Aloe vera gel: an update on its use as a functional edible coating to preserve fruits and vegetables

Iolanda Nicolau-Lapeña, Pilar Colàs-Medà, Isabel Alegre, Ingrid Aguiló-Aguayo, Peter Muranyi, Inmaculada Viñas*

Progress in Organic Coatings

https://doi.org/10.1016/j.porgcoat.2020.106007

Abstract

Aloe vera L. is a common succulent plant that has been used for centuries regarding their healing properties and health benefits. Nowadays, scientific investigations on its gel have gained more attention because of its interesting antioxidant and antimicrobial properties. Also, the food industry encounters the need to preserve safety and quality of fresh produce; fruits and vegetables are in high demand due to their reported health benefits, and fresh-cut products are a new trend that meets the restless needs of the society. Edible coatings are an effective way to maintain freshness of these products, extend their shelf life, and even act as an alternative to modified atmosphere packaging to be used in conventional packaging. *Aloe vera* gel is a natural hydrocolloid, composed mainly by polysaccharides, that has been applied in the last years on fruits and vegetables. It can act as a semipermeable barrier for gases and water vapor, decreasing the respiration and ripening processes of the fruit, thus maintaining weight, firmness and valuable compounds. Its antioxidant and antimicrobial properties make it also an interesting material for increasing the shelf-life of fruits and vegetables. This review aims to describe the preparation and preservation of *Aloe vera* gel as well as the properties and compounds that are effective against oxidation and microbial growth. Moreover, the recent findings of its use – with or without additives – as an edible coating on fruits and vegetables have been widely detailed, showing that *Aloe vera* gel is a promising preservative method in this industry.

Keywords

Antioxidant, antimicrobial, shelf-life, firmness, color, respiration, fresh-cut

Abbreviations:

AA	acid ascorbic
AC	antioxidant capacity
AVG	*Aloe vera* gel
CFU	colony forming units
FC	flavonoid content
FV	fruits and vegetables
FW	fresh weight
n.d.	not determined
POD	phenol peroxidase
PPO	polyphenol oxidase
SAEW	slightly acidic electrolyzed water
TA	titratable acidity
TPC	total phenolic compound
TSS	total soluble solids

1 Introduction: *Aloe vera*

Aloe vera L. is a succulent plant that belongs to the *Asphodelaceae*, a family of the genus Aloe, and has been used for *centuries* as a healing plant (Chase, 2016). It is a shrubby, perennial, green plant. Its leaves, arranged in a rosette pattern at the stem, have a high capacity to retain water, enabling the plant to survive harsh conditions (Iwu, 2014). It grows mainly in the dry regions of Africa, Asia, Europe and America (Amar, 2008). Among various species of Aloe, *Aloe vera* L. (AV) is considered to be the most popular, commercially important and the most potent one in the research field (Maan, 2018).

AV leaves have broadly three parts; (i) the rind, (ii) the yellow sap (*Aloe* latex), containing mainly anthraquinones, which are bitter and laxative, and (iii) the internal transparent mucilaginous jelly, called *Aloe vera* gel (AVG) (Eshun, 2004). AVG contains a large amount of bioactive compounds, including flavonoids, terpenoids, lectins, fatty acids, anthraquinones, mono- and polysaccharides, tannins, sterols, enzymes, salicylic acid, minerals (calcium, chromium, copper, iron, magnesium, manganese, potassium, phosphorus, sodium and zinc) and vitamins (A, C, E, β-carotene, B1, B2, B3, B6, choline, B12, folic acid) (Hęś, 2019).

AVG is considered safe, but a few remarks regarding the complications must be done. When ingested in high doses, it can cause abdominal cramps or flatulence (Mulay, 2013), and it can also cause allergic responses by its application on skin of susceptible people (Surjushe, 2008). Despite this, the composition of AVG makes it valuable in different areas, outstanding pharmacy, skincare, and food preservation. There are a number of scientific papers reviewing the process to obtain AVG from the aloe plant (Eshun, 2004) and the uses of AVG in medical applications, including antiviral and antitumor activity, promotion of the immune system, wound healing, hepatoprotective and antidiabetic effects, laxative properties (Maan, 2018; Radha, 2015; Sahu, 2013), skincare (Maenthaisong, 2007; Richardson, 2005), dentistry (Wynn, 2005), and also of the biological effect of its individual components (Choi, 2003; Hęś, 2019). Furthermore, and as reviewed in (Ahlawat, 2011), the AVG or juice have many possible applications in the food industry as a functional ingredient or preservative: they have been added to dairy and baked products, fruits and vegetables juices or purées and, in general, to foods that have an adequate consistency, such as jams or jellies. When used as a preservative, the quality of the products was maintained during storage and microbial counts remained under control. For instance, AVG 20 % was added to mango nectar, and total bacterial counts decreased from 3.9 to 2.1 log CFU / mL, and maintained good quality attributes during 6 months of storage (Elbandy, 2014). Similarly in another study, aloe vera yoghurt was made with lactic acid bacteria and compared it with yoghurt prepared using dried skim milk and it was found that quality retention of aloe vera yoghurt at 5 °C for 15 days was better than the milk yoghurt (Lee, 1997).

As stated before, the aloe industry is flourishing worldwide. AVG has been recently proposed as an edible coating for whole or fresh-cut fruits and vegetables. Edible coatings are thin layers composed mainly by polysaccharides, proteins, or lipids that are formed directly on the fruit surface and act as a protective layer against chemical, physical or microbiological changes. In many cases, the selected raw materials have additional functional properties (e.g. antimicrobial, antioxidant) or are enriched with additives, which can contribute to enhance the product shelf life and safety. In addition to commercial purposes, the ingestion of the AVG as an ingredient for coated products should pose beneficial effects for human health besides those already reviewed for the fruits and vegetables themselves (e.g. cancer risk diminution, coronary diseases and cognitive decline prevention) (Blekkenhorst, 2018; Loef, 2012; Ruxton, 2006). AVG consumption has been related with a number of valuable effects: digestive diseases protection, antidiabetic effect, cardioprotective effect, antiinflammation, antimicrobial and prebiotic activity, cancer reduction, as well as bone protection (Foster, 2010; Sánchez, 2020).

Nowadays, fruits and vegetables are in high demand because of the healthy and nutritional values, but they have a limited shelf-life due to their perishable nature (Nath, 2007). Edible coatings provide a promising approach to prevent deterioration during storage, as they can act as a semipermeable barrier to O_2, CO_2 and water-vapor, thus preventing water loss, changes in firmness or oxidation, amongst others (Raghav, 2016). Misir (2014) highlighted the attractiveness and potential of the use of AVG as an edible coating to preserve fruits by minimizing the rate of respiration and maintaining quality attributes (color, flavor etc.). Moreover, AVG has antifungal and antibacterial properties, which provide a defensive barrier against microbial contamination of fruits and vegetables. Alternatives to synthetic preservatives for fruits and vegetables are needed to satisfy consumers' needs, and AVG seems to be a capable choice for that, as it is edible, invisible, odorless and does not affect the taste of products on which it is applied.

This review aims to provide a general view on the usage of AVG in food applications, specifically as an edible coating for prolonging the shelf-life of fruits and vegetables, combined or not with other functional additives in order to increase its efficacy. A general overview of the AVG composition and preparation for food coatings is done, and the recent studies of their impact on the physicochemical and nutritional quality as well as microbiological safety of fruits and vegetables are described.

2 Aloe vera gel: composition, preparation and preservation

According to Zhang (2018) AVG average composition consists of water (96 %) and dry matter (4 %), which contains organic acids (22.8 %), dietary fiber (18.8 %), polysaccharides (8.8 %), protein (4.7 %), lipids (2.7 %), and ashes (16.0 %) (w/w). The main compounds of each class can be found in Table 1 in more detail, and were reviewed extensively by (Ahlawat, 2011; Gupta, 2017; Hęś, 2019).

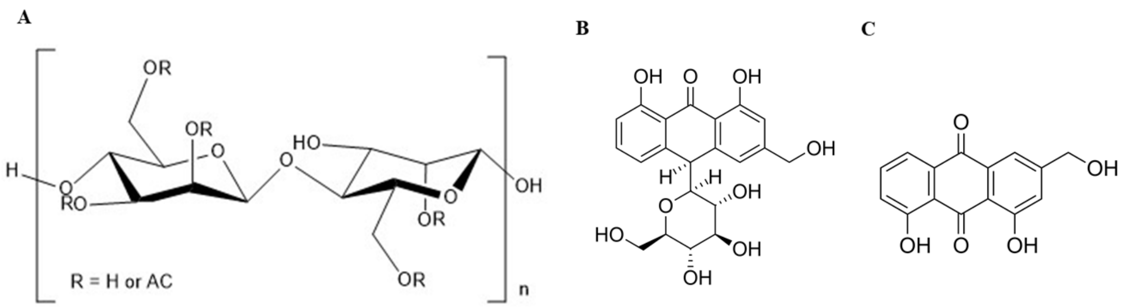

Figure 1. Active compounds characteristic of *Aloe vera* gel: (**A**) acemannan, (**B**) aloin, and (**C**) aloe emodin.

Polysaccharides contribute to bulk, body, viscosity, stability of emulsions and foams, water-holding capacity, and freeze-thaw stability (Ahmed, 2013). Amongst them, the mucopolysaccharide acemannan (Figure 1A), which is an acetylated mannose-rich polymer that functions as storage polysaccharide, is considered one of the most bioactive compounds of AV, thus having a lot of applications in the medicine field (Liu, 2019; Rodrigues, 2019). Lectins (aloctin A and B) are a group of glycoproteins that are characteristic for AV. They have shown antitumor effects in mice, by agglutinating carcinogenic cells (Akev, 2007). Aloe emodin and aloin (Figure 1B, Figure 1C) are the main anthraquinones in AVG, which mainly exhibit laxative properties (Salehi, 2018) and aloin has also shown antiviral activity against influenza (Huang, 2019). Even so, the beneficial properties of AVG are more likely to be due a synergistic action of the compounds – polysaccharides, glycoproteins, anthraquinones, polyphenols - rather than a single one (Hamman, 2008).

