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Harvesting and postharvest handling of avocados

Colheita e manejo pós-colheita de abacates

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RESUMO

O abacateiro (*Persea americana* Mill.) é uma espécie vegetal da família *Lauraceae* que compreende três raças geográficas e cultivares resultantes da hibridização de duas ou mais raças e essas variedades são cultivadas mundialmente. A distribuição original desta espécie foi na América tropical, do México através da América Central até a Colômbia, Venezuela, Equador e Peru. Esta fruta tem sido referida como a mais nutritiva de todas as frutas. É altamente valorizado não só pela sua textura única, sabor e aroma requintados, mas também pelo seu perfil nutricional. A qualidade dos frutos de abacate depende de aspectos associados às práticas agronômicas pré-colheita e pós-colheita. Doenças e distúrbios são considerados o fator mais importante para danos em frutas nos níveis cosmético, organoléptico e nutricional, induzindo uma redução na percepção de qualidade multifuncional. A baixa temperatura é fundamental para prolongar a vida útil dos abacates, retardando o metabolismo através da redução das taxas de respiração. Este trabalho visa fornecer informações sobre a cadeia produtiva do abacate, reunindo diversos aspectos interessantes desde a colheita até a embalagem desses frutos.

Palavras-chave: Abacate; Doenças pré e pós-colheita; Armazenamento; Escurecimento

ABSTRACT

The avocado (*Persea americana* Mill.) is a plant species of the family *Lauraceae* that includes three geographic races and cultivars resulting from the hybridization of two or more races and these varieties are cultivated worldwide. The original distribution of this species was in tropical America, from Mexico through Central America to Colombia, Venezuela, Ecuador and Peru. This fruit has been referred to as the most nutritious of all fruits. It is highly valued not only for its unique texture, exquisite taste and aroma, but also is nutritional profile. Quality of avocado fruits depends on aspects associated with pre-harvest and postharvest agronomical practices. Diseases and disorders are considered the most important factor for fruit

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damage at cosmetic, organoleptic and nutritional levels inducing a reduction in the perception of multifunctional quality. Low temperature is fundamental in extending the shelf life of avocados by retarding the metabolism through reduced respiration rates. This work aims to provide information about the avocado production chain, bringing together several interesting aspects from the harvest to the packaging of these fruits.

Keywords: Avocados; Pre-harvest and postharvest diseases; Packaging house; Browning.

INTRODUCTION

Currently, avocados are cultivated in 59 countries, both in subtropical and tropical regions. The Americas are home to 60% of the avocado plantations in the world, and Mexico is the top producer, with 28% of the global avocado production (Ramírez-Gil et al., 2017). There are several cultivars avocados around the world, according to the climate in which they grow, with different shapes, flavors, textures, colors and smells. The most well-known and commercial varieties are Hass and Fuerte (Araújo et al., 2018a).

Avocado fruits are harvested mature, but not ready to eat, which requires determining the harvesting time accurately. Fruits that are harvested at an immature stage are likely to shrivel, ripen abnormally or have a rubbery texture after postharvest storage time resulting in low eating quality (Ncama et al., 2018). However, a significant challenge to increase the consumption of avocados is to maintain its high nutritional value through its supply chains and/or processing due to its fast ripening caused by lipid auto-oxidation and high enzymatic concentration. The phenolases catalyze oxidative reactions such as the hydroxylation of a phenolic substrate to form a diphenol, or by deprotonation of the phenolic substrate to form ortho-quinones, which are responsible for the enzimatic browning of avocados. In addition, during ripening, other enzymes such as lipoxygenases and lipases also corroborate to cause chemical alterations in the biological compounds present in the avocado. These alterations compromise the quality, taste and shelf life of the fruit (Dantas et al., 2018).

Harvested avocados may need to be kept immature from to 2 to 4 weeks under normal air to facilitate long-distance export or storage in distribution centers. Storage generally means maintaining the fruits between 4 ° C and 6 °C, at which temperatures ripening is decelerated without inducing the adverse effects of chilling injury observed when avocados are stored at lower temperatures. Although symptoms of rot and chilling injury, such as skin or flesh discoloration, are the major quality defects associated with avocados, flesh firmness and skin color are two important quality indicators used to evaluate avocado ripening. However, changes in skin color depend on the geographical region of production and maturity at harvest time (Gwanpua et al., 2018).

Avocados are susceptible to fungal infection during pre and postharvest handling. Postharvest diseases of fruits and vegetables are a major problem during storage and significantly affect the cost of food production and trade (Arias Bustos & Moors, 2018). Fruit rots are a major risk to the quality of the avocado fruit in international trade. Stem-end rot, caused by *Lasiodiplodia theobromae*, is one of the most common diseases of avocados in storage. This pathogen has a large host range and causes serious losses in warm and humid growing areas. It requires free moisture on the surface of fruits to penetrate. The symptoms of stem-end rot include softening of the tissues, color changes of the infected tissue from green to brown and a foul odor (Bowen et al., 2018; Chávez-Magdaleno et al., 2018; Maftoonazad et al., 2007).

The most important pathogen for avocados is *Colletotrichum gloeosporioides* (Penz.) Penz. and Sacc.. Anthracnose (caused by *Colletotrichum gloeosporioides Penz*.), which is another important post-harvest disease, is one of the major issues within the avocado supply chain, affecting marketability. A combination of hot water with synthetic fungicides is generally used to control fungal rots of most fruits and vegetables. Nowadays, prochloraz®, which is a synthetic fungicide, is used in packinghouses to control anthracnose (Chávez-Magdaleno et al., 2018; Glowacz et al., 2017; Sarkhosh et al., 2017)

The Avocado

The word “avocado” derives from the Aztec word “ahuacatl”, which after modifications by the Spanish language, resulted in the word “ahuacate” or “aguacate (Araújo et al., 2018b). In the exotic tropical fruits segment, açaí, avocado, cupuaçu, jabuticaba, custard apple, among others stand out as commercially relevant fruits, particularly in Brazil. Among these, avocado (*Persea americana* var. americana) deserves special attention because of its great market potential, given the diversity of its functional compounds and vitamins. Avocados are normally consumed fresh in Brazil (Rezende et al. 2016).

The botanical name for avocado is *Persea americana* Mill., and three ecological or horticultural races (in some of the literature erroneously referred to as botanical varieties or subspecies) are recognized. The Mexican race has been referred to as *Persea americana* var. *drymifolia*, the Guatemalan race as *Persea americana* var. *guatemalensis*, and the West Indian race as *Persea americana* var. *americana*. However, some researchers have concluded that the validity of these ‘botanical varieties’ is questionable and requires further study (Cowan & Wolstenholme, 2016; Donadon, 2009).

The fruit (berry) is pear-shaped, oval, or round with a short neck. Fruit length can vary from 7.7 to 33 cm and its width can be up to 15 cm. The skin color of the fruit can vary from yellowish green, dark green or reddish purple, to dark purple (almost black). The edible portion of the fruit, that is, its flesh or pulp, can be pale to bright yellow in color, and the fruit flavor is described as a buttery or nut-like flavor. Its single seed is situated at the center of the fruit, the shape of the seed can be oval, round, or oblong, and generally the length of the seed is around 5–6.5 cm long, but may be smaller. The seed is covered by a thin, brown seed coat that adheres to the seed cavity (Bill, Sivakumar, Thompson, et al., 2014).

Worldwide avocado production exceeded 5.6 million tonnes in 2016, representing approximately 56% increase over a decade. The annual trade of avocados was 1.2 million tonnes in 2013, representing approximately 3-fold increase in trade figures over a decade. In the same period, average global consumption of avocado fruits almost doubled, reaching approximately 0.7 kg per capita per year (Mazhar et al., 2018a).

Avocados are cultivated in various countries. Mexico is the largest producer, with a total production of about 1.5 million tonnes (28% of world production). Other important producing countries are Chile (8%), Dominican Republic (7%), Indonesia (6%), Colombia (5%), Peru (5%), United States (5%), Brazil (4%), Kenya (4%) and Rwanda (3%). It is cultivated in almost all Brazilian states and the largest producer of avocados is the state of São Paulo with 47.5%, followed by Minas Gerais (19.0%) and Paraná (11.2%) (Araújo et al., 2018b; Krumreich et al., 2018).

More than 500 varieties of avocado have been identified, but most of them are not commercially produced due to diverse problems, such as production time, quality in terms of protein and fat contents, resistance problems and damage during transportation. There are many differences between the varieties of avocado, namely, form, weight, size, and flavor, but the most prominent difference is the color of the skin during ripening. Among the most important commercial cultivars of the ‘subtropical’ avocado are ‘Hass’, ‘Fuerte’, ‘Ettinger’, and ‘Pinkerton’, which were all selected from chance seedlings with superior fruit quality. The avocado is considered as complementary food that can provide several types of nutrients and phytochemicals found in many other sweet-tasting, sugar-rich fruits and bitter-tasting vegetables. In nutritional terms, avocados contain many lipophilic phytochemicals and bioactive compounds that may confer health benefits (e.g., sterols, polyhydroxylated fatty alcohols (PFA), alkaloids, acetogenins and volatile oils) (Araújo et al., 2018b; Cowan & Wolstenholme, 2016; Krumreich et al., 2018; Menzel & Le Lagadec, 2014).

The average composition of an avocado is 73–74% moisture, 15–17% lipids, 5–8.5% total carbohydrates (including soluble fiber like pectin), 1.5–6.7% total dietary fiber, 2–2.2% protein, counting all the essential amino acids (valine, lysine, phenylalanine, isoleucine, threonine and methionine) and 1–1.6% minerals (potassium, phosphorous, calcium, iron, sodium). The chemical composition of the edible portion of the fruit is presented in Table 1. The triacylglycerol and health-promoting fatty acid composition (high oleic acid) content is comparable with those for olive oil, with high concentrations of β-sitosterol, chlorophyll and carotenoids (particularly lutein) (Martínez-Padilla et al., 2017). Avocados present a unique richness in vitamins E, C, B6, as well as β-carotene and potassium and they also contain approximately 2% protein and various sugars (mainly glucose, sucrose, and heptulose). The fruit has various phenolic compounds, which are affected by the degree of maturity. The phenolic compounds found are p-hydroxybenzoic, protocatechuic, β-resorcyclic, γ-resorcyclic, α-resorcyclic, gallic, isovanillic, vanillic, syringic, o-coumaric, m-coumaric, p-coumaric, caffeic, ferulic and sinapic acids. Besides giving protection against atherosclerosis and thrombosis, the phytochemicals extracted from the avocado fruit can act as agents for cancer prevention (Abaide et al., 2017; Araújo et al., 2018b; Bill, Sivakumar, Thompson, et al., 2014; Dantas et al., 2018; Dávila et al., 2017).

Table 1. Chemical compositions of avocado fruit (per 100g of edible portion).

Energy value (cal)	245.00	K (mg)	368.00
Protein (g)	1.70	P (mg)	38.00
Fat (g)	26.40	Mg (mg)	35.00
Total carbohydrate (g)	5.10	S (mg)	28.50
Crude fiber (g)	1.80	Chlorine	11.00
B - carotene	0.17	Ca (mg)	10.00
Ascorbic acid (mg)	16.00	Mn (mg)	4.21
Niacin (mg)	1.01	Na (mg)	368.00
Riboflavin (mg)	0.13	Fe (mg)	0.60

Thiamine (mg)	0.06

Source:(Bill, Sivakumar, Thompson, et al., 2014)

Typically, the avocado fruit is either consumed fresh or its pulp is processed and shelf-stable spreads, such as guacamole, fresh chilled halves and frozen cubes. The avocado oil can be extracted industrially at a yield of 21–30% of the fruit weight and contains high levels of mono-unsaturated fatty acids (around 70% of oleic acid) and other valuable compounds, with health benefits, such as tocopherols, phytosterols, lutein and vitamins. The seed and peel of avocado can be retained as residues after its processing. The avocado seed (15–16% of the fruit weight) is one of the best sources of dietary fiber and it contains valuable compounds such as fatty acids, polyphenols, steroids, antioxidants and potassium. The avocado seed also contains saponin, flavonoids, phenols and cyanogenic glycosides, phytosterols, triterpenes, furanoic acids, flavonol dimers and proanthocyanidins. The avocado peel has been reported to contain flavonoids, saponins, tannins, phenols and steroids and thus exhibits antioxidative activity. However, the phenols occur in free or membrane-bound forms and they are present in the avocado mesocarp in low concentrations of ‘free’ phenols but ‘cell membrane-bound’ forms are present in a higher concentration. This reduces the ability of phenolic compounds to function as antioxidants since the availability of free hydroxyl groups on the phenol ring is important to neutralize free radicals (Dávila et al., 2017; Tesfay et al., 2011).

One of the major problems of avocados is their high susceptibility to qualitative and quantitative quality losses. Postharvest processing of the avocado is complex compared to other fruits and entails appropriate handling of the fruits at the right stage of maturity, specific packaging, storage atmospheres and temperatures, transport distance and time, and pest management among other factors. Inappropriate postharvest management leads to physical damage and/or physiological disorders which degrade the nutritional and commercial quality of the fruits (Vargas-Ortiz et al., 2017).

The avocado fruit is a subtropical climacteric fruit, and it is extremely unusual, since unlike other fruits it does not produce ethylene and does not ripen while attached to the tree. However, after harvesting, avocado fruits produce higher concentrations of ethylene (80–100 $\mu L\ L^{-1}$) in comparison with other climacteric fruits such as mangoes (3 $\mu L\ L^{-1}$) and bananas (40 $\mu L\ L^{-1}$), and the climatization of avocados must be carried out, before consumption. Mature fruits display a characteristic respiratory pattern that coincides with increased ethylene production. The increase in the respiration rate and ethylene biosynthesis is accompanied by a complex of biochemical changes, including increased cellulose activity, resulting in fruit softening, changes in the flesh color, and synthesis of the flavor and aroma chemicals (Bill, Sivakumar, Thompson, et al., 2014; Donadon, 2009).

The avocado in the unripe state that has been freshly harvested is characterized by having an extremely firm texture. The fruit undergoes an extensive softening of the mesocarp tissue during ripening and several biochemical analyses have shown a large increase in the activities of the cell wall hydrolytic enzymes. This can influence not only the commercialization of avocados in terms of fruit quality, but also the storage conditions required. As with many other fruits, the temperature that avocados are exposed to during ripening impacts both the time needed for the fruit to soften and the subsequent fruit quality. The fruits are often held for short periods after harvest at relatively high temperatures both in the field, and in storage during preconditioning (ethylene ripening), or prior to ripening with unknown effects on subsequent quality (Arpaia et al., 2018; Defilippi et al., 2018; Hershkovitz et al., 2009; Ortiz-Viedma et al., 2018).

After harvesting the maturation process of avocados may be considerably retarded through storage at low temperatures (2-5 ° C) on an industrial level. However, some research indicates that refrigerated storage damages fruits and this is manifested as a discoloration of the mesocarp, improper softening and bad taste. In addition, the cell membrane exhibits separations between the phospholipids and the two-layer proteins due to cold storage. This damage, however, is more accelerated under storage conditions that are used by small producers who do not have industrial refrigeration and store the product under domestic conditions (8-10 °C) (Ortiz-Viedma et al., 2018).

Preharvest factors

Postharvest quality of all fruit is achieved during its growth and maturation and can be maintained but never improved by postharvest handling. Several preharvest factors, if not well managed, can severely affect the quality of the fruit. Understanding these factors and how they should be managed can help minimize postharvest losses of avocado fruits. A summary of the preharvest factors that have an inherent effect on the postharvest quality of the fruit is shown in Table 2.

Table 2 – Preharvest factors that affects the postharvest quality of avocados

Preharvest factor	Postharvest effect on fruit quality	Management
Climate or environment: temperature, wind and rainfall	Increased disease incidence, chilling injury	Pruning to expose the fruit to direct sunlight
Rootstock or scion	Susceptibility to physiological disorders during the cold chain, postharvest decay	Choose less susceptible rootstock or scion
Pruning practices	Poor fruit storability	Strike a balance between vegetative and reproductive growth and correct timing is important
Pest and disease management	Changes in fruit composition influences the ripening behavior and decay development (anthracnose)	Maintain a clean orchard and correct application of chemical is important
Plant nutrition (N/Ca)	Development of physiological disorders (mesocarp discoloration or gray pulp) and rots	Manage vegetative growth and avoid excessive nitrogen during fruit development
Plant growth regulators	Poor storability	Mange vegetative growth
Irrigation	Influences polyphenol oxidase levels thus mesocarp discoloration	Avoid water stress during fruit growth and development

(Bill, Sivakumar, Thompson, et al., 2014)

Harvesting and post harvesting of avocados in Brazil

A major challenge for the global avocado market is to provide a homogenous product in terms of fruit-ripening behavior, especially considering the significant variability in quality that can be found within a box or pallet of the fruit. Fruit-ripening behavior and postharvest quality can be associated with different cultural practices, including irrigation management, and also with the composition of macronutrients and micronutrients, such as calcium, nitrogen and zinc, within the fruit. Furthermore, some metabolites of photosynthesis, such as the C7 sugars (mannoheptulose and perseitol) may well play a major role in controlling/triggering the ripening process, and that their reduction to a certain threshold has been postulated as a physiological prerequisite for fruit ripening. However, the potential involvement of these C7 sugars in triggering/inhibiting ripening after the fruit has been detached from the tree is still not explained (Hernández et al., 2016; Pedreschi et al., 2014; Rivera et al., 2017). In general, postharvest handling of avocados involves a series of steps:

1. Fruit reception with weighing and identification of lots (different plots in a single property, partner producers, variety, date of harvest, etc.);
2. First selection: removal of peduncle and any defective fruits;
3. Hygiene using a chlorine-based product;
4. Use of room temperature for drying or drying tunnel;
5. Optional fungicide application followed by another drying;
6. Second selection: removal of any remaining defective fruits;
7. Classify fruit by size and fruit category;
8. Packing in cardboard boxes;
9. Labeling of boxes with sorting and identification data;
10. Palletizing; storage and shipping for sale.

Fruits should be harvested and transported in clean and undamaged plastic boxes to avoid contamination and physical damage. Roads must have good asphalt to reduce vibration, abrasion and impacts on the avocados. In case of physical damage to fruits there will be several consequences which will only be observed during sales and consumption. The Packinghouse location should be as close to the field as possible. After harvesting, the avocados will be received in a specific area inside the Packinghouses. The boxes will be arranged on pallets, in order to facilitate the load handling. If fruits are not handled in the packinghouses immediately, these should be kept in a refrigerated chamber, at a maximum temperature of 20ºC. With the handling line ready to use, the newly arrived fresh fruits, or those that were kept under refrigeration, will be subjected to the first selection. The priority of the first selection will be to remove any fruits with physical defects and symptoms of diseases, as well as those with remaining stalk (Figure 1A and 1B). All fruits discarded are sent to produce organic (Ladaniya & Ladaniya, 2008; Rivera et al., 2017). In the packinghouse, the selected fruits are then washed with a chlorine-based solution and then left to dry naturally or dried in a drying tunnel to speed up the process (Figure 1C). Optionally, the avocados can be submitted to fungicide application by immersion or spraying and subjected to another natural or forced drying. After that, a second selection is made to remove any damaged or diseased fruits that escaped the first selection (Fischer et al., 2018).

Using conveyors belts, the avocados are then moved to the sorting section, which can be manual or mechanized (Figure 2A). The classification machine separates the fruit by weight, which corresponds to its size, sorting out the avocados, from the heavier to the lighter (Figure 2B). This step allows each packer to do a faster job of placing the fruits in the boxes, since only fruits of a specific size come to him/her. When each box is full (with the correct number of avocados), labeling is performed with batch identification, maturation stage and size, and released to be palletized (Figure 3A). Fruit that does not have the standard weight or visually has mechanical injuries is collected, weighed again and classified as Category 3 (refuse) or as organic waste (Adamu & Shehu, 2018).

The palletizing process consists of arranging the boxes on wooden pallets measuring 1.00 x 1.20 m (Figure 3B). Stacking is performed according to the boxes specification and stacking limits for the boxes being used. Finally, four paper angles are placed, to adjust the position of the boxes. Then, a plastic strap is used to hold the boxes on the pallet. Additionally, the whole pallets can be covered with a plastic film for greater protection and promote a passive modified atmosphere. Finally, the pallets receive a new label including the destination and identification data (Boelema, 1987).

The pallets are now ready to be transferred to a cold storage chamber at a temperature of between 4 and up to 20ºC, according the maturation stage of the avocados and distance to their final destination. Relative humidity should also be adjusted to 85%, in order to reduce weight loss of the fruits. The shipment of these pallets must use cold chain system to avoid any drastic temperature oscillations between the cold chamber and the truck. The opening of the cooling chamber should be sized according to the height and width of the truck door. In addition, the loss of the cooling temperature must be avoided as much as possible (Pedreschi et al., 2014). Figure 4 shows a general flowchart of handling avocados inside a packinghouse.

Figure 1 - Avocado packaging house - Harvested fruit (A); Conveyor table reception (B); Cleaning (C). Source: Jaguacy Avocado Brasil.

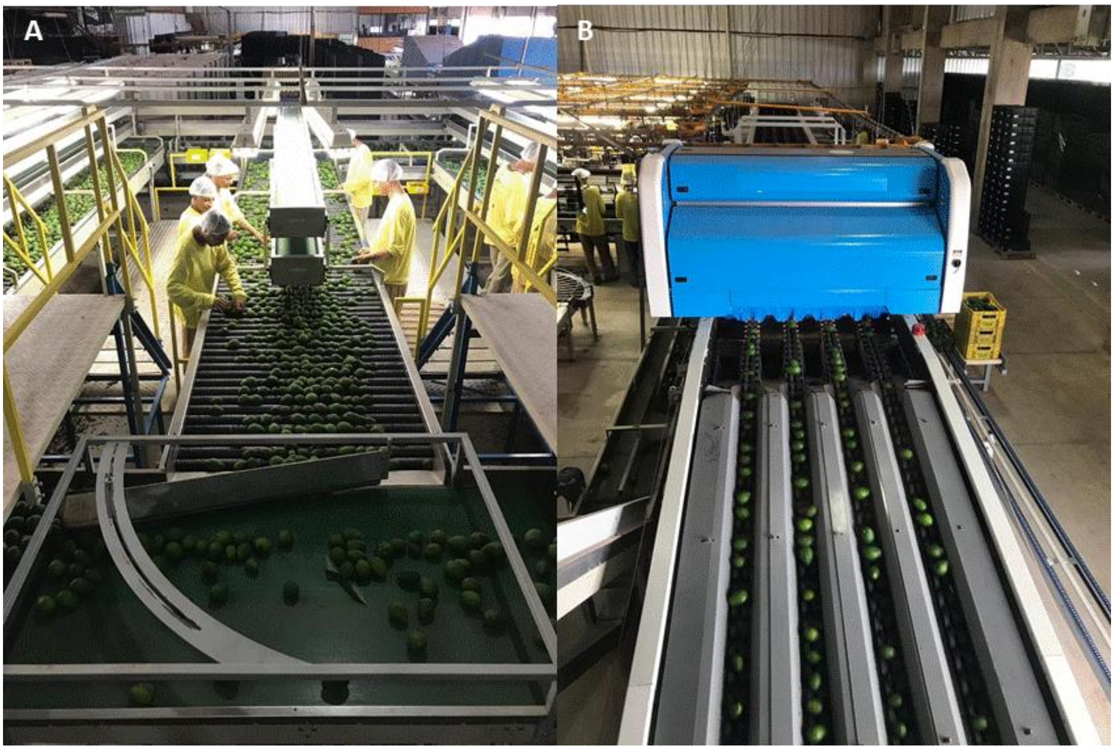

Figure 2 - Avocado packaging house - Sorting (A); Mechanical classification (B). Source: Jaguacy Avocado Brasil.

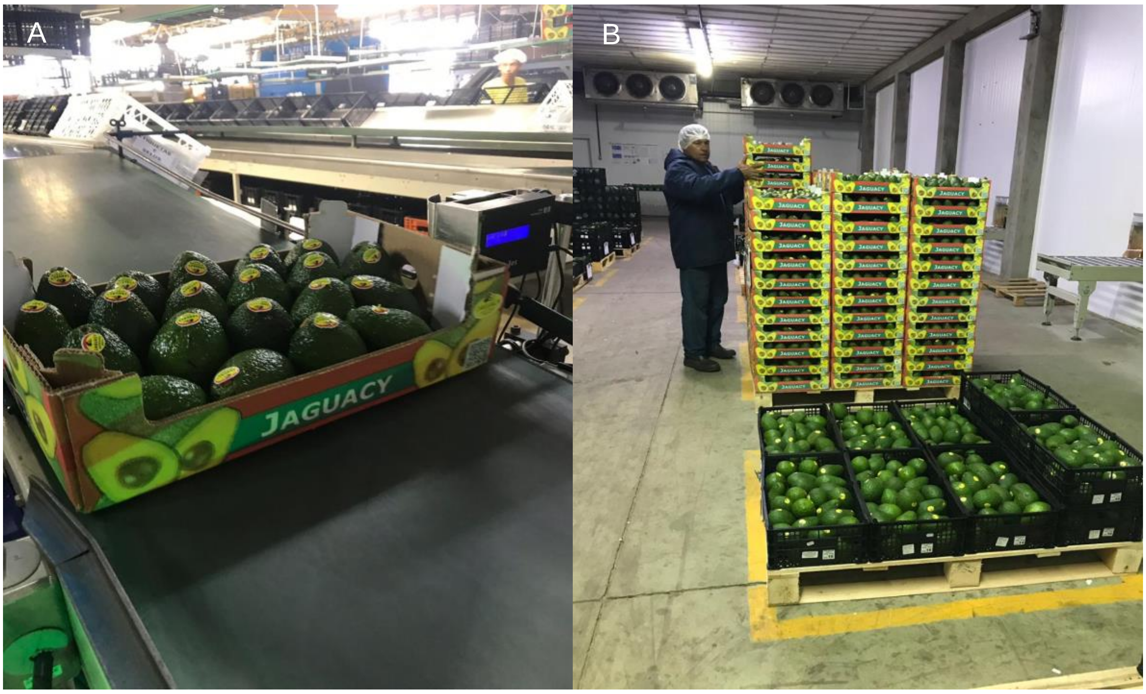

Figure 3 - Avocado packaging house - Packaging (A); Palletizing (B). Source: Jaguacy Avocado Brasil.

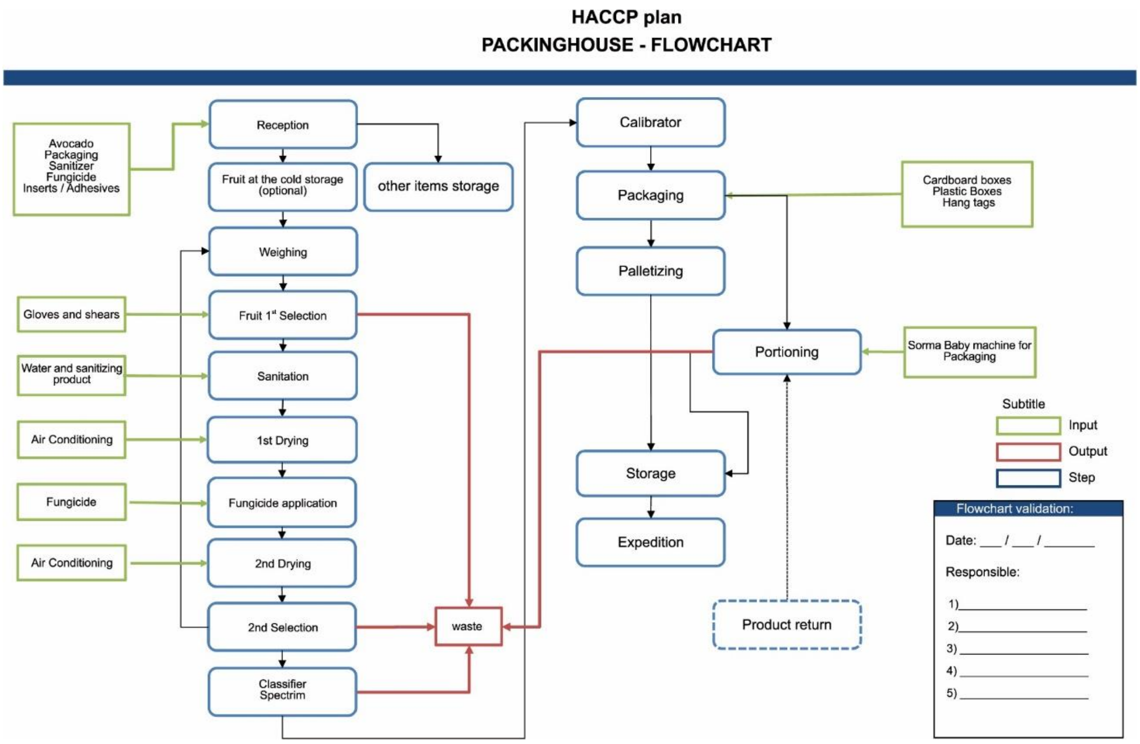

Figure 4 - Flowchart for packaging avocados in cardboard boxes for internal and external markets. Source: Jaguacy Avocado Brasil.

Avocado fruit has a high economic value; however, major post-harvest losses are encountered throughout the supply chain mostly due to anthracnose caused by the fungus *Colletotrichum gloeosporioides*. Anthracnose is a common postharvest disease and it affects the fruit quality, marketability and shelf life of avocados. Nevertheless, increasing consumer concerns regarding food safety and a demand for organically produced fruits makes it necessary to search for natural environmentally friendly alternative products and processes for the fruit industry, particularly in disease control. In Brazil, a lot of agricultural production is lost during the post-harvest phase, due to the lack of knowledge of conservation techniques. To reduce losses, some post-harvest techniques are used, including fungicide treatment, temperature and humidity control, application of wax. Both field spraying and postharvest treatments are necessary to achieve high quality fruit (Bill, Sivakumar, Korsten, et al., 2014; Oliveira et al., 2000; Rivera et al., 2017; Siddique et al., 2018).

Mesocarp bruising of avocado fruit is an important postharvest problem for the industry. Bruise expression may be influenced by inherent fruit characteristics, and pre- and postharvest handling practices and conditions (Mazhar et al., 2018b). Bruising in fruit is the result of mechanical damage caused by compression or impact forces and it manifests as a dark, well defined area close to the impact site. The bruise develops in response to two subsequent processes in fruit tissue that takes place at the cellular level: tissue disruption with cell wall failure and release of cytosolic components from cells, and enzymatic activities in the disturbed environment of the cells and tissues (Mazhar et al., 2015).

Avocado is an extremely perishable fruit, with a very high metabolic rate, which results in a short postharvest life of about three to five weeks when stored under optimum conditions. The postharvest storage life of avocado fruit is limited by its climacteric ripening pattern which exhibits high ethylene accumulation, stimulating faster ripening as a result of the high rate of respiration. Besides, avocado fruits have a high postharvest mass loss, and this is mostly due to moisture loss through transpiration, which contributes to about 90% of the total fruit mass loss. This causes undesirable consequences to the fruit quality and can lead to tremendous financial losses since the price of fruit is determined by its mass. Essentially, any postharvest treatments that reduce moisture loss and maintain fruit turgidity and firmness has a potential to reduce respiration and ripening (Tesfay et al., 2017).

Enzymatic browning of the pulp

The loss of nutritional and organoleptic properties of fruits and vegetables during post harvesting, storing and processing is an important problem in the food industry. Several physical and chemical processes are responsible for this issue, but one of the most important is the browning effect. The browning mechanism in foods is a well-known phenomenon and it can be of enzymatic or non-enzymatic origin. Many factors have been implicated in postharvest oxidative browning and among the most highly studied are a group of enzymes known as polyphenol oxidases (PPO), a copper-containing family of isoenzymes that affects the preservation of the avocado pulp color. PPOs catalyze the oxidation reaction of σ-diphenols, present in the tissue of fruits and vegetables, with molecular oxygen into o-quinones. These o-quinones are later polymerized with other o-quinones and other substances and produce dark brown pigments. Avocado is a climacteric fruit that is highly susceptible to enzymatic browning. Research to inactivate avocado PPOs has been carried out using anti-browning agents, modified atmospheres for packaging, thermal and high pressure treatments. In general, avocado PPO activity is more sensitive to lower environmental pH, higher temperatures, and higher levels of pressure. The intensity of browning is influenced by the amount of active enzymes and polyphenols in the fruit tissue (Bi et al., 2015; Bustos et al., 2015; Fuentes Campo et al., 2018; Quevedo et al., 2011). PPO activity has been found to correlate with the postharvest browning that frequently occurs after shipment and storage of avocados. Hershkovitz et al. (2005) identified a strong correlation between an increase in PPO activity and the mesocarp browning that resulted from chilling injury (George & Christoffersen, 2016).

Also due to the fact that avocado is a climacteric fruit, a softening process begins after harvest. During ripening, the mesocarp changes in texture, skin color and aroma. Then the avocado undergoes an extensive softening of the mesocarp tissue which affects fruit quality and cold storage capacity. Softening is commonly associated with cell wall disassembly in climacteric fruits. The majority of avocado proteins are oxidative enzymes such as polyphenol oxidase, lipoxygenase and lipases which rapidly spoil the pulp when the avocado is processed (Defilippi et al., 2018; Vargas-Ortiz et al., 2017).

Mesocarp bruising is one of the most important negative issues experienced by avocado consumers. The visible symptoms of mesocarp bruising in fruit result from cell and tissue damage where the cell walls and membranes deform under external impact or compression forces above their bio-yield threshold. The cellular decompartmentalization resulting from this allows polyphenol oxidase (PPO) activity to catalyze browning of the affected mesocarp tissue. The rate of browning is dependent on the concentration of phenolic substrates and the mesocarp pH. Some factors considered to affect the expression of visible bruising in avocado include fruit maturity, fruit firmness, fruit holding duration and fruit holding temperature (Mazhar et al., 2018a).

Impact damage in fruit generally manifests itself as visible bruising of the flesh due to enzymatic browning reactions involving a phenolic substrate and polyphenol oxidases. 'Hass' avocados at softening, firm-ripe and soft-ripe stages can develop bruising 24 h after impact from a drop of 25 cm. Conversely, unripe 'Hass' avocados at the hard firmness stage failed to develop bruising when subjected to a drop of 100 cm, despite detection of apparent tissue damage by MRI. The absence of flesh browning was also reported in unripe 'Hass' fruit wounded by cutting and incubated for 24 h at 25 °C. Mazhar et al. (2015) speculated that injured hard fruit do not develop bruising because PPO exists as an inactive form and / or flesh pH is not within the range for PPO activity (Perkins et al., 2019).

Modifications to cell wall polysaccharides are believed to be mediated by the coordinated action of several cell wall hydrolases, although other non-enzymatic mechanisms may be involved. Polygalacturonase (PG) and pectin methylesterase (PME) have been considered the main pectin-degrading enzymes in fruits. PME is responsible for catalyzing the reaction that removes methyl groups from HGA, while PG cleaves the galacturonic linkages of the HGA backbone. The high levels of PG activity observed in avocados have been related to the extensive solubilization and depolymerization of pectins that take place during avocado ripening. On the other hand, several studies have suggested that HGA, which is present in a highly methylesterified form in the cell wall, is more susceptible to PG activity if this polysaccharide is partially de-esterified. The role of de-esterification of HGA is attributed to PME activity in several fruits including avocados (Defilippi et al., 2018).

Chilling injury of avocados

Subtropical fruits, including avocados, are sensitive to low temperatures. A major limitation in the storage of the 'Hass' avocado is the development of external chilling injury at low temperatures. This occurs at temperatures of about 3 °C or less, and is expressed as skin blackening and pitting(Woolf et al., 2003). Darkening of the mesocarp during cold storage is one of the chilling injury (CI) symptoms expressed in avocado fruit and browning of the pulp causes major export losses every year. Mesocarp discoloration in the form of brown pulp results from oxidation of o-diphenols to o-quinones, by polyphenol oxidase (PPO), and these continue to oxidize to form brown melanin pigment(Pesis et al., 2002).

Main phytopathological problems

The potential yield of agricultural and horticultural crops can be affected by biotic and abiotic stress factors such as insects, nutrition deficiencies, pathogens, weed or drought stress, which have the potential to reduce the quantity and quality of production. Crop production can be reduced by diseases (18%), animal pests (18%) and weeds (32%), if no control is carried out. Plants are in contact with a myriad of microorganisms found in the environment; however, in order for a disease to develop the host must be susceptible to a virulent pathogen and the environment must be conducive to the infection. Furthermore, in terms of the efficacy of actual crop protection practices, the control of diseases caused by fungi and bacteria is considerably lower than this obtained for other factors. Although disease response processes in plants have been extensively studied, in the case of postharvest fruits many of them are still unknown, and also the results are different for each pathosystem. Plant diseases are not only a threat to the economic aspects, but also they can have disastrous consequences for new hosts when faced with alien pathogens. New diseases, associated with host jumps, climate change and the invasion of naïve ecosystems by exotic pathogens have been reported and have been developing at an alarming speed in trees around the world (Abdulridha et al., 2018; Perato et al., 2018).

Avocado is a crop of increasing economic importance worldwide. Global production has been rising rapidly and exceeded 5 million tonnes in 2014. A growing consumer awareness of the culinary versatility and nutritional benefits of this fruit has fuelled demand. However, meeting consumer expectations in terms of postharvest fruit quality remains a challenge and avocado crops are threatened by economically important diseases that could limit its production and reduce fruit quality. Internal defects affecting more than 10% of the flesh cause considerable consumer dissatisfaction and negatively impact repeat purchasing intentions. Flesh bruising and body rots are of greatest concern, as they are the most prevalent internal defects that occur in avocados at the retail level. These defects are generally indiscernible to consumers until after the fruit has been purchased and cut open, particularly in dark-skinned cultivars such as 'Hass' (Perkins et al., 2019). Most cultivars are sensitive to water deficits, and to excess soil water caused by poor drainage. The trees are very susceptible to root rot caused by *Phytophthora cinnamomi* in areas with poor soils or high water tables (Granada et al., 2018; Menzel & Le Lagadec, 2014).

The avocado is a climacteric fruit characterized with high ethylene production and respiration rate during postharvest storage. The high rate of biological activities as well as postharvest fungal diseases is a major cause of avocado postharvest losses. Anthracnose caused by *Colletotrichum gloeosporioides* and stem-end rot caused by different fungal species of *Colletotrichum, Botryodiplodia, Dothiorella, Phomopsis* and *Lasiodiplodia genera* are the most common fungal diseases in the avocado industry (Tesfay et al., 2017).

The most relevant diseases in avocado are root rot, caused by *P. cinnamomi* and anthracnose, caused by *Colletotrichum spp*. Although the use of agrochemicals has prevailed in controlling this type of plant pathogens, the problems caused by their indiscriminate applications have motivated the search for new alternative controls. In addition, some of the pesticides used to control postharvest diseases are not accepted by the international community or their residual limits are strictly monitored, causing rejection of the fruit and economic losses for producers (Granada et al., 2018).

Avocado fruit is mainly susceptible to postharvest fungal pathogens that gain entry via natural openings, wounded surfaces and by direct penetration into the host cell tissue. Considerable postharvest losses, limiting storage and marketability of the fruit, are caused mainly by anthracnose (*Colletotrichum gloeosporioides* (Penz. &Sacc.) and stem-end rot (including *Lasiodiplodia theobromae* (Pat.) Griffon & Maubl.. Anthracnose is predominantly caused by fungi within the *Colletotrichum gloeosporioides* species complex, although in some countries it is also caused by fungi within the *Colletotrichum gloeosporioides*, *Colletotrichum acutatum*, C*olletrotrichum boninense* and *Colletotrichum godetiae* species complexes and it was reported that this disease can cause postharvest losses of avocado fruit up to 80%. The germination and growth of latent rots of *Colletotrichum gloeosporioides* has been associated to the lack of antifungal compounds in the avocado fruit skin (Boonruang et al., 2017; Bowen et al., 2018; Campos-Martínez et al., 2016; Cannon et al., 2012; Obianom et al., 2019). The initial infection usually occurs at the preharvest stage when the fungal spores or mycelia infect young fruit through pedicel and peel wounds. Normally, preharvest infection remains latent or hidden until the fruit undergoes ripening, which offers appropriate conditions and nutrients for fungal growth, and then the symptoms appear. Although controlled atmosphere or modified atmosphere packaging (MAP) could delay ripening and prolong the shelf-life of many fruits, anthracnose decay is usually observed at the end of storage after the fruit has ripened (Boonruang et al., 2017).

The symptoms of anthracnose include limited, and often sunken necrotic lesions on leaves, stems, flowers and fruit, as well as crown and stem rots, and seedling blight. Within each of these fungi species, a number of newly described species are now known to cause anthracnose in avocados, based on recent taxonomic revisions of the genus *Colletotrichum* (Bowen et al., 2018; Cannon et al., 2012; Obianom et al., 2019).

At the moment prochloraz®, a synthetic fungicide, is used in the packhouses to control anthracnose disease. However, since there is an increasing demand to reduce the use of fungicides there is clearly a need for new techniques that could reduce undesired fungal decay (Bill, Sivakumar, Thompson, et al., 2014; Glowacz et al., 2017).

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REFERÊNCIAS

Abaide, E. R., Zabot, G. L., Tres, M. V., Martins, R. F., Fagundez, J. L., Nunes, L. F., Druzian, S., Soares, J. F., Dal Prá, V., Silva, J. R. F., Kuhn, R. C., & Mazutti, M. A. (2017). Yield, composition, and antioxidant activity of avocado pulp oil extracted by pressurized fluids. *Food and Bioproducts Processing*, *102*, 289–298. https://doi.org/10.1016/J.FBP.2017.01.008

Abdulridha, J., Ampatzidis, Y., Ehsani, R., & de Castro, A. I. (2018). Evaluating the performance of spectral features and multivariate analysis tools to detect laurel wilt disease and nutritional deficiency in avocado. *Computers and Electronics in Agriculture*, *155*, 203–211. https://doi.org/10.1016/J.COMPAG.2018.10.016

Adamu, A. A., & Shehu, A. (2018). Development of an Automatic Tomato Sorting Machine Based on Color Sensor. *International Journal of Recent Engineering Research and Development (IJRERD)*, *03*(11), 1–7.

Araújo, R. G., Rodriguez-Jasso, R. M., Ruiz, H. A., Pintado, M. M. E., & Aguilar, C. N.

(2018a). Avocado by-products: Nutritional and functional properties. *Trends in Food Science & Technology*, *80*, 51–60. https://doi.org/10.1016/J.TIFS.2018.07.027

Araújo, R. G., Rodriguez-Jasso, R. M., Ruiz, H. A., Pintado, M. M. E., & Aguilar, C. N. (2018b). Avocado by-products: Nutritional and functional properties. *Trends in Food Science & Technology*, *80*, 51–60. https://doi.org/10.1016/J.TIFS.2018.07.027

Arias Bustos, C., & Moors, E. H. M. (2018). Reducing post-harvest food losses through innovative collaboration: Insights from the Colombian and Mexican avocado supply chains. *Journal of Cleaner Production*, *199*, 1020–1034. https://doi.org/10.1016/j.jclepro.2018.06.187

Arpaia, M. L., Collin, S., Sievert, J., & Obenland, D. (2018). 'Hass' avocado quality as influenced by temperature and ethylene prior to and during final ripening. *Postharvest Biology and Technology*, *140*, 76–84. https://doi.org/10.1016/J.POSTHARVBIO.2018.02.015

Bi, X., Hemar, Y., Balaban, M. O., & Liao, X. (2015). The effect of ultrasound on particle size, color, viscosity and polyphenol oxidase activity of diluted avocado puree. *Ultrasonics Sonochemistry*, *27*, 567–575. https://doi.org/10.1016/J.ULTSONCH.2015.04.011

Bill, M., Sivakumar, D., Korsten, L., & Thompson, A. K. (2014). The efficacy of combined application of edible coatings and thyme oil in inducing resistance components in avocado (Persea americana Mill.) against anthracnose during post-harvest storage. *Crop Protection*, *64*, 159–167. https://doi.org/10.1016/J.CROPRO.2014.06.015

Bill, M., Sivakumar, D., Thompson, A. K., & Korsten, L. (2014). Avocado Fruit Quality Management during the Postharvest Supply Chain. *Food Reviews International*, *30*(3), 169–202. https://doi.org/10.1080/87559129.2014.907304

Boelema, T. (1987). Long-distance transport of avocados. *Mechanical Engineering*, *10*, 153–156.

Boonruang, K., Kerddonfag, N., Chinsirikul, W., Mitcham, E. J., & Chonhenchob, V. (2017). Antifungal effect of poly(lactic acid) films containing thymol and R-(-)-carvone against anthracnose pathogens isolated from avocado and citrus. *Food Control*, *78*, 85–93. https://doi.org/10.1016/J.FOODCONT.2017.02.032

Bowen, J., Billing, D., Connolly, P., Smith, W., Cooney, J., & Burdon, J. (2018). Maturity, storage and ripening effects on anti-fungal compounds in the skin of 'Hass' avocado fruit. *Postharvest Biology and Technology*, *146*, 43–50. https://doi.org/10.1016/J.POSTHARVBIO.2018.08.005

Bustos, M. C., Mazzobre, M. F., & Buera, M. P. (2015). Stabilization of refrigerated avocado pulp: Effect of Allium and Brassica extracts on enzymatic browning. *LWT - Food Science and Technology*, *61*(1), 89–97. https://doi.org/10.1016/J.LWT.2014.11.026

Campos-Martínez, A., Velázquez-del Valle, M. G., Flores-Moctezuma, H. E., Suárez-

Rodríguez, R., Ramírez-Trujillo, J. A., & Hernández-Lauzardo, A. N. (2016). Antagonistic yeasts with potential to control Colletotrichum gloeