources have emerged as alternative packaging for food applications and have received attention due to their advantages, such as their biodegradable and renewable nature, availability, and cost. The use of edible coatings for the preservation of vegetables in the postharvest condition, whether intact or minimally processed, has been identified as an emerging technology of great

potential as they can control the internal atmosphere of MPVs. Biopolymers such as polysaccharides, lipids, and proteins have been evaluated in the formulation of these coatings. The choice of appropriate material will depend on the characteristics of the plant, the biopolymer, and the intended objectives of the film. This review aims to present some application examples, the main types of edible coatings, and the application techniques used in MPVs based on the literature, to assist a choice that can generate greater coating efficiency.
Keywords: Active packaging; Biopolymers; Shelf-life.

Resumen

El mercado de las verduras mínimamente procesadas (VMP) viene creciendo en las últimas décadas. Este crecimiento está relacionado con el cambio del estilo de vida y los hábitos alimenticios de los consumidores, que buscan alimentos prácticos y saludables para su consumo. Mantener las características y la calidad de las VMP es uno de los principales desafíos para los productores y los comerciantes. Las etapas de procesamiento mínimo aumentan la vida de estos VMP incrementando las reacciones oxidantes y aumentando su tasa metabólica. Investigaciones encaminadas a desarrollar tecnologías que reduzcan esas reacciones han ganado importancia. Películas y revestimientos comestibles producidos a partir de fuentes naturales han surgido como envases alternativos para aplicaciones alimentarias y han recibido atención debido a sus ventajas, como la naturaleza biodegradable y renovable, la disponibilidad y el coste. El uso de recubrimientos comestibles en la conservación de vegetales en condiciones de post cosecha, intactos o mínimamente procesados, ha sido identificado como una tecnología emergente con gran potencial, pues puede controlar la atmósfera interna de la VMP. Biopolímeros como polisacáridos, lípidos y proteínas han sido evaluados en la formulación de estos revestimientos. La elección del material apropiado dependerá de las características de la planta, del biopolímero y de los objetivos perseguidos para el recubrimiento. El presente estudio tiene objetivo presentar algunos ejemplos de aplicación, los principales tipos de recubrimientos comestibles y las técnicas de aplicación utilizadas en el VMP basadas en la bibliografía, a fin de ayudar una elección que pueda generar una mayor eficiencia de la cobertura.
Palabras clave: Embalaje activo; Biopolímeros; Vida útil.

1. Overview

Most postharvest vegetables, especially those from tropical environments, have accelerated maturation and deterioration as a result of biochemical and physiological changes as well as the packaging procedures and handling practices adopted (Assis & Britto, 2014).

In Brazil, it is estimated that approximately 10% of the food produced is lost or wasted. Losses and waste are higher in fruit and vegetable chains, between 30% and 50%, respectively, as they are highly perishable foods that require more care in handling and transportation (Lugullo & Salles, 2018).

According to the Brazilian Association of Supermarkets (ABRAS), in 2015, losses in the fruit and vegetable retail chains were 8.29% of net sales, the largest among all departments. In 2016, the FV (fruits and vegetables) section continued to represent the most losses, with an index of 6.09%. This result, however, is below the average recorded in the previous study, signaling improvements in the management and operation of this sector.

These improvements are mainly due to the use of postharvest technologies, which aim to maintain quality through appearance, texture, taste, nutritional value, and food safety, as well as reduce qualitative and quantitative losses between harvest and consumption (Spagnol, Silveira Junior, Pereira, & Filho, 2018).

The development of research focused on technologies that promote the reduction of postharvest losses is fundamental for the economy since, in addition to reducing loss, they increase competitiveness and seek to meet the qualities of an increasingly demanding market (Santos, 2012).

Different physicochemical processes have been studied in order to be used in the maintenance of food quality, with appropriate packaging for the conservation and commercialization of the product being necessary (Botrel, Soares, Camilloto, & Fernandes, 2010). Edible films and coatings have been presented as an effective technique for preserving fruits and vegetables (Jia et al., 2009).

Recent research has explored the potential of edible films and coatings to maintain quality and extend the shelf life of fresh products. The application of these semipermeable barriers was proven to be effective in several perishable tropical fruits such as banana (Sousa et al., 2019), peach (Jiaoa et al., 2019), apple (Vieira et al., 2019), carrot (Fai et al., 2016; Shigematsu et al., 2018), papaya (Narsaiah et al., 2015), and acerola (Ferreira et al., 2016).

Although it is an emerging technology, applying coatings on plants to extend preservation is not exactly a new practice.

Emulsions derived from mineral oils have been employed since the thirteenth century in China to extend the preservation of citrus fruits and other perishable products transported over long distances, mainly by sea (Hardenburg, 1967).

In the 1950s, carnauba wax was widely used for this purpose, but due to the matte appearance resulting from its application, polyethylene and paraffin were added for a better visual result. In the 1960s, waxes and varnishes processed from water-soluble gums became popular in the coating of citrus and fruit in general (Assis & Britto, 2014).

Edible toppings, as they are known today, are newer and date from the late decades of the last century. They gained space due to the expanded supply of processed products and the need for better conservation (Gomes et al., 2017).

The search for products made from renewable and sustainable biodegradable resources plays a central role in the effort to reduce the impact of food packaging on the environment by reducing the accumulation of synthetic materials (Pinheiro et al., 2010). In this context, edible coatings based on polysaccharides, lipids, and proteins appear as potential substitutes for synthetic packaging due to their abundant and renewable availability, low cost, biodegradable nature, and biocompatibility (Shankar & Rhim, 2016; Tresseler et al., 2009).

Since edible coatings can maintain quality and extend the shelf life of fresh products, the purpose of this review is to present some application examples, the main types of edible coatings, and application techniques used in MPV, based on the literature. This study aims to assist a choice that can generate greater coverage efficiency since edible coatings can be a sustainable and ecologically friendly packaging option.

2. Methodology

Searches were performed in 3 bibliographic databases - PubMed, Scielo, and Science Direct. Duplicate references were excluded.

Articles and books published between 2005 and 2019, in English and Portuguese, were selected.

The search of the articles for review was performed by combining the terms: edible coating, minimally processed vegetables, active packaging, and additives.

3. Minimally Processed Vegetables

The fruit and vegetable market increased significantly with the fastest-growing minimally processed vegetables (MPV) segment. This trend is justified by practicality, which has currently been the main focus of consumers. These foods have the advantage of being marketed already cleaned and cut (Nascimento et al., 2014).

The purpose of MPVs is to provide the consumer with a fresh product with a long shelf life and, at the same time, to ensure product safety while maintaining nutritional and sensory quality (Botrel et al., 2010). Minimal processing involves ginning, washing, cutting, packaging, and storage steps (Fai et al., 2016; Narsaiah et al., 2015). Maintaining the quality of minimally processed vegetables involves controlling everything from raw material production to exposure in the consumer market.

Vegetables, whether whole or minimally processed, are especially perishable and more susceptible to postharvest deterioration, due to high moisture content (80-90%), limiting storage time, and shelf life, causing considerable economic losses throughout the globe (Alotaibi & Tahergorabi, 2018). Although these MPVs are practical and easy for the consumer, minimal processing increases their perishability as oxidative reactions and metabolic rate increase (Chitarra & Chitarra, 2005).

According to Temiz and Ayhan (2017), mechanical damage causes increased respiratory activity and ethylene production, increasing some biochemical effects, such as enzymatic discoloration, texture loss, taste change, lipid oxidation, and loss of nutritional value. According to Nascimento *et al.* (2014), the changes that undermine the quality of MPVs should be reduced, as it is a ready-to-eat food without any additional technology. Maintaining its characteristics is a big challenge for producers and traders.

The adoption of Good Manufacturing Practices (GMP) can ensure that MPVs have a longer shelf life and pose no health risk (Gomes et al., 2017). In addition to the adoption of GMP, research aimed at developing techniques that minimize these losses and maintain plant quality has been promising and served as a focus for the development of preservation technologies and techniques, such as refrigeration, controlled and modified atmosphere packaging, high-pressure processing, coatings, and edible films (Ansorena, Marcovich e Roura, 2011; Luvielmo e Lamas, 2012; Pereira et al., 2018; Prado et al., 2018).

Temperature influences respiration rate, ethylene production, sweating, and enzymatic activity. Therefore, vegetables must be kept under refrigeration to increase storage time and minimize processing injuries (Turhan, 2010). The use of edible film and coating is another technique that extends the shelf life of MPVs and is gaining popularity and acceptability, due to awareness of the harmful environmental effects of non-biodegradable packaging waste (Assis & Britto, 2014; Galus & Kadzinka, 2015; Ghidelli, Sanchís, Rojas-Argudo, Pérez-Gago, & Mateos, 2018; Shigematsu et al., 2018).

They usually come from natural and biodegradable substances, which are most acceptable to the consumer due to their non-polluting nature. Edible films and coatings are food terms and often used without distinction. However, it is important to distinguish them. The film is prepared separately from the food, and it is formed by drying the biopolymer solution and subsequently applying it. The coating is formed by directly spraying or dipping the surface of whole or minimally processed foods to create thin layers of biopolymers. (Hamzah et al., 2013; Pinheiro et al., 2010).

In recent years, with the increasing popularization of minimally processed products, this technology has been gaining ground worldwide, and new formulations have been researched. Due to the addition of a protective barrier on the freshly-processed vegetable, the use of edible MPV coatings can reduce water loss and respiratory rate while maintaining texture without altering the original food components (Oriani et al., 2014; Saki et al., 2019).

4. Edible Coatings or Films

The main functions of edible coatings applied in MPVs are: controlling the internal atmosphere of gases, reducing the respiration rate of the vegetable, and serving as a water vapor barrier, thus minimizing moisture loss and postponing vegetable dehydration. This way, the senescence of the product is delayed, consequently increasing its post-harvest shelf life (Chitarra & Chitarra, 2005). Edible coatings do not contribute to environmental pollution due to their biodegradable nature when compared to conventional synthetic polymers (Narsaiah et al., 2015).

In the preparation of coatings, the formulation should be liquid or viscous, and capable of uniformly cover the surface of the product. Also, it must have some characteristics such as being invisible, sufficiently adherent to prevent removal during handling, and unable to introduce changes in taste or original aromas.

As they become part of the food, the materials used in the production of coatings should be considered Generally Recognized as Safe (GRAS), that is, non-toxic and safe for consumption (Soares et al., 2009). While the process of preparing these coatings requires specific protocols and reactive sequences, coating itself is a simple procedure with large-scale applications. Edible coatings can be applied by different methods such as panning, spraying, and dip-coating, the latter being the most used.

The panning process consists of depositing the product to be coated in a large rotating pan. The coating solution is then placed, with a ladle or pulverized, into the rotating container, and the product (or food) is deposited within that container to receive the coating solution uniformly on its surface. The coating is dried by forced or ambient air (Geschwindner &

Drouven, 2009). Particularly small products, such as nuts and raisins, are coated with panning (Talbot, 2009).

The spraying method is used to apply a thick or thin layer on the food surface uniformly. Unlike other systems, spray coating can work with large surface areas. Spraying allows the deposition of various types of aqueous solutions or suspensions, such as liquefied lipids (Azeredo, 2012). The dip-coating method involves submerging the food in an immersion tank containing the filmogenic solution. This method is advantageous when the product requires a full coating as it allows uniformity throughout a complex and rough surface. After dipping and draining, the solution is dried around the product at the temperature and time determined, with or without forced air circulation (Andrade et al., 2012).

However, problems may occur when using the dip-coating method, such as coating dilution, residue buildup, and growth of microorganisms in the dipping tank (Assis & Britto, 2014; Zhong et al., 2014). Another disadvantage of the method is that the solution can dilute the outer layer of the food surface and degrade its functionality. For example, the natural wax layer of fruit and vegetables can be removed after soaking (Jiang et al., 2019). This method is mainly used for fruits, vegetables, and meat (Andrade et al., 2012; Tavassoli-Kafrani et al., 2016; Zhong et al., 2014).

The coating performance depends mainly on its physical properties (viscosity, density, and surface tension) and the characteristics of the food to be coated (Zhong et al., 2014). Knowledge of surface interactions between the coating-forming materials and the product surface is essential for adhesion and optimized coating performance in terms of barrier and mechanical properties (Assis & Britto, 2014; Hassan et al., 2018). Coating adhesion and durability are essential for vegetables to receive the advantage of coating, which must remain adhered to the food surface during storage and transport (Narsaiah et al., 2015; Sarantópoulos & Cofcewicz, 2016).

The bases used in the formation of coatings can be classified into two categories: hydrophilic (water-soluble) and hydrophobic (water-insoluble). Hydrophilic coatings are characterized by materials that have polar covalent bonds. They are structures in which there is a predominance of amino or hydroxyl and carboxyl groups (NH_3, OH, and COO^-). Because they are hydrophilic, they have good solubility in an aqueous medium. Some examples of these materials are polysaccharides, such as starch, xanthan gum, and cellulose. These coatings are suitable for sliced surfaces and fruits with shiny aspects and the presence of surface charges (Assis & Britto, 2014).

Hydrophobic coatings, on the other hand, are materials whose connections tend to be electrically neutral, that is, they do not have definite polar configurations. In this class are protein-based (gelatin, whey protein, zein) or lipid-based (beeswax, carnauba wax) coatings. In this case, the use of nonpolar solvents such as acetone, alcohol, and hexane is required. These coatings are best suited to cover vegetables with a high transpiration rate (Assis & Britto, 2014).

The raw materials used in the formation of edible coatings may be of plant, animal origin, or a hybrid with a combination of both. The choice depends on the characteristics of the food to be coated and the desired effect with the coating to be applied (Galus & Kadzinka, 2015; Leite et al., 2015; Sapper & Chiralt, 2018). Polysaccharides, lipids, and proteins of various origins have been the most commonly used raw materials in the formulation of edible coatings and films. The different bases used have both specific advantages and disadvantages of coverage (Aksu et al., 2016; Schmid & Müller, 2018).

Lipids may be added to the protein-based formulation to increase the water vapor barrier. However, the coating obtained from this combination (lipid-protein) is generally opaque, unstable, and fragile. In this way, studies report that the addition of a polysaccharide in the formulation of lipid and protein coatings eliminates these problems and maintains the qualities of each component (Enujiugha & Oyinloye, 2018; Rubilar et al., 2015).

Lipids

Lipids are characterized as hydrophobic, in which molecules with structures whose bonds tend to be neutral predominate. In the presence of water, they can agglomerate and exclude polar molecules. These materials have excellent oxygen and water barrier properties. They are indicated for the coating of vegetables with a high rate of transpiration, in which the degradation occurs mainly by the loss of water, leading to dehydration and alteration of the superficial aspect (Rubilar et al., 2015; Trevisani, Cecchini, Siconolfi, Mancusi, & Rosmini, 2017). The main types of lipids used as a base for coatings are carnauba wax and beeswax (Fagundes et al., 2015; Hager et al., 2019; Trevisani et al., 2017).

Formiga et al. (2019) extended the shelf life of 'Pedro Sato' red guavas by 6 days using edible coatings of hydroxypropyl methylcellulose (HPMC) and beeswax (BW). The coatings reduced mass loss, retained green color, and increased firmness compared to control fruit. Miranda-Linares et al. (2018) showed that the use of active nanoparticle-based Carnauba and Goma-Xantana wax coatings had a positive effect on the quality parameters related to the

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efficient conservation and shelf life of tomatoes stored at 12 °C due to the modification of barrier properties, resulting in a reduction of metabolic changes. González-Reza et al. (2018) showed that the same coating reduced the guava browning index and firmness loss, which shows its high potential for use in fresh fruit cuts.

Proteins

Proteins are divided into two categories: fibrous and globular. Fibrous proteins are water-insoluble and are the dominant materials in animal tissue structures. Globular proteins are soluble in water and aqueous acid, base, or salt solutions, besides performing various functions in living systems. Globular proteins can unfold and cross-link as new polymeric structures, thus being excellent bases for coatings and films (Han, 2014; Scopes, 1994). Compared to polysaccharides and lipids, protein coatings have higher stability and often prolonged durability (Schmid & Müller, 2018).

For protein-based coatings, the solvent generally used for its formulation is limited to ethanol, water, or a combination of both (Scopes, 1994). Chain-to-chain interaction determines coating strength, with higher interactions producing stronger coatings, but being less permeable to vapors, liquids, and gases. Therefore, protein coatings are considered highly effective oxygen blockers even at low relative humidity (RH). Different types of protein have been used to produce edible coatings, including whey protein, wheat gluten, gelatin, corn zein, casein, and soy protein (Hassan et al., 2018).

Yousuf & Srivastava (2019), combined honey-isolated soy protein-based coatings and evaluated its effectiveness in fresh pineapples. The honey-embedded coating synergistically caused higher retention of phenolic compounds, as well as helping to retard microbial development. Ghidelli et al. (2018) also found that the application of protein-based coatings of soy and casein can prolong the shelf life of minimally processed eggplant. Scartazzini et al. (2019) have shown that edible gelatin-based coatings incorporated with peppermint essential oil are effective in inhibiting the development of the microorganisms Botrytis cinerea and Rhizopus stolonifer.

Polysaccharide

Polysaccharides such as cellulose, starch, chitosan, xanthan gum, and pectin are also characterized as hydrophilic materials. They are polymers widely used to prepare edible films or coatings (Cazón et al., 2017). Polysaccharides function as effective oxygen blockers due to their well-ordered hydrogen-linked polymer network form, but they do not behave well as moisture barriers (Coltelli et al., 2016; Hassan et al., 2018).

Polysaccharide coatings are colorless, with an oil-free appearance and lower caloric content, and can be applied to extend the shelf life of fruits, vegetables, shellfish, or meat products, significantly reducing dehydration, surface browning, and oxidation (Cazón et al., 2017). Recently, Falcó et. al (2019), observed that the combination of carrageenan and green tea extract showed significant antiviral activity against murine norovirus, a cultivable norovirus substitute, and the hepatitis A virus in raspberry and blueberry stored at 10 °C and 25 °C for 7 and 14 days, respectively.

Another study demonstrated the effectiveness of cashew gum combined with carboxymethylcellulose (CMC) in increasing the shelf life of guavas stored at room temperature (Forato et al., 2015). The results showed that cashew gum treatment has an antimicrobial effect, indicating that fungal proliferation in the mesocarp/pericarp was reduced compared to control fruits. Also, the coating retarded internal degradation and maintained the external appearance of the fruit during 12 days of storage.

5. Additives and Coating Activation

The development of food packaging with particular properties has motivated the application of various additives to change the desired polymeric characteristics, whether physical or mechanical properties, or the insertion of active functions in the material, providing improvement in the desired properties (Lee, Dangaran, & Krochta, 2002; Vital et al., 2018). Good elasticity, flexibility, high toughness, and low brittleness are a prerequisite for edible coatings to avoid cracking during handling and storage (Sapper & Chiralt, 2018).

The rigidity of the polymer results from its intra and intermolecular interactions (van der Walls forces and hydrogen bonds). Plasticizers break such interactions by increasing the distance between chains, consequently increasing the flexibility of the material (Azeredo, 2012; Botelho et al., 2016). The most commonly used compounds include polyols (glycerol and sorbitol), lipids, and derivatives (fatty acids, esters, and phospholipids) (Mali et al., 2005; Sapper & Chiralt, 2018; Sharma et al., 2019). The concentration may range from 10% to 60%, depending on the hydrocolloid (Galus & Kadzinka, 2015).

Emulsifiers may be added to the coating solutions to improve wettability and to allow a more uniform coating. The addition of surfactants or emulsifiers increases the ability of the coating to suppress ripening. The most commonly used emulsifier in edible coating preparations is Tween 80 (Fagundes et al., 2015). Among the additive materials, the so-called active food packaging is equipped with a technology that allows the interaction with modification in the conditions of the food in a desirable way, which is important to preserve the freshness and to obtain a higher shelf life of the products (Soares et al., 2009; Teixeira et al., 2014).

These packages may be immobilized or incorporated with additives to promote active functions such as absorption of oxygen, carbon dioxide, ethylene, moisture, odor, and unpleasant aromas; and to release ethanol, sorbates, antioxidants and other preservatives, and antimicrobial compounds (Han, 2014; Vital et al., 2018). Alternative technologies have been studied, like the use of nanotechnology, the incorporation of probiotics, and the use of essential oils and new surfactants as antimicrobial agents. The use of nanotechnology has occupied a valuable place in the food industry. With size reduction, there is an increase in surface area, which leads to the modification of properties with potential effectiveness in preserving fresh vegetables (González-Reza et al., 2018).

The coatings produced with chitosan nanoparticles applied to apples showed positive results with alteration in the respiratory rate of the fruits, reducing the ethylene production 33% and controlling the enzymatic activity of polyphenol oxidase and peroxidase (Sahraei Khosh Gardesh et al., 2016). The effect of Ag-chitosan nanocomposite incorporation in edible coatings on the quality of fresh melon over 13 days at 5 °C was studied by Ortiz-Duarte et al. (2019). The respiration rate of the freshly cut melon has been reduced, as well as the development of fruit microorganisms after coating treatments. The use of edible probiotic coating is a method that aims to develop functional foods and helps extend the shelf life of vegetables (Gunasekara et al., 2011; Pavli et al., 2018; Pereira et al., 2018).

A study by Khodaei & Hamidi-Esfahani, (2019), showed that the use of probiotics as a bioactive compound in edible carboxymethylcellulose (CMC) coatings, a carrier to provide an adequate amount of Lactobacillus plantarum in fresh strawberries, not only improved the shelf life of the fruit but also guaranteed the functionality and health properties of the food. In another study by Oregel-Zamudio et al., (2017), the effectiveness of combined preservation methods with edible candelilla wax coating and biocontrol bacteria was verified. This combination significantly reduced the damage caused by R. stolonifer, extending the shelf life of strawberries.

Essential oils (OEs) extracted from plants and spices show antimicrobial and antioxidant activity, making them components of interest in the food industry. Most of these

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are categorized as GRAS (Generally Recognized as Safe), which is non-toxic and safe for the consumer and can be incorporated into foods as a natural preservative (Hassan et al., 2018). The active edible coating based on sodium alginate and lemongrass essential oil applied to minimally processed “Fuji” apples significantly reduced the ethylene production rate, slowing fruit browning (Salvia-Trujillo et al., 2015).

Ethyl lauroyl arginate (LAE) is a new surfactant derived from lauric acid and arginine and is used mainly as a preservative in food. It can be used alone or in conjunction with other food preservatives such as enzymes, essential oils, sorbates, benzoates, and others. LAE has been successfully incorporated into conventional polymer systems to inhibit various pathogenic bacteria. (Gaikwad et al., 2017; Otero et al., 2014; Xu et al., 2018).

Table 1 illustrates the bases that are used for coating formation, the active compound, and the function of such coating in the food.

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Coating Base	Active Compound	Coating Function	References
Polysaccharides			
Agar-agar	Inherent to base	Protect bananas against postharvest fungal diseases caused by *Colletotrichum musae and Fusarium moniliforme*	(Hussein Ziedan et al., 2018)
Sodium Alginate	Rhubarb Extract	Improve postharvest quality and extend the life of peach fruits	(Li et al., 2019)
Starch	Lemongrass essential oil	Maintain physicochemical characteristics and inhibit microbial growth in papaya	(Alotaibi & Tahergorabi, 2018);
continuation			
Carrageenan	ZnO nanoparticles; Ascorbic acid	Reduce physical and biological deterioration of mango; Postpone changes in color, taste, and texture of minimally processed pears;	(Barriobero et al., 2018); (Hamzah et al., 2013);

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Cellulose (carboxymethylcellulose)	Moringa leaf and seed extracts	Improve avocado postharvest quality and reduce disease imminence	(Tesfay et al., 2018)
Chitosan	Thymol essential oil;	Maintain the quality of fresh figs over time;	(Saki et al., 2019)
continuation			
Proteins			
Gelatine	Amla powder;	Decrease the oxidation rate of oil while frying banana chips;	(Ishra & Kalita, 2017);
	Aloe Vera Gel and Black and Green Tea Extract	Maintain physicochemical and sensory characteristics and inhibit microbial development in minimally processed and refrigerated oranges	(Radi et al., 2017)
Whey Protein Concentrated (WPC)	Citric acid and ascorbic acid	Antioxidant action preventing the darkening of minimally processed apples.	(Amaral, 2014)
Whey Protein Isolated (WPI)	Rosemary Extract	Decreased acrylamide content and improved crisp firmness	(Trujillo-Agudelo et al., 2019)

Zein	Benzoic acid	Preserve physicochemical attributes and retard the growth of microorganisms in sliced pumpkins	(Hager et al., 2019)
Lipids			
Beeswax	Hydroxypropyl methylcellulose	Extend the life of 'Pedro Sato' red guavas	(Formiga et al., 2019)
Carnauba wax	Glycerol Monolaurate;	Extend the commercial validity of Indian jelly beans and maintain the quality of these fruits;	(Chen, Sun & Yang, 2019);
	Inherent to base	Maintain physical and chemical quality of 'Valencia Delta' oranges during storage	(Pereira et al., 2016)

In Table 1, it is possible to observe that the main types of base coatings can be added with different compounds, acquiring one or more different active characteristics, the main ones being antimicrobial and antioxidant. The activity provided by the active edible coating allows the maintenance of the quality and the extension of vegetable life.

It is also noted that, in some studies (Pereira et al., 2016; Hussein et al., 2018), there was no need for an additive because the coating itself creates a physical barrier. This barrier protects the plant against water loss, mechanical damage, increased metabolic rate, and contamination by microorganisms, maintaining quality for a longer time when compared to the vegetable without the coating (Oriani et al., 2014; Saki et al., 2019).

6. Conclusions and perspectives

This article reviewed current studies on postharvest applications of edible coatings for MPVs. Several studies have shown that edible coatings effectively preserve food quality and extend their shelf life.

In order to the edible coating to be effective in its covering, variables such as the type of vegetable and the method of application must be taken into account. There is no single coat that meets all the needs of all vegetables, nor a universal method for application. It is necessary to know the characteristics of the vegetable so that the coating will act as expected.

The addition of additives or the combination of different bases should take into consideration the optimization of the physical, mechanical, barrier, and rheological properties of the coating. As for the possible activation of the material, the quality and safety of the MPV must be considered, so that it can act as an important packaging vehicle, maintaining its freshness and extending its shelf life.

Despite the benefits of applying edible MPV coatings, commercial applications are still limited. Prospects include the production of large-scale edible coatings, as they are a good option for adding functionality to minimally processed vegetables since they can be produced homogeneously, safely, and cost-effectively.

Further research is needed into the field of product research on edible composite coatings containing two or more combinations of techniques and additives, which enhance and adds unique functionality to MPVs.

With the existence of global concern in the health and environment aspect, studies aiming at the development of edible coatings with environmentally friendly bases and additives with natural and organic compounds should be continuously explored, aiming to offer the consumer an increasingly safe and quality food.

Thus, it is concluded that developing technologies that not only maintain the quality and safety of MPVs but also add commercial and nutritional value are important and necessary.

Acknowledgements

The authors thank the Coordination for the Improvement of Higher Education Personnel (CAPES), National Council for Scientific and Technological Development (CNPq), Federal University of Rio de Janeiro (UFRRJ), and Fluminense Federal University (UFF).

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Percentage of contribution of each author in the manuscript

Maria Clara Guimarães – 30%

Joyce Fagundes Gomes Motta – 15%

Dayana Ketrin Silva Francisco Madella – 15%

Lívia de Aquino Garcia Moura – 10%

Carlos Eduardo de Souza Teodoro – 10%

Nathália Ramos de Melo – 20%