Table 1. Composition of *Aloe vera* gel (AVG) (Eshun, 2004; Ahlawat, 2011; Gupta, 2017; Hęś, 2019)

Class	Compounds
Polysaccharides	Pure mannan, acetylated mannan, acetylated glucomannan, glucogalactomannan, galactan, galactogalacturan, arabinogalactan, galactoglucoarabinomannan, pectic substance, xylan, cellulose, hyaluronic acid
Saccharides	Mannose, glucose, L-rhamnose, aldopentose
Lipids	Arachidonic acid, γ-linolenic acid, steroids (campesterol, cholesterol, β-sitosterol), triglicerides, triterpenoid
Amino acids	Alanine, arginine, aspartic acid, glutamic acid, glycine, histidine, hydroxyproline, isoleucine, leucine, lysine, methionine, phenylalanine, proline, threonine, tyrosine, valine
Proteins	Lectins, lectin-like substance
Enzymes	Alkaline phosphatase, amylase, carboxypeptidase, catalase, cyclooxidase, cyclooxygenase, lipase, oxidase, phosphoenol, pyruvate carboxylase, superoxide dismutase
Minerals	Calcium, chlorine, chromium, copper, iron, magnesium, manganese, potassium, phosphorous, sodium, zinc
Vitamins	A, B1, B2, B6, C, β-carotene, choline, folic acid, α-tocopherol
Anthraquinones/anthrones	Aloe-emodin, aloetic-acid, anthranol, aloin A and B (or collectively known as barbaloin), isobarbaloin, emodin, ester of cinnamic acid
Chromones	8-C-glucosyl-(2'-O-cinnamoyl)-7-O-methylaloediol A, 8-C-glucosyl-(S)-aloesol, 8-C-glucosyl-7-O-methyl-(S)-aloesol, 8-C-glucosyl-7-Omethylaloediol, 8-C-glucosyl-noreugenin, isoaloeresin D, isorabaichromone, neoaloesin A
Hormones	Auxins, gibberellins
Other organic compounds	Lignins, potassium sorbate, salicylic acid, uric acid

The composition of AVG will depend on the cultivar, the season and also the method in which the gel is processed (Ni, 2004). For instance, acemannan can be affected by the pasteurization temperature and time conditions due to a decrease in its swelling properties – from 305 ± 3.7 mL / g at 65 ºC for 15 min, to 245 ± 2.9 mL / g at 85 ºC for 25 min –, water retention behavior – from 23.0 ± 0.2 to 15.9 ± 0.1 g H_2O/g at 65 ºC for 15 min or 85 ºC for 25 min, respectively – and fat adsorption capacity– which went from 33.20 ± 0.5 to 26.50 ± 0.4 when pasteurization conditions were 65 ºC, 15 min, or 85 ºC, 25 min, respectively – (Minjares-Fuentes, 2018). On the contrary, UV-C irradiation (24.2 mJ / cm^2 pH 3.5) could be an alternative to thermal treatments which has been suggested for efficiently preserving the characteristics of acemannan, as it reduces its degradation up to 27 % (Rodríguez-Rodríguez, 2019).

To prepare AVG for the edible coatings, most of the authors follow the same process with slight variations in the conditions and some steps (Table 2). First, a washing step is done to remove the external dirt of the leaves and chlorine to disinfect them. It is advisable that the processing of the leaves is completed within the first 36 h after the harvest, in order to avoid the decomposition of the biological activity (Ramachandra, 2008). Then, the leaf will be separated from the parenchyma to obtain the gel, which is then normally homogenized by blending with a shredder and filtered with a cloth to remove the fibers. On occasion, it can be filtered with active carbon to remove the anthraquinones, which could have a laxative effect in dependency of the dose (Nasution, 2015). Sometimes, the pH is adjusted between 3 and 4, to stabilize and avoid enzymatic browning during storage. Then, the gel is pasteurized at temperatures ranging from 65 to

85 ºC for 10 s up to 30 min, with longer times at low temperatures. However, it is suggested that the best method for a gentle pasteurization is a high temperature for a short time (HTST), followed by flash cooling to 5 ºC (Eshun, 2004).

Table 2. Preparation of *Aloe vera* gel (AVG)

Cleaning	Filtration	Blending	pH adjustment	Pasteurization	Source
Water + blanching 100 ºC, 4 min	Activated carbon	n.d.	3.0, citric acid	85 ºC, 1 min + cool down 5 ºC	(Nasution, 2015)
n.d.	n.d.	n.d.	4.0, citric and ascorbic acid	70 ºC	(Ali, 2016)
Water + blanching 100 ºC, 4 min	Yes	Yes	3.0, citric acid	85 ºC, 1 min + cool down 5 ºC	(Chrysargyris, 2016)
Chlorine 0.03%	Yes	Yes	No	No	(Sogvar, 2016)
n.d.	Yes	Yes	No	No	(Martinez-Romero, 2018)
Chlorine 0.1 %, 3 min	Sterile muslim cloth	Yes	3.75, citric acid	65 ºC, 30 min	(Ali, 2019)
Yes	Yes	Yes	3.75, phosphoric acid	80 ºC, 10 s + cooling down 5 ºC	(Khaliq, 2019)
Chlorine 0.03 %	Yes	No	No	No	(Mirshekari, 2019)
Chlorine 2 %	Yes	Yes	No	No	(Rasouli, 2019)

According to some authors, processing may cause changes in the structure of the components of AVG, mainly attributed to the high temperatures. The rate in which acemannan undergoes a loss of mannosyl residues increases with advanced temperatures higher than 60 ºC and times longer than 1.6 h Femenia (2003). High temperatures over 70 ºC, can lead to a decrease in barbaloin and other polysaccharides from AVG (Sánchez-Machado, 2017), losses that would be detrimental to AVG bioactivities and functionality. Consistency and viscosity of the gel are also affected by high temperatures, as acetylated glucomannans are responsible for the plasticity of the gel (Hamman, 2008; Huang, 2019)A good approach to maintain the composition and the properties of AVG is the use of a non-thermal pasteurization, such as high hydrostatic pressure (HHP). Pressures of 300 to 500 MPa were applied for 1 and 3 min at 20 ºC on AVG, and although viable spore formers were detected by enrichment, the HHP treatment completely suppressed microbial growth during at least 90 days at 4 ºC (Reyes, 2012). Such treatments exert no major effect on gel properties or rheological activities (Opazo-Navarrete, 2012), and pressures below 500 MPa can increase antioxidant activity and aloin content of AVG (Vega-Gálvez, 2011).

Cool temperatures are advisable for AVG storage, for a better preservation of the color, vitamin C content, antioxidant potential and acemannan structure, amongst others (Saberian, 2013). Stored at room temperature, these parameters, pH, and viscosity are maintained for 2 days, while at refrigerating temperatures, AVG can last up to 5 days without any significant changes (Suriati, 2018).

As aforementioned, conditions in which extraction, preparation and storage of the AVG are carried out affect its composition and physical properties. To be used as an edible coating, it is important that AVG has the adequate plasticity and consistency, and is rich in the characteristic compounds giving functionality to prevent fruit and vegetable deterioration. For this, when processing *Aloe vera* leaves, it will be imperative to optimize and control the parameters that could affect somehow the quality and functionality of the final product.

3 *In vitro* properties with potential for food applications

3.1 Antioxidant activity

Most plant extracts possess antioxidant activity, acting as free radical scavengers or breaking chain oxygen reactions, due to their phenolic compounds and other bioactive molecules with this effect (Aqil, 2006; Wong, 2006). Antioxidant activity of AVG will not only play a role in reducing oxidative stress of the vegetable tissue on which it is applied as an edible coating, delaying the alteration of metabolic processes (i.e. ethylene production, relative electrical conductivity, transpiration, senescence and nutritional composition) (Hussein, 2019). When consumed, it will also pose a benefit to human health, as antioxidant activity of foods has been related with the prevention of some non-concomitant diseases such as coronary problems, obesity or Parkinson (Shahidi, 2015).

The IC_{50} – half maximal inhibitory concentration, which corresponds to the concentration of an inhibitor where the response is reduced by 50 %, and it is an indicator of the effectiveness of a substance in inhibiting a specific biochemical compound – of a methanolic extract of AVG was 572.14 μg / mL against DPPH·, 195.26 μg / mL against ABTS and 46.3 μg / mL inhibiting NO generation (Ray, 2013). Some of the bioactive compounds of AVG are aloe-emodin, which has been proven to inhibit oxidation of linolenic acid by 78 % (Abdul Qadir, 2017), or anthraquinones, that exert a protection against lipid peroxidation (Sánchez-Machado, 2017). Acemannan, specifically its acetyl and hydroxyl groups, has also been proven to have scavenging effects on free radicals, as well as chelating activity and reducing ability against iron ions (Liu, 2019). The age of the plant can also influence its antioxidant properties. For instance, AVG from 3-year-old plants had higher polyphenol content and antioxidant activity than that from 2-year-old AV, which was correlated with the DPPH· inhibition (Hu, 2003). Furthermore, the antioxidant capacity also depends on the different monosaccharides available in the plant. Kang (2014)reported that rhamnose and arabinose are the sugars with antioxidant activity within the polysaccharide structure.

In fact, the antioxidant properties of the aloe vera gel may vary amongst extracts or preparation methods, and the quantity and quality of the antioxidant content of the plant depend on the age of the plant, climate, or position of leaves on the stem, amongst others (Hęś, 2019). It is therefore advisable that processors of AVG consider all the factors in order to obtain with a high and consistent quality. For this, a further approach in the scientific field could include the prediction of the composition and physical properties of the AVG resulting from a certain prime matter and the adequate processing conditions.

3.2 Antimicrobial properties

Even though the antimicrobial activity is not the main reason why AVG is used, it has shown to be effective in inhibiting the growth of some microorganisms. The understanding of AVG's antimicrobial compounds and their action modes, as well as the target microorganisms and the effective concentrations, will be essential to guide the application of AVG to certain products with specific microorganism control requirements.

AVG has already shown some fungal control. For instance, Das (2011) isolated a protein from AVG with antifungal properties. Its structure is homologous to other antifungal proteins from plants, and it has proven to inhibit the growth of some *Candida* species, including *Candida krusei*, which can be found in food products. The concentration of this protein needed to reduce the growth halo to 50 % was 50.41 µM. Although AVG was not effective in inhibiting the growth of *Aspergillus carbonarius*, it was able to reduce ochratoxin production up to 75.69 %, depending on the concentration (Dammak, 2018), somehow affecting the mold's biosynthetic pathway for this toxin. The inhibition of the mycelium growth of *Botrytis cinerea, Penicillium digitatum, P. expansum* and *P. italicum* was well correlated with the concentration of AVG, and the gel also decreased the percentage of infected aloe leaves, that were artificially inoculated with these molds (Zapata, 2013). As an example, AVG 50 % showed a decrease of 11.3 % the mycelial growth ratio of the such molds. The authors found a correlation between mold inhibition and aloin content of the gels, and suggested this compound could be responsible for the antifungal activity, although its action mechanism has not yet been fully understood. It has been proposed that aloin and barbaloin affect the phospholipid membrane, leading to significant changes in the membrane physical properties, which affect the lipid/water interface in negatively charged phospholipids, with disruptions of the core of the bilayer (Estepa, 2004). Other authors have also reported antimicrobial activity of aloin against some foodborne pathogens, including*, Escherichia coli, Salmonella typhi* and *S. typhimurium, Staphylococcus aureus,* and *Vibrio chloreae*. In that study, minimum inhibitory concentrations of aloin ranged from 0.06 to 0.96 mM (Asamenew, 2011).

According to Hęś (2019), acemannan has also bactericidal, virucidal and fungicidal properties. For instance, it can decrease the adhesive properties of multiresistant strains of *Helicobacter pylori*, thus reducing its pathogenicity (Cellini, 2014). Acemannan has shown an inhibitory effect against both planktonic and sessile cells of foodborne pathogens *S. aureus* and *Pseudomonas aeruginosa*, which could contribute to the inhibition of biofilm formation (Cataldi, 2015). Salah (2017)reported that the efficacy of acemannan depends on the deacetylation degree, with a higher antimicrobial effect at lower deacetylation degree. In that study, it was also observed that Gram-negative bacteria (*E. coli, P. aeruginosa*) were more sensitive than Gram-positive bacteria (*S. aureus, E. faecalis*) to acemannan's biofilm inhibition activity.

Fewer are the reports on AVG used against viruses. Aloin, aloe emodin and other anthraquinone derivatives, such as rysophanol, aloetic acid, anthranol, anthracine, anthranon, barbaloin, ethereal oil, cinnemonic acid, isobarbaloin, and resistannol have been reported to have antiviral effects against influenza virus (Borges-Argáez, 2019) or hepatitis A virus, by inhibiting their polymerase activity (Parvez, 2019). However, as norovirus is the most prevalent virus in fruits and vegetables, especially in berries (Opinion, 2014), more information about the activity of AVG against it would be useful.

4 Application of AVG as edible coating for fruits and vegetables

Typically, AVG has been applied to whole or fresh-cut fruits and vegetables as edible coating at a postharvest level and prior to commercialization step. However, it should be noted promising results were also observed by coating fresh produce. For instance, Castillo (2012) incorporated a coating of AVG (66 %) by applying a fine mist until run off so that the entire leaf and fruit surfaces were wetted, one or one and seven days before harvest. After harvest and during storage, quality attributes of the grapes were maintained and rotten berries per cluster decreased from 13 % to 3 % in treated products. Similarly, the coating was applied to strawberries at preharvest, and the authors observed that aloe sprays reduced fruit weight loss, the incidence of decay, and fruit and calyx defects, while exhibited no effect on respiration and on certain quality attributes like antioxidant activity or color (Kafkaletou, 2018). At a postharvest level, immersion in the AVG preparation, with or without other ingredients or preservatives, is the preferred technique to create an edible coating for fruits and vegetables. However, AVG films formed by spraying have also been characterized, and were optimized to AVG 10 % for rambutan fruits for decreasing their respiration rate 15.08 mL O_2/kg·h to 5.77 mL O_2/ kg·h at 10 °C storage temperature (Darmawati, 2019).

4.1 Prevention of weight loss and firmness

Weight loss in fruits and vegetables mainly occurs due to water loss by transpiration and respiration, and it is more marked on fresh-cut fruits. As the water loss rate depends on the gradient between fruit tissue and the surroundings, AVG is able to reduce water loss by making a physical barrier around the fruit (Misir, 2014). Polysaccharides are suggested to be good non-fatty coatings for preventing water loss, and AVG has high contents of polysaccharides, which ordinarily provide homogenous edible coatings that are colorless, have an oily-free appearance and a minor caloric content (Hassan, 2018).

The effectiveness of AVG in reducing weight loss has been reported by a number of studies (Table 3). AVG at a concentration of 50% significantly reduced the weight loss, when compared to the non-coated samples, in rambutan fruit (Yingsanga, 2018), litchi (Ali, 2019), or white button mushroom (Mirshekari, 2019). But even lower concentrations were effective for this purpose: AVG 20% in grapes (Ali, 2016), in peach (Hazrati, 2017), or 4% to 6% AVG in bell pepper (Ullah, 2017) proved to be a good barrier for water loss.

This effect can be improved by adding other components to the AVG coating. For instance, carnauba wax was used at 0.1% to increase the water barrier properties of the film, as the hydrophobic characteristics of this lipidic component act along with the polysaccharides of the AVG (Pérez, 2016). Nasution (2015) used $CaCl_2$ 2% in fresh-cut guava, because the presence of calcium ions forms a complex (chelate) with the cell wall and middle lamella pectin, reinforcing the barrier properties. It also contributed on the maintenance of the texture by protecting the membrane integrity, leading to increased turgor cell pressure.

Not only with additives texture can be maintained. AVG, which is able to preserve moisture in the product, also contributes to delay the loss of firmness. The intracellular water in fruits and vegetables is maintained, keeping their natural turgor pressure. Retarding of decay and fruit softness has been described in all the works that studied firmness in fruits coated with AVG alone (Table 3). Firmness preservation can be explained by, on one hand, the barrier properties against O_2, which reduces the respiration rate of the product, thereby slowing the metabolic activity and ripening process (Asamenew, 2011). On the other hand, the reduction of the activity of the main cell wall degrading enzymes: α-galactosidase, polygalacturonase, and pectinmethyl-esterase, attributed to a slow-down on the ripening processes and a decreased stress of the plant (Martínez-Rubio, 2015).

4.2 Prevention of color changes

Color and appearance affect consumers' buying or eating opinion. These attributes are the first getting consumer attention, and they often will contribute in the decision whether the product is accepted or rejected (Barrett, 2010). The colors are derived from natural pigments, namely chlorophylls (green), carotenoids (yellow to red), anthocyanins (blue-red), betalaines (red) or flavonoids (yellow). Colors that are not appropriate, such as dull-like or browning, may suggest a loss of freshness or lack of ripeness (Shewfelt, 1993).

To delay color changes in fruits and vegetables, AVG has been applied to whole and fresh-cut pieces (Table 3). In some cases, when used alone at different concentrations, e.g. 50 % or 100 % AVG on rambutan fruit (Yingsanga, 2018) or 5 %, 10 %, 15 % or 20 % AVG on tomatoes (Chrysargyris, 2016), it did not have a significant effect on color retention. It is possible that for certain fruits and vegetables, the only use of AVG is not enough to prevent the color change, so the addition of other active compounds to the coating may prove to be a good option. Exploration of new antioxidant extracts to be incorporated in AVG, especially those of natural origin or coming from food by-products, could be a benefit for AVG-coated products. Nowadays, AVG has already been used as a carrier for anti-browning agents, such as 4-hexylresorcinol 0.01 %, ascorbic acid 0.5 %, $CaCl_2$ 0.2 %, or 0.1 % cysteine in AVG 15 % in fresh-cut apple (Kumar, 2018), having synergistic effect, compared with the separate use of AVG or the additives. Other authors have also reported an improvement when adding some substances to AVG. For instance, Sogvar (2016) used AVG 50 %, carnauba wax 0.1 %, polisorbate 0.1 % and glycerol 0.1 % on fresh-cut mango, and found that change of color of AVG coated fruits was half of the change of control fruits, or Nasution (2015) that applied AVG 100 % with ascorbic acid 1.5 %, $CaCl_2$ 2 % or potassium sorbate 0.2 %, as well as their combinations on fresh-cut guava, in which the lower lightness and higher redness and yellowness - indicating higher browning – was observed in control fruits.

Nevertheless, AVG has also been used alone with positive results. Ali (2016) described good gloss and best visual effects when using 20 % AVG on grapes, which was attributed to a better preservation of anthocyanins. In green or red-yellow fruits, other pigments such as chlorophylls can be maintained, or carotenoid synthesis promoted, by the creation of a modified atmosphere with AVG (Nasution, 2015). The degradation of such pigments has been related with the oxidative stress, which occurs due to the presence of high amounts of reactive oxygen species. When creating a barrier between the fruit and the environment, AVG reduces the amount of oxygen available for degradation reactions (Yamauchi, 2014). Mirshekari (2019) also stated a browning delay when applying AVG 50 or 75 % on white button mushrooms, and Ali, (2019) reported a decrease in browning after storage of litchi fruit coated with AVG 50 % when compared to the control. Browning of fruits is attributed to the activity of polyphenol oxidase (PPO), that is enhanced when the fruit is cut, as the vegetal cell walls are disrupted and the enzyme can get easily in contact with oxygen and substrates (Kasim, 2015). An inhibition of PPO activity was observed for AVG-coated white mushrooms, in which PPO activities were 2.25-fold lower than in non-coated samples (Mirshekari, 2019), and for wax-apple coated with 75 % AVG, treatment that controlled the PPO activity after 6 days of storage when compared with non-treated samples (Supapvanich, 2016). Both of the studies mention the relationship between and the decrease in PPO activity, but the exact mechanism for which this happens needs further investigation. It has been theorized that one option for that is that AVG may act as a physical protection to the fruit tissue: as it has been reported by Ali (2019). In fact, in another study, AVG maintained significantly higher membrane integrity of the guava, and PPO and peroxidase activities were 1.36-fold lower in comparison to the uncoated control (Hazrati, 2017). However, there is no information on how the characteristic components of AVG interact with the browning enzymes, and neither about the role of the phenolic compounds present in AVG, that may act as substrates or antioxidants for PPO (Fukumoto, 2000).

4.3 Impact of AVG coatings on respiration and ripening processes

Respiration, ripening and senescence are expected processes in fruits and vegetables. The rate at which they occur depends on many parameters, such as harvesting time, storage conditions (temperature, gas atmosphere) or mechanical damages e.g. by industrial cutting operations. Despite being inherent in the fruit, these processes lead to a progressive loss of quality (Irtiza, 2019). For instance, respiration and ripening lead to an increase in total soluble solids (TSS) and a decrease in acidity provided by organic acids, which will affect the sensory properties of the fruit (Thompson, 2010). Included in the reported advantages of edible coatings are their gas barrier properties. As suggested by Misir (2014), AVG acts as a semipermeable coating, by which the gas exchange between the fruit and the environment decreases, and so the respiration rate does.

Recent studies show the effect of AVG on respiration and ripening of fruits and vegetables. For instance, Mendy (2019) used AVG at concentrations ranging from 5 to 50 % on fresh-cut papaya, and observed that coated fruits had lower content of (TSS), 8.29 % in comparison to the non-coated control, 10.50 %. Furthermore, they reported that AVG 25 % was the optimal concentration for keeping titratable acidity (TA) higher than it was in control fruits. This was attributed to the lower metabolism of the fruit, and reduced use of the organic acids, thus maintaining TA values. Sogvar (2016) also observed this effect on strawberries when using AVG 33 % combined with 1 to 5 % ascorbic acid. Until day 12 of storage, the fruits kept lower TSS, from 7.5 to 9 ºBrix, compared to 10 ºBrix of the control, and pH was maintained. It was suggested that the higher maturation of the non-coated fruit had led to a solubilization of cell wall polyuronides and hemicellulose, thus increasing its TSS values when compared to coated fruits.

Moreover, membrane leakage can happen while fruit senescence, and incremented with tissue cutting or damage. In this regard, Ullah (2017)stated that AVG between 4 to 6 %, enriched with cinnamon oil, helped in reducing 10 to 20 % the membrane leakage of red bell pepper. Moreover, Ali (2019) showed that protection of membrane integrity was improved in litchi fruit covered with AVG 50 % itself. Even though, there are some contradictory studies where an increase of TA and TSS was observed in strawberries and tomatoes, respectively (Falah, 2018; Khatri, 2020). Due to the different characteristics of the matrices, the climacteric vs. non-climacteric nature, or the different formats in which they are presented (whole or fresh-cut), it is of high importance to evaluate the effect of each AVG formulation on the targeted matrix.

The majority of the studies seem to confirm that these effects on selected produce quality parameters are a consequence of the formed AVG layer, which decreases the gaseous exchange, and therefore, the ripening processes. The lower gas exchange induces lower O_2 and higher CO_2 concentrations in the internal atmosphere of the fruit, creating a modified atmosphere (Dhall, 2013). Pérez (2016) reported that fresh-cut mango coated with AVG 50 % had low rates of O_2 consumption and controlled CO_2 production, being 4.5 or 4.3 mL O_2 or CO_2 / kg · h compared to untreated samples, whose values were 7.0 or 6.3 mL gas / kg · h, for O_2 or CO_2, respectively. Contrarily, Chrysargyris (2016) showed that respiration rate of AVG 5 to 20 % coated tomatoes was not significantly different than it as for non-coated tomatoes. However, they also reported a decrease in ethylene production, which was 4.5 and 2.5 µL ethylene / kg · h, for non-coated and AVG 10 % coted tomatoes, which was related to the slowdown of the ripening process. Martínez-Rubio (2015)observed similar results when using an AVG coat with 0.5 % citric acid and 0.5 % ascorbic acid on pomegranate arils. As control arils were also immersed in citric and ascorbic acid, this effect was attributed mainly to AVG. Also, essential oils have been added to AVG to enhance its barrier properties because of their lipophilic nature. It seems that the incorporation of essential oils increases the water vapor retention and the gas barrier by adding hydrophobicity to the coating and, but this effect depends on the coating composition, as the interactions between the components of AVG and the essential oil tend to be complex (Sánchez-González, 2011). E.g., Martínez-Romero (2018) found that diminution of respiration rates could be enhanced by adding rosehip oil to AVG coating for plums and prunes.

AVG coating has proved to be a good way to decrease the respiration rate of fruits, by creating a semipermeable layer that minimizes gas exchange, thus retarding maturation and keeping the quality parameters of the products. Future investigations should be focused on the optimization of the gas barrier properties without a major impact in the mouthfeel of the edible coating. Moreover, the addition of substances such as essential oils could be explored to improve gas and water vapor barriers, and subsequently further decrease the metabolic rate of the fruits and vegetables. In fact, essential oils have been a trend in the last decades not only for their abovementioned functionality in edible coatings but also for the antioxidant and antimicrobial activities they exert, showing potential to be more incorporated in AVG coatings completing a multipurpose.

4.4 Preservation of bioactive compounds and antioxidant activity

Fruits and vegetables are rich in bioactive compounds, such as polyphenols, including anthocyanins, carotenoids, vitamins, phytoestrogens, and glucosinolates. These compounds not only receive increased attention due to their potential health benefits, but also to the impact that they have on the color of the fruits and vegetables and their antioxidant activity, contributing to the plant defense mechanisms (Hazrati, 2017).

As a coating for fruits and vegetables, AVG has been reported to have an impact on the retention of these compounds (Table 4). In most of the cases, AVG has proved to be effective in maintaining TPC or FC values, or at least delaying their loss during storage, from AVG 20 % in tomatoes (Chrysargyris, 2016) to AVG 100 % in sweet cherries (Serrano, 2017). On the contrary, non-coated fruits show a decrease in the levels of total phenolic content (TPC) and flavonoid content (FC) during storage, and accordingly, their antioxidant activity. Sometimes, AVG-coating is not enough to maintain these values, and it is used as a carrier for other antioxidants. For instance, ascorbic acid in combination with AVG 33 % in strawberries resulted in higher levels of TPC and FC, which could not be maintained with AVG alone (Sogvar, 2016). Also, the addition of *Fragaria cretica* extract 1 % to AVG 50 % was more efficient in preserving these compounds than AVG alone.

Preservation of TPC and FC due to AVG can be explained by taking into account a sum of factors. First, the decrease in respiration rate and delayed senescence, which, on the one hand, increases the resistance of tissues against decay and thus enhances their antioxidant system, and, on the other hand, conserves the compartmentation of plant cells, leading to less oxidant-enzyme activities (Ali, 2019; Hassanpour, 2015). Resistance of tissues may also prevent the degradation of anthocyanins, which occurs due to breakdown of the vacuoles, making them more accessible to degradation enzymes (Jiang, 2018). Second, the gas barrier formed by AVG reduces the amount of available oxygen, thus avoiding the oxidation of phenols and flavonoids. The antioxidant activity is also carried out by aloe emodin, which also prevents the degradation of these compounds (Khaliq, 2019). And third, AVG has been reported to enhance phenylalanine ammonia lyase (PAL) activity - an enzyme involved in the biosynthesis of polyphenol compounds and flavonoids in plants -, although the mechanisms for which this enzyme increases its activity are not fully understood (Hassanpour, 2015; Khaliq, 2019; Mirshekari, 2019).

Other bioactive compounds, especially carotenoids including lycopene or vitamins such as ascorbic acid, are also better preserved with AVG coatings (Table 4). As an example, litchi coated with AVG 50 % showed 1.46-fold higher ascorbic acid content than the non-coated control Ali (2019). Oxidative degradation is the main cause of their loss, and AVG provides a barrier against oxygen and thus controlling the auto-oxidation or enzymatic oxidation of such compounds (Leong, 2012).

4.5 Control of microbial spoilage

One of the issues that concerns fresh-cut fruits and vegetables is the microbial quality and safety. These products have a natural microbial load, and may have been contaminated by means of several ways, including harvesting practices, cross-contamination in the industry or handling (Kalia, 2006). Their processing does not include any pasteurizing step, indeed, the cutting and washing operations itself may increase the risk of microbial contamination and growth, due to the availability of nutrients from inside the vegetable cell (Bhagwat, 2006).

As it has been described in section 3.2, AVG has shown antimicrobial activities against bacteria, yeasts, and molds. However, in the past few years, its antimicrobial effect when applied as an edible coating on fruits and vegetables has not been widely studied. Hassanpour (2015) studied the effect of AVG 25 %, 50 % and 75 % on raspberries, and observed a reduction in the incidence of fungal decay on treated fruits, from 22.5

to 10.5 % of affected fruits, with no difference between the investigated concentrations. Also, (Ullah, 2017) coated bell pepper with 4 to 6 % of AVG and also reported a reduction in decay incidence and symptoms of fungal decay. Nasution (2015) used AVG 100 % on fresh-cut guava, and observed a delay of two days in the growth of total aerobic mesophylls, and also, the aerobic populations of coated guava were 2.5 log lower than in the control at the end of 14-day storage. The authors attributed this effect to the content on pyrocatechol, cinnamic acid and p-coumaric acid in AVG and to the enhanced tissue resistance against bacterial attack given by AVG, which strengthened the cell walls of the fruit. Additives, such as ascorbic acid 1.5 %, calcium chloride 2 % and potassium sorbate 0.2 % supported this effect, as the decrease in the pH creates an unfriendly environment for microorganisms, and the undissociated form of sorbic acid inhibited the growth of yeasts and molds. Other authors have also used citric and ascorbic acid in combination with AVG, in pomegranate arils and in strawberry fruit, respectively (Martínez-Rubio, 2015; Sogvar, 2016). In this case, Sogvar (2016) reported that AVG significantly reduced epyphitic microbiota counts, due to the saponins, anthraquinones and acemannan. After 18-day storage, total mesophyllic population decreased with the addition of AVG, from 3.63 to 3.31 log CFU / g and yeast and mold counts from 4.28 to 3.74 log CFU / g. When 5 % of ascorbic acid was added to the coating, aerobic mesophylls and yeasts and molds – 3.13 and 3.47 log CFU / g, respectively – were significantly lower than without this compound. Only one study, carried out by Pérez (2016), did not report any significant reduction of total aerobic mesophylls, yeasts or molds, when using a coating consisting on AVG 50%, carnauba wax 0.1 %, polysorbate 0.01 % and glycerol 1 % on mango.

The studies concerning the antimicrobial effect of AVG coatings on fruits and vegetables have focused on the epiphytic microbiota of the products. More research should be carried out to enlarge the knowledge about the effect that AVG coating could have on pathogenic microorganisms. In this regard, focusing on *Listeria monocytogenes* would be interesting, as these psychotropic bacteria may grow at lower temperatures that usually are recommended for this product's storage.

4.6 Other parameters

The effect of AVG on other quality parameters of fruits and vegetables, such as enzymatic activity, chilling injury or sensory attributes, have been little studied in the past few years.

The impact of AVG on the enzymatic activity of raspberries was studied by Hassanpour (2015). Berries were coated with three different percentages of AVG (25, 50 or 75 %), and superoxide dismutase was higher in all of them than it was in the non-coated control. Berries coated with AVG 50 % showed the highest activity of glutathione reductase and POD, and the highest content in reduced glutathione, which is one of the most abundant reducing thiols in the majority of cells, playing a role in the control of reactive oxygen species (Couto, 2016). Also, the ascorbate peroxidase enzyme was triggered in AVG 50 %, which is another of the major H_2O_2 scavenging enzymes in plant cells. Supporting this result, Ali (2016)also reported a lower content in H_2O_2 in litchi fruit coated with AVG 50% compared to the control, being 48 and 28 μmol / kg, respectively. Also, Mirshekari (2019) found similar results for white bottom mushrooms coated with AVG 50 %, that when compared to the control, H_2O_2 was 48 and 20 μmol / kg fresh weight, respectively, preventing then the peroxidation of the membranes.

Chilling injury was studied in oranges coated with AVG 30 % with glycerol 1 % by Rasouli (2019), but no difference was detected between them and the control samples in this regard. Contrarily, Ullah (2017) found less symptoms of chilling injury in bell pepper coated with AVG 4, 5, or 6 %, effect that was enhanced by arabic gum and cinnamon oil addition.

Regarding flavor, it is of high importance to carefully get rid of the latex in *Aloe vera* leaves, as its composition gives a bitter taste (Ramachandra, 2008). But if correctly prepared, and as it is exemplified by

Martínez-Romero (2018), AVG coatings did not impart any undesirable flavor to the plums studied. Hazrati (2017) also reported that AVG coated peaches were more favorable in terms of color appearance, taste, chewing ability and the overall quality for the consumers when compared to non-coated ones. Nasution (2015) indicated that additives such as 1.5 % ascorbic acid, 2 % calcium chloride, and 0.2 % potassium sorbate enhanced the sensory evaluation of the fresh-cut guava coated with AVG.

From the studies aforesaid, it is patent that AVG used as an edible coating has many advantages, that should be deeper investigated. More studies focused on the effect of AVG on parameters mentioned in this section should be carried out in order to gain a better understanding of the effect that AVG can have on the shelf-life of fresh and fresh-cut produce.

Table 3. Effect of AVG on weight loss, texture and color of fruits and vegetables during storage.

AV coat	Fruit (T °C)	Weight loss	Texture	Color	Source
AVG 10%, 20%, or 30% (Control: water)	Grapes (0ºC)	Coated fruits significantly lost less weight than control fruits. Non-coated: 9% weight loss, AVG 10, 20, and 30%, 5, 3, and 4.5% weight loss, respectively.	AVG significantly reduced firmness losses, whereas losses >50% were detected in control grapes after 21 days of storage.	AVG provided good gloss. AVG 20% gave the best visual results.	(Ali, 2016)
AVG 5%, 10%, 15%, or 20% (Control: water)	Tomatoes (11ºC)	No significant effect.	At the end of the 14-day storage, firmness of control and AVG 15% coated tomatoes was 15.4 and 18.9 N, respectively.	No significant effect.	(Chrysargyris, 2016)
AVG 30% (Control: water)	Peach (1ºC)	AVG had a significant effect in reducing the weight loss. Control and AVG coated lost 5.5 and 4.0% of weight, respectively.	AVG coating resulted in less fimness loss. At the end of storage, control firmness was 4 kg·N/cm whereas AVG coated firmness was 5 kg·N/cm.	During all storage, AVG coated fruits had higher Hue angle value in comparison with control fruits, which was 0.8 and 0.5, respectively. Chroma values were significantly different, being 42 and 60 for control and AVG coated fruit, respectively.	(Hazrati, 2017)
AVG 100% (Control: water)	Sweet cherry (2ºC)	n.d.	Firmness loss was significantly delayed in AVG coated fruits. At the first storage day, firmness was 5.3 ± 0.1 N. After 14 days, firmness was 4.2 ± 0.1 and 4.8 ± 0.1 N for control and AVG coated fruits, respectively.	Color evolution, measured in decrease of Chroma index, was significantly delayed in AVG coated fruits. Initial chroma value was 3.76 ± 0.7. Final Chroma values were significantly different, 25.2 ± 1.7 and 28.9 ± 0.7 for control and AVG coated fruits, respectively.	(Serrano, 2017)

AV coat	Fruit (T °C)	Weight loss	Texture	Color	Source
AVG 50% (Control: water)	Litchi fruit (20ºC)	After 8 days, weight loss was 2.56-fold less than control was.	n.d.	AVG coated fruits showed significantly reduced browning index (BI) during storage. Browning was delayed for two days compared with the control. At day 4, BI had increased 2.5 and 0.2 in non-coated and coated samples, respectively.	(Ali, 2019)
AVG 15%, AVG 25%, or AVG 50% (Control: water)	Fresh-cut papaya (28ºC)	Weight was better maintained by coated fruits. Control fruits lost 6.5% weight.	AVG coated fruits maintained some degree of firmness up to last day of storage, especially AVG 50%. Control fruits showed the highest softening. At the end of storage, firmness was 12.65 and 52.29 N, for non-coated and AVG 50%, respectively.	n.d.	(Mendy, 2019)
AVG 25%, AVG 50%, or AVG 75% (Control: water)	White button mushroom (4ºC)	AVG 50% and AVG 70% resulted in the lowest weight loss (3.5%) compared to the control (6.0%).	n.d.	All AVG delayed the development of postharvest browning. Browning was 20-25% lower in AVG 50 and AVG 75% than it was in the control.	(Mirshekari, 2019)
AVG 100% + [ascorbic acid 1.5%, $CaCl_2$ 2%, potassium sorbate 0.2%, or a combination] (Control: non-coated)	Fresh-cut guava (5ºC)	Weight loss was lower in AVG coated fruit (9.9%) than it was in control fruit (15.1%). Addition of $CaCl_2$ 2% decreased the weight loss to 3.6%.	Hardness of all samples decreased, but it was more pronounced in control fruit than coated fruit. Addition of $CaCl_2$ in combination or not with ascorbic acid helped to retain hardness.	At the end of storage period (12 days), control samples had lower lightness and higher redness and yellowness, indicating higher browning. Amongst coated fruits, AVG 100% without additives had highest browning.	(Nasution, 2015)

AV coat	Fruit (T °C)	Weight loss	Texture	Color	Source
AVG 50% + citric acid 0.5% + ascorbic acid 0.5% (Control: citric acid 0.5% + ascorbic acid 0.5%)	Pomegranate arils (3ºC)	n.d.	AVG coating significantly reduced firmness losses, whereas losses >20% were detected in control arils.	n.d.	(Martínez-Rubio, 2015)
AVG 50% + carnauba wax 0.1% + polisorbate 0.1% + glycerol 1% (Control: water)	Fresh-cut mango (4ºC)	AVG coating contributed to the significant reduction of the weight loss (1 %) when compared to control(2 %).	Firmness of AVG coated fruits was stabilized, and firmness values were significantly higher (28 N) than those of the control fruit (20 N).	Change of color of AVG coated fruits was half of the change of control fruits.	(Pérez, 2016)
AVG 33% + [ascorbic acid 0, 1, 3 or 5%] (Control: water)	Strawberries (1ºC)	By the end of storage, weight loss of control, AVG and AVG + ascorbic acid of strawberries was 21.3, 18.1 and 12.6%, respectively.	AVG and AVG + ascorbic acid coated fruits softened more slowly than control (1N at the end of storage). AVG + ascorbic acid retained texture more than AVG alone (up to 3.5 N compared to 2 N).	n.d.	(Sogvar, 2016)
AVG 100%, AVG 100% + rosehip oil 2% (Control: water)	Plums (2/20ºC)	AVG 100% + rosehip oil 2% had the lowest weight loss, being 13.08 ± 0.21 %, compared to non-coated or AVG 100%, which were 15.30 ± 0.37 and 15.32 ± 0.35, respectively.	AVG 100% coating retarded softening. At the end of 28-day storage, firmness was 8 and 12 N, for non-coated and AVG 100%, respectively	Hue values remained close to those obtained at the harvest, especially AVG 100% + rosehip oil 2%.	(Martínez-Romero, 2017)

AV coat	Fruit (T °C)	Weight loss	Texture	Color	Source
AVG 25%, AVG 32.5%, or AVG 40% + CMC 0.5% + corn syrup 2.5% + ethanol (Control: non-coated)	Strawberry (4ºC/10ºC)	At 4 ºC, weight loss was higher in fruits coated with AVG 40% than it was in AVG 25%. At tropical conditions, all AVG reduced weight loss when compared to the control, extending shelf-life.	AVG 40% showed the most stable texture among treatments, extending the shelf-life up to 14 days.	n.d.	(Falah, 2018)

n.d. not determined

Table 4. Changes in total phenolic content (TPC), flavonoid content (FC), antioxidant capacity (AC) and other important bioactive compounds of fresh fruit and vegetables, when coated with AVG with or without additives

AV coat	Fruit (T °C)	Total phenolic content, flavonoid content and antioxidant capacity	Bioactive compounds[1]	Source
AVG 5%, 10%, 15%, or 20% (Control: water)	Tomatoes (11ºC)	**TPC**: It remained stable for all treatments except for AVG 20%, in which TPC increased 2-fold compared with others.	**Carotenoids**: Lycopene and β-carotene contents increased 20% more compared to the control fruits, at the end of 14-day storage. **AA**: Coating significantly delayed the decline of AA content in coated samples in comparison to control samples. At day 14, AA content was 0.06 and 0.08 mg / g FW for control and AVG 10%, respectively.	(Chrysargyris, 2016)
AVG 100% (Control: water)	Sweet cherry (2ºC)	**TPC**: It increased during storage, but it was delayed by the application of AVG 100%. At day 0, TPC was 130.24 ± 5.56 mg / 100 g FW, and 170.48 ± 7.25 mg / 100g FW after 28 days. **FC**: Increase in anthocyanin content was delayed by coating with AVG 100%. At day 0, TPC was 110 mg / 100 g FW, and 120 mg / 100g FW after 28 days.		(Serrano, 2017)
AVG 50% (Control: water)	Litchi fruit (20ºC)	**TPC**: On day 8 storage, TPC of AVG coated fruit was 1.66-fold higher than control. **FC**: AVG coated fruit had significant higher content of anthocyanins throughout storage. On day 8, it was 2-folf higher in AVG fruit.	**AA**: At the end of the storage, coated fruit showed 1.46-fold higher AA content than the control.	(Ali, 2019)

AV coat	**Fruit (T °C)**	**Total phenolic content, flavonoid content and antioxidant capacity**	**Bioactive compounds**[1]	**Source**
AVG 15%, AVG 25%, or AVG 50% (Control: water)	Fresh-cut papaya (28ºC)	**TPC**: Coated fruits were able to maintain better the TPC than control fruits did. **AC**: Highest antioxidant activity as DPPH· scavenger was observed in AVG 50% after 9 days of storage. **FC**: Highest flavonoid content was observed in AVG 50% (12.9 mg/100 g) after 15-day storage.	**AA**: Highest content of AA was recorded on AVG 50% coated fruit, whereas the lowest content was found in control fruits. **Carotenoids**: At the end of storage, coated fruits were able to maintain higher carotenoid content than uncoated.	(Mendy, 2019)
AVG 25%, AVG 50%, or AVG 75% (Control: water)	White button mushroom (4ºC)	**TPC**: AVG resulted in higher levels of TPC than in controls during all storage assessments. TPC was 34.16 and 41.75 mg / 100 g FW for control and AVG 50 %, respectively. **AC**: AVG resulted in higher antioxidant activity measured as DPPH· scavenging than in controls during all storage assessments. DPPH· inhibition for control and AVG 50% was 38.96 and 48.73 % respectively		(Mirshekari, 2019)
AVG 30% + glycerol 1% (Control: non-coated)	Orange (4ºC)	**TPC**: No significant differences were observed between coated and uncoated fruits. Average values were 180.0 ± 9.21 mg gallic acid / 100 g FW for both treatments.	**AA**: The rate of decrease in vitamin C was higher in the control than in the coated samples. At the end of 80-day storage, vitamin C was 33 and 37 mg AA / 100 g FW, for control and coated samples, respectively.	(Rasouli, 2019)

AV coat	Fruit (T °C)	Total phenolic content, flavonoid content and antioxidant capacity	Bioactive compounds[1]	Source
AVG 33% + [ascorbic acid 0, 1, 3 or 5%] (Control: water)	Strawberries (1°C)	**TPC**: Highest TPC content was found in AVG 33% + ascorbic acid 5%. At the end of 18-day storage, TPC was 14, 27, and 35 mg gallic acid / kg FW, for control, AVG, and AVG + 5 % AA, respectively. **AC**: Antioxidant activity decreased in all the samples. AVG 33% alone could not maintain antioxidant activity, while the addition of ascorbic acid delayed its decrease. At the end of 18-day storage, AC was 63, 68, and 80 % for control, AVG, and AVG + 5 % AA, respectively. **FC**: Increase in anthocyanin content was greater in coated fruit than in control. AVG 33% + 3 or 5% ascorbic acid coated fruits had the highest anthocyanin content. At the end of 18-day storage, anthocyanin content was 120, 145 and 165 mg pelargonidin glucoside / 100 g FW for control, AVG, and AVG + 5 % AA, respectively.	**AA**: Vitamin C content decreased from 69.7 mg/kg to 26.9, 38.5, 40.8 50.0 and 55.4 mg/kg fresh weight during storage, for control, AVG 33% + 1, 3, or 5% AA, respectively.	(Sogvar, 2016)
AVG 1%, or AVG 1% + chitosan 1% (Control: water)	Tomatoes (4°C)	**TPC**: In AVG 1% + chitosan 1%, TPC was slowly induced during storage period of 42 days. **AC**: AVG 1% + chitosan 1% had significantly induced the DPPH· radical scavenging activity, as control fruits did not have at the end of storage.	**AA**: Lowest level of AA content was observed in control fruits (0.59 mg/g), whereas all coated samples had higher contents. **Lycopene**: The highest level of lycopene was achieved at 35-day of storage (66.4 nmol/g fresh weight), and AVG+ chitosan was the most effective coat to maintain it.	(Khatri, 2020)

n.d. not determined

5 Conclusions

Aloe vera L. has gotten the attention of many industrial branches, such as pharmacy, cosmetics and food. As reviewed herein, its gel has shown promising antioxidant activities and antimicrobial effects, attributed to its characteristic active components, which include aloin, aloe emodin and other anthraquinone as well as the mucopolysaccharide acemannan.

In the last years, *Aloe vera* gel has become subject of current research regarding its applicability as an edible coating for fresh and fresh-cut produce. The present study highlights the recent scientific observations published in this regard, remarking the effects aloe vera gel had in fruit and vegetable quality retention: maintenance of color, firmness, antioxidant values and vitamins, as well as ripening delay has been reported by many studies.

Overall, AVG seems to be a promising alternative for preserving fresh produce, used alone or together with other preservatives. Its use offers the consumers a natural and sustainable edible coating that can contribute to shelf life prolongation or enhanced food safety, while promoting some health benefits on them.

Acknowledgements

I.Nicolau-Lapeña is in receipt of a predoctoral grant (BES 2017 079779) awarded by the Spanish Ministry of Economy, Industry and Competitiveness (MINECO). Dr. I. Aguiló-Aguayo thanks the National Programme for the Promotion of Talent and Its Employability of MINECO and the European Social Fund for her Postdoctoral Senior Grant 'Ramon y Cajal' (RYC-2016-2019 949).

Conflict of interests

The authors declare no conflict of interests.

References

Abdul QM, Shahzadi SK, Bashir A, Munir A, & Shahzad S. (**2017**). Evaluation of phenolic compounds and antioxidant and antimicrobial activities of some common herbs. *International Journal of Analytical Chemistry*, *2017*. https://doi.org/10.1155/2017/3475738

Ahlawat KS, & Khatkar BS. (**2011**). Processing, food applications and safety of *Aloe vera* products: A review. *Journal of Food Science and Technology*, *48*(5), 525–533. https://doi.org/10.1007/s13197-011-0229-z

Ahmed M, & Hussain F. (**2013**). Chemical composition and biochemical activity of *Aloe vera* (*Aloe barbadensis Miller*) leaves. *International Journal of Chemical and Biochemical Sciences*, *3*, 29–33.

Akev N, Turkay G, Can A, Gurel A, Yildiz F, Yardibi H, Ekiz EE, & Uzun H. (**2007**). Tumor preventive effect of *Aloe vera* leaf pulp lectin (aloctin I) on *Ehrlich ascites* tumours in mice. *Phytotherapy Research*, *21*, 1070–1075. https://doi.org/10.1002/ptr

Ali J, Pandey S, Singh V, & Joshi P. (**2016**). Effect of coating of *Aloe vera* gel on shelf life of grapes. *Current Research in Nutrition and Food Science*, *4*(1), 58–68. https://doi.org/10.12944/CRNFSJ.4.1.08

Ali S, Khan AS, Nawaz A, Anjum MA, Naz S, Ejaz S, & Hussain S. (**2019**). *Aloe vera* gel coating delays postharvest browning and maintains quality of harvested litchi fruit. *Postharvest Biology and Technology*, *157*(April), 110960. https://doi.org/10.1016/j.postharvbio.2019.110960

Amar S. (**2008**). *Aloe vera*: a short review. *Indian Journal of Dermatology*, *53*(4), 163–166. https://doi.org/10.4103/0019-5154.44785

Aqil F, Ahmad I, & Mehmood Z. (**2006**). Antioxidant and free radical scavenging properties of twelve traditionally used Indian medicinal plants. *Turkish Journal of Biology*, *30*(3), 177–183.

Asamenew G, Bisrat D, Mazumder A, & Asres K. (**2011**). *In vitro* antimicrobial and antioxidant activities of anthrone and chromone from the latex of *Aloe harlana* Reynolds. *Phytotherapy Research*, *25*(12), 1756–1760. https://doi.org/10.1002/ptr.3482

Barrett DM, Beaulieu JC, & Shewfelt R. (**2010**). Color, flavor, texture, and nutritional quality of fresh-cut fruits and vegetables: Desirable levels, instrumental and sensory measurement, and the effects of processing. *Critical Reviews in Food Science and Nutrition*, *50*(5), 369–389. https://doi.org/10.1080/10408391003626322

Bhagwat AA. (**2006**). Microbial safety of fresh-cut produce: where are we now? In Matthews KR (Ed.), *Microbiology of Fresh Produce* (1st ed., pp. 121–125). ASM Press.

Blekkenhorst L, Sim M, Bondonno C, Bondonno N, Ward N, Prince R, & Hodgson J. (**2018**). Cardiovascular health benefits of specific vegetable types: a narrative review. *Nutrients*, *10*(5), 595.

Borges-Argáez R, Chan-Balan R, Cetina-Montejo L, Ayora-Talavera G, Sansores-Peraza P, Gómez-Carballo J, & Cáceres-Farfán M. (**2019**). *In vitro* evaluation of anthraquinones from *Aloe vera* (*Aloe barbadensis* Miller) roots and several derivatives against strains of influenza virus. *Industrial Crops and Products*, *132*(Feb), 468–475. https://doi.org/10.1016/j.indcrop.2019.02.056

Castillo S, Navarro D, Zapata PJ, & Guillén F. (**2012**). Using aloe vera as a preharvest treatment to maintain postharvest organic table grape quality. *Acta Horticulturae*, *933*, 621–626.

Cataldi V, Di Bartolomeo S, Di Campli E, Nostro A, Cellini L, & Di Giulio M. (**2015**). *In vitro* activity of *Aloe vera* inner gel against microorganisms grown in planktonic and sessile phases. *International Journal of Immunopathology and Pharmacology*, *28*(4), 595–602. https://doi.org/10.1177/0394632015600594

Cellini L, Di Bartolomeo S, Di Campli E, Genovese S, Locatelli M, & Di Giulio M. (**2014**). *In vitro* activity of *Aloe vera* inner gel against *Helicobacter pylori* strains. *Letters in Applied Microbiology*, *59*(1), 43–48. https://doi.org/10.1111/lam.12241

Chase MW, Christenhusz MJM, Fay MF, Byng JW, Judd WS, Soltis DE, Mabberley DJ, Sennikov AN, Soltis PS, Stevens PF, Briggs B, Brockington S, Chautems A, Clark JC, Conran J, Haston E, Möller M, Moore M, Olmstead R, … Weber A. (**2016**). An update of the angiosperm phylogeny group classification for the orders and families of flowering plants: APG IV. *Botanical Journal of the Linnean Society*, *181*(1), 1–20. https://doi.org/10.1111/boj.12385

Choi S, & Chung M-H. (**2003**). A review on the relationship between Aloe vera components and their biologic effects. *Seminars in Integrative Medicine*, *1*(1), 53–62. https://doi.org/10.1016/S1543-1150(03)00005-X

Chrysargyris A, Nikou A, & Tzortzakis N. (**2016**). Effectiveness of Aloe vera gel coating for maintaining tomato fruit quality. *New Zealand Journal of Crop and Horticultural Science*, *Published*(July). https://doi.org/10.1080/01140671.2016.1181661

Couto N, Wood J, & Barber J. (**2016**). The role of glutathione reductase and related enzymes on cellular redox homoeostasis network. *Free Radical Biology and Medicine*, *95*, 27–42. https://doi.org/10.1016/j.freeradbiomed.2016.02.028

Dammak I, Lasram S, Hamdi Z, Ben Moussa O, Mkadmini Hammi K, Trigui I, Houissa H, Mliki A, & Hassouna M. (**2018**). In vitro antifungal and anti-ochratoxigenic activities of Aloe vera gel against Aspergillus carbonarius isolated from grapes. *Industrial Crops and Products*, *123*(February), 416–423. https://doi.org/10.1016/j.indcrop.2018.07.023

Darmawati E, Nava N, & Suyatma N. (**2019**). Aloe vera as a coating material for tropical fruits using spray method. *Earth Environmental Science*, *309*, 012011. https://doi.org/10.1088/1755-1315/309/1/012011

Das S, Mishra B, Gill K, Ashraf MS, Singh AK, Sinha M, Sharma S, Xess I, Dalal K, Singh TP, & Dey S. (**2011**). Isolation and characterization of novel protein with anti-fungal and anti-inflammatory properties from Aloe vera leaf gel. *International Journal of Biological Macromolecules*, *48*(1), 38–43. https://doi.org/10.1016/j.ijbiomac.2010.09.010

Dhall RK. (**2013**). Advances in edible coatings for fresh fruits and vegetables: A review. *Critical Reviews in Food Science and Nutrition*, *53*(5), 435–450. https://doi.org/10.1080/10408398.2010.541568

European Food Safety Authority (EFSA). (**2014**). Scientific Opinion on the risk posed by pathogens in food of non-animal origin. Part 2 (*Salmonella* and Norovirus in tomatoes). *EFSA Journal*, *12*(10), 3832. https://doi.org/10.2903/j.efsa.2014.3832

Elbandy MA, Abed SM, & Gad SSA. (**2014**). *Aloe vera Gel as a Functional Ingredient and Natural Preservative in Mango Nectar*. *9*(2), 191–203. https://doi.org/10.5829/idosi.wjdfs.2014.9.2.1139

Eshun K, & He Q. (**2004**). *Aloe vera*: A valuable ingredient for the food, pharmaceutical and cosmetic industries - A review. *Critical Reviews in Food Science and Nutrition*, *44*(2), 91–96. https://doi.org/10.1080/10408690490424694

Estepa A, Micol V, Alves DS, & Pe L. (**2004**). *Membrane-related effects underlying the biological activity of the anthraquinones emodin and barbaloin*. *68*, 549–561. https://doi.org/10.1016/j.bcp.2004.04.012

Falah, M.A.F. Yuliastuti P, & Khuriyati N. (**2018**). Quality and shelf-life improvement of fresh strawberry (Fragaria sp. 'Holibrite') using Aloe vera coating during storage in a tropical environment. *Acta Horticulturae*, *Proc. VIII*, 665–672. https://doi.org/10.17660/ActaHortic.2018.1194.95

Femenia A, García Pascual P, Simal S, & Rosselló C. (**2003**). Effects of heat treatment and dehydration on bioactive polysaccharide acemannan and cell wall polymers from Aloe barbadensis Miller. *Carbohydrate Polymers*, *51*, 397–405.

Foster M, Hunter D, & Sammam S. (**2010**). Evaluation of the nutritional and metabolic effects of Aloe vera. In I. Benzie & S. Wachtel-Galor (Eds.), *Herbal Medicine: Biomolecular and Clinical Aspects* (2nd ed., pp. 37–54). Taylor and Francis Group.

Fukumoto LR, & Mazza G. (**2000**). Assessing antioxidant and prooxidant activities of phenolic compounds. *Journal of Agricultural and Food Chemistry,* 48, 3597-3604.

https://doi.org/10.1021/jf000220w

Gupta A, & Rawat S. (**2017**). Clinical importance of *Aloe vera*. *Research Journal of Topical and Cosmetic Sciences*, *8*(1), 30. https://doi.org/10.5958/2321-5844.2017.00004.8

Hamman JH. (**2008**). Composition and applications of *Aloe vera* leaf gel. *Molecules*, *13*(8), 1599–1616. https://doi.org/10.3390/molecules13081599

Hassan B, Chatha SAS, Hussain AI, Zia KM, & Akhtar N. (**2018**). Recent advances on polysaccharides, lipids and protein based edible films and coatings: A review. *International Journal of Biological Macromolecules*, *109*, 1095–1107. https://doi.org/10.1016/j.ijbiomac.2017.11.097

Hassanpour H. (**2015**). Effect of *Aloe vera* gel coating on antioxidant capacity, antioxidant enzyme activities and decay in raspberry fruit. *LWT - Food Science and Technology*, *60*(1), 495–501. https://doi.org/10.1016/j.lwt.2014.07.049

Hazrati S, Beyraghdar-Kashkooli A, Farhad K, Zeinolabedin H, Tahmasebi-Sarvestani Z, & Sadeghi AR. (**2017**). Evaluation of *Aloe ve*ra gel as an alternative edible coating for peach fruits during cold storage period. *Gesunde Pflanzen*, *69*, 131–137. https://doi.org/10.1007/s10343-017-0397-5

Hęś M, Dziedzic K, Górecka D, Jędrusek-Golińska A, & Gujska E. (**2019**). *Aloe vera* (L.) Webb.: natural sources of antioxidants – A review. *Plant Foods for Human Nutrition*, *Published*. https://doi.org/10.1007/s11130-019-00747-5

Hu Y, Xu J, & Hu Q. (**2003**). Evaluation of antioxidant potential of *Aloe vera* (*Aloe barbadensis* Miller) extracts. *Journal of Agricultural and Food Chemistry*, *51*(26), 7788–7791. https://doi.org/10.1021/jf034255i

Huang CT, Hung CY, Hseih YC, Chang C, Velu AB, He YC, Huang YL, Chen TA, Chen TC, Lin CY, Lin YC, Shih SR, & Dutta A. (**2019**). Effect of aloin on viral neuraminidase and hemagglutinin-specific T cell immunity in acute influenza. *Phytomedicine*, *64*(March), 152904. https://doi.org/10.1016/j.phymed.2019.152904

Hussein Z, Fawole OA, & Opara UL. (**2019**). Harvest and postharvest factors affecting bruise damage of fresh fruits. *Horticultural Plant Journal*, *6*(1), 1–13. https://doi.org/10.1016/j.hpj.2019.07.006

Irtiza S, Bhat A, Wani AB, Khan FA, Murtaza I, & Younus-Wani Y. (**2019**). Physiological and biochemical interactions for extending the shelf life of fruits and vegetables: A review. *International Journal of Chemical Studies*, *7*(1), 2153–2166. https://doi.org/E-ISSN: 2321–4902

Iwu MM. (**2014**). *Handbook of African medicinal plants* (2nd ed.). Taylor & Francis.

Jiang X, Lin H, Shi J, Neethirajan S, Lin Y, Chen Y, Wang H, & Lin Y. (**2018**). Effects of a novel chitosan formulation treatment on quality attributes and storage behavior of harvested litchi fruit. *Food Chemistry*, *252*, 134–141. https://doi.org/10.1016/j.foodchem.2018.01.095

Kafkaletou M, Ouzounidou G, & Tsantili E. (**2018**). Effect of preharvest aloe (*Aloe vera* L.) spray on physiological and quality attributes of strawberries during storage. *Acta Horticulturae*, *1194*, 105–112. https://doi.org/10.17660/ActaHortic.2018.1194.17

Kalia A, Gupta RP (**2006**). *Handbook of fruits and fruit processing* (Hui HY; 1st ed.). Blackwell Publishing. ISBN-10: 0-8138-1981-4

Kang MC, Kim SY, Kim YT, Kim EA, Lee SH, Ko SC, Wijesinghe WAJP, Samarakoon KW, Kim YS, Cho JH, Jang HS, & Jeon YJ. (**2014**). *In vitro* and *in vivo* antioxidant activities of polysaccharide purified from aloe vera (*Aloe barbadensis*) gel. *Carbohydrate Polymers*, *99*, 365–371. https://doi.org/10.1016/j.carbpol.2013.07.091

Kasim MU, & Kasim R. (**2015**). Color quality of fresh-cut fruits and vegetables. *Iternational Scientific Agricultural Symposium*, *6*. https://doi.org/10.7251/AGSDY15051007K

Khaliq G, Ramzan M, & Baloch AH. (**2019**). Effect of *Aloe vera* gel coating enriched with *Fagonia cretica* plant extract on physicochemical and antioxidant activity of sapodilla fruit during postharvest storage. *Food Chemistry*, *286*, 346–353.

https://doi.org/10.1016/j.foodchem.2019.01.135

Khatri D, Panigrahi J, Prajapati A, & Bariya H. (**2020**). Attributes of *Aloe vera* gel and chitosan treatments on the quality and biochemical traits of post-harvest tomatoes. *Scientia Horticulturae*, *259*, 108837. https://doi.org/10.1016/j.scienta.2019.108837

Kumar P, Sethi S, Sharma RR, Singh S, & Varghese E. (**2018**). Improving the shelf life of fresh-cut 'Royal Delicious' apple with edible coatings and anti-browning agents. *Journal of Food Science and Technology*. https://doi.org/10.1007/s13197-018-3308-6

Lee J, & Hand-Yoon Y. (**1997**). Characteristics of aloe vera suspended liquid yoghurt inoculated with Lactobacillus casei YIT 9018. *Korean Journal of Animal Science*, *39*, 93–100.

Leong SY, & Oey I. (**2012**). Effects of processing on anthocyanins, carotenoids and vitamin C in summer fruits and vegetables. *Food Chemistry*, *133*(4), 1577–1587. https://doi.org/10.1016/j.foodchem.2012.02.052

Liu C, Cui Y, Pi F, Cheng Y, Guo Y, & Qian H. (**2019**). Extraction, purification, structural characteristics, biological activities and pharmacological applications of acemannan, a polysaccharide from *Aloe vera*: A review. *Molecules*, *24*(8), 1554. https://doi.org/10.3390/molecules24081554

Loef M, & Walach H. (**2012**). Fruit, vegetables and prevention of cognitive decline or dementia: a systematic review of cohort studies. *The Journal of Nutrition, Health and Aging*, *16*(7), 626–630.

Maan AA, Nazir A, Iqbal-Khan MK, Ahmad T, Zia R, Murid M, & Abrar M. (**2018**). The therapeutic properties and applications of *Aloe vera*: A review. *Journal of Herbal Medicine*, *12*, 1–10. https://doi.org/10.1016/j.hermed.2018.01.002

Maenthaisong R, Chaiyakunapruk N, Niruntraporn S, & Kongkaew C. (**2007**). The efficacy of *Aloe vera* used for burn wound healing: A systematic review. *Burns*, *33*(6), 713–718. https://doi.org/10.1016/j.burns.2006.10.384

Martínez-Romero D, Paladines D, Valverde M, Guille F, Zapata PJ, & Valero D. (**2018**). Rosehip oil added to Aloe vera gel as postharvest coating of 'Songría' plums and 'President' prunes. *Actia Horticulturae*, *Proc. VIII*, 321–326. https://doi.org/10.17660/ActaHortic.2018.1194.46

Martinez-Romero D, Paladines D, Valverde M, Guillén F, Zapata PJ, & Valero D. (**2018**). Rosehip oil added to Aloe vera gel as postharvest coating of 'Songría' plums and 'President' prunes. *Acta Horticulturae*, *1194*, 321–325. https://doi.org/10.17660/ActaHortic.2018.1194.46

Martínez-Romero Domingo, Zapata PJ, Guillén F, Paladines D, Castillo S, Valero D, & Serrano M. (**2017**). The addition of rosehip oil to Aloe gels improves their properties as postharvest coatings for maintaining quality in plum. *Food Chemistry*, *217*, 585–592. https://doi.org/10.1016/j.foodchem.2016.09.035

Martínez-Rubio D, Pina N, Guillén F, Valero D, Zapata PJ, Serrano M, Valverde JM, Castillo S, Díaz-Mula HM, & Martínez-Romero D. (**2015**). Application of an edible coating based on Aloe vera to improve general quality of minimal processed pomegranate arils. *Acta Horticulturae*, *1071*, 489–494.

Mendy T., Misran A, Mahmud TM., & Ismail S. (**2019**). Application of *Aloe vera* coating delays ripening and extend the shelf life of papaya fruit. *Scientia Horticulturae*, *246*, 769–776. https://doi.org/10.1016/j.scienta.2018.11.054

Minjares-Fuentes R, Femenia A, Comas-Serra F, & Rodríguez-González V. (**2018**). Compositional and structural features of the main bioactive polysaccharides present in the *Aloe vera* plant. *Journal of AOAC International*, *101*(6), 1711–1719. https://doi.org/10.5740/jaoacint.18-0119

Mirshekari A, Madani B, & Golding J. (**2019**). *Aloe vera* gel treatment delays postharvest browning of white button mushroom (*Agaricus bisporus*). *Journal of Food Measurement and Characterization*, *Published*. https://doi.org/10.1007/s11694-019-00040-8

Misir J, Bristhi F., & Hoque M. (**2014**). *Aloe vera* gel as a novel edible coating for fresh fruits: A review.

American Journal of Food Science and Technology, *2*(3), 93–97. https://doi.org/10.12691/ajfst-2-3-3

Mulay S, Borade A, Bele A, & Khale A. (**2013**). *Aloe vera* - A review. *International Journal of Pharmaceutical and Phytopharmacological Research*, *3*(3), 203–211. https://doi.org/E-ISSN; 2249-6084

Nasution Z, Ye JNW, & Hamzah YY. (**2015**). Characteristics of fresh-cut guava coated with *Aloe vera* gel as affected by different additives. *Kasetsart Journal - Natural Science*, *49*(1), 111–121.

Nath S, Vidinamo F, & Spriggs J. (**2007**). Preservation and storage of perishable fruit and vegetables in the highlands of Papua New Guinea. *National Conference: Agriculture and Engineering - Challenge Today, Technology Tomorrow.*

Ni Y, Turner D, Yates KM, & Tizard I. (**2004**). Isolation and characterization of structural components of *Aloe vera* L. leaf pulp. *International Immunopharmacology*, *4*, 1745–1755. https://doi.org/10.1016/j.intimp.2004.07.006

Opazo-Navarrete M, Tabilo-munizaga G, Vega-Gálvez A, Miranda M, & Pérez-Won M. (**2012**). Effects of high hydrostatic pressure (HHP) on the rheological properties of *Aloe vera* suspensions (Aloe barbadensis Miller). *Innovative Food Science and Emerging Technologies*, *16*, 243–250. https://doi.org/10.1016/j.ifset.2012.06.006

Parvez MK, Al-Dosari MS, Alam P, Rehman M, Alajmi MF, & Alqahtani AS. (**2019**). The anti-hepatitis B virus therapeutic potential of anthraquinones derived from *Aloe vera*. *Phytotherapy Research*, *33*, 2960–2970. https://doi.org/10.1002/ptr.6471

Pérez F, Aristizábal ID, & Restrepo JI. (**2016**). Conservation of minimally processed ango 'Tommy atkins' by applying an *Aloe vera (Aloe barbandensis* Miller) coating. *Vitae, Revista de La Facultad de Ciencias Farmacéuticas y Alimentarias*, *23*(1), 65–77.

Radha MH, & Laxmipriya NP. (**2015**). Evaluation of biological properties and clinical effectiveness of *Aloe vera*: A systematic review. *Journal of Traditional and Complementary Medicine*, *5*(1), 21–26. https://doi.org/10.1016/j.jtcme.2014.10.006

Raghav PK, Agarwal N, Saini M, Vidhyapeeth J, & Vidhyapeeth J. (**2016**). Edible coating of fruits and vegetables: a review. *International Journal of Scientific and Modern Education*, *I*(I), 188–204.

Ramachandra CT, & Srinivasa Rao P. (**2008**). Processing of *Aloe vera* leaf gel: A review. *American Journal of Agricultural and Biological Science*, *3*(2), 502–510. https://doi.org/10.3844/ajabssp.2008.502.510

Rasouli M, Koushesh M, & Ramezanian A. (**2019**). Inhibitory effect of salicylic acid and *Aloe vera* gel edible coating on microbial load and chilling injury of orange fruit. *Scientia Horticulturae*, *247*, 27–34. https://doi.org/10.1016/j.scienta.2018.12.004

Ray A, Gupta SD, & Ghosh S. (**2013**). Evaluation of anti-oxidative activity and UV absorption potential of the extracts of *Aloe vera* L. gel from different growth periods of plants. *Industrial Crops and Products*, *49*, 712–719. https://doi.org/10.1016/j.indcrop.2013.06.008

Reyes JE, Guanoquiza MI, Tabilo-Munizaga G, Vega-Galvez A, Miranda M, & Pérez-Won M. (**2012**). Microbiological stabilization of A*loe vera (Aloe barbadensis* Miller) gel by high hydrostatic pressure treatment. *International Journal of Food Microbiology*, *158*(3), 218–224. https://doi.org/10.1016/j.ijfoodmicro.2012.07.019

Richardson J, Smith JE, McIntyre M, Thomas R, & Pikington K. (**2005**). *Aloe vera* for preventing radiation-induced skin reactions: A systematic literature review. *Clinical Oncology*, *17*(6), 478–484. https://doi.org/10.1016/j.clon.2005.04.013

Rodrigues L., Silva S., & Reis R. (**2019**). Acemannan-based films: an improved approach envisioning biomedical applications. *Materials Research Express*, *6*(9), 095406. https://doi.org/10.1088/2053-1591/ab2f66

Rodríguez-Rodríguez M., Meléndez-Pizarro CO, Espinoza-Hicks JC, Quintero-Ramos A, Sánchez-Madrigal M, Meza-Velázquez JA, & Jiménez-Castro JA. (**2019**). Effects of UV-C irradiation and traditional thermal processing on acemannan contained in *Aloe vera* gel blends. *Carbohydrate*

Polymers, *222*, 114998. https://doi.org/10.1016/j.carbpol.2019.114998

Ruxton C, Gardner E, & Walker D. (**2006**). Can pure fruit and vegetable juices protect against cancer and cardiovascular disease too? A review of the evidence. *International Journal of Food Sciences and Nutrition*, *57*(3–4), 249–272.

Saberian H, Hamidi-Esfahani Z, & Abbasi S. (**2013**). Effect of pasteurization and storage on bioactive components of *Aloe vera* gel. *Nutrition and Food Science*, *43*(2), 175–183. https://doi.org/10.1108/00346651311313553

Sahu PK, Giri DD, Singh R, Pandey P, Gupta S, Shrivastava AK, Kumar A, & Pandey KD. (**2013**). Therapeutic and medicinal uses of *Aloe vera*: A Review. *Pharmacology & Pharmacy*, *04*(08), 599–610. https://doi.org/10.4236/pp.2013.48086

Salah F, ElGhoul Y, Mahdhi A, Majdoub H, Jarroux N, & Sakli F. (**2017**). Effect of the deacetylation degree on the antibacterial and antibiofilm activity of acemannan from Aloe vera. *Industrial Crops and Products*, *103*, 13–18. https://doi.org/10.1016/j.indcrop.2017.03.031

Salehi B, Albayrak S, Antolak H, Kręgiel D, Pawlikowska E, Sharifi-Rad M, Uprety Y, Fokou PVT, Yousef Z, Zakaria ZA, Varoni EM, Sharopov F, Martins N, Iriti M, & Sharifi-Rad J. (**2018**). *Aloe* genus plants: From farm to food applications and phytopharmacotherapy. *International Journal of Molecular Sciences*, *19*(9), 2843. https://doi.org/10.3390/ijms19092843

Sánchez-González L, Vargas M, González-Martínez C, Chiralt A, & Cháfer M. (**2011**). Use of essentia oils in bioactive edible coatings. *Food Engineering Reviews*, *3*, 1–16. https://doi.org/10.1007/s12393-010-9031-3

Sánchez-Machado D., López-Cervantes J, Sendón R, & Sanches-Silva A. (**2017**). *Aloe vera*: Ancient knowledge with new frontiers. *Trends in Food Science and Technology*, *61*, 94–102. https://doi.org/10.1016/j.tifs.2016.12.005

Sánchez M, González-Burgos E, Iglesias I, & Gómez-Serranillos M. (**2020**). Pharmacological update properties of Aloe vera and its major active constituents. *Molecules*, *25*, 1–37.

Serrano M, Castillo S, Valero D, Valverde J., Guille F, & Martı D. (**2017**). Effect of *Aloe vera* gel treatment on bioactive compounds and antioxidant activity during storage of sweet cherry. *Acta Horticulturae*, *Proc. VII INternational cherry symposium*, 607–612. https://doi.org/10.17660/ActaHortic.2017.1161.97

Shahidi F, & Ambigaipalan P. (**2015**). Phenolics and polyphenolics in foods, beverages and spices: Antioxidant activity and health effects - A review. *Journal of Functional Foods*, *18*, 820–897. https://doi.org/10.1016/j.jff.2015.06.018

Shewfelt RL. (**1993**). Consumer eating habits and perceptions of fresh produce quality. In: *Postharvest hanlding: a systems approach*. Chapter (Shewfelt RL & Prussie SE (Eds.)) Academic Press, San Diego. pp. 28-37.

Sogvar O., Koushesh Saba M, & Emamifar A. (**2016**). *Aloe vera* and ascorbic acid coatings maintain postharvest quality and reduce microbial load of strawberry fruit. *Postharvest Biology and Technology*, *114*, 29–35. https://doi.org/10.1016/j.postharvbio.2015.11.019

Supapvanich S, Mitrsang P, Srinorkham P, Boonyaritthongchai P, & Wongs-Aree C. (**2016**). Effects of fresh *Aloe vera gel* coating on browning alleviation of fresh cut wax apple (*Syzygium samarangenese*) fruit cv. Taaptimjaan. *Journal of Food Science and Technology*, *53*(6), 2844–2850. https://doi.org/10.1007/s13197-016-2262-4

Suriati L, Mangku IGP, & Rudianta IN. (**2018**). The characteristics of *Aloe vera* gel as an edible coating. *IOP Conference Series: Earth and Environmental Science*, *207*(1). https://doi.org/10.1088/1755-1315/207/1/012051

Surjushe A, Vasani R, & Saple DG. (**2008**). *Aloe vera*: a short review. *Indian Journal of Dermatology2*, *53*(4), 163.

Thompson A. (**2010**). Postharvest chemical and physical deterioration of fruit and vegetables. In

Chemical deterioration and physical instability of food and beverages. Woodhead Publishing Limited. https://doi.org/10.1533/9781845699260.3.483

Ullah A, Abbasi N., Shafique M, & Qureshi A. (**2017**). Influence of edible coatings on biochemical fruit quality and storage life of bell pepper cv. "Yolo Wonder." *Journal of Food Quality*, *2017*, 1–11.

Vega-Gálvez A, Miranda M, Aranda M, Henriquez K, Vergara J, Tabilo-munizaga G, & Pérez-Won M. (**2011**). Effect of high hydrostatic pressure on functional properties and quality characteristics of Aloe vera gel (Aloe barbadensis Miller). *Food Chemistry*, *129*, 1060–1065. https://doi.org/10.1016/j.foodchem.2011.05.074

Wong SP, Leong LP, & William Koh JH. (**2006**). Antioxidant activities of aqueous extracts of selected plants. *Food Chemistry*, *99*(4), 775–783. https://doi.org/10.1016/j.foodchem.2005.07.058

Wynn RL. (**2005**). *Aloe vera* gel: Update for dentistry. *General Dentistry*, *53*(1), 6–9.

Yamauchi N. (**2014**). Postharvest chlorophyll degradation and oxidative stress. In A. Kanayama & A. Kochetov (Eds.), *Abiotic stress in agricultural plants* (1st ed., pp. 101–113). https://doi.org/10.1007/978-4-431-55251-2

Yingsanga P, & Srinon T. (**2018**). Shelf life extension of 'Rongrien' rambutan fruit, non- spinterned, using *Aloe vera* gel. *Acta Horticulturae*, *1210*, 151–156. https://doi.org/10.17660/ActaHortic.2018.1210.21

Zapata PJ, Navarro D, Guillén F, Castillo S, Martínez-Romero D, Valero D, & Serrano M. (**2013**). Characterisation of gels from different *Aloe* spp. as antifungal treatment: Potential crops for industrial applications. *Industrial Crops and Products*, *42*(1), 223–230. https://doi.org/10.1016/j.indcrop.2012.06.002

Zhang Y, Bao Z, Ye X, & Xie Z. (**2018**). Chemical investigation of major constituents in *Aloe vera* leaves and several commercial *Aloe* juice powders. *Journal of AOAC International*, *6*, 1741–1751. https://doi.org/10.5740/joacint.18-0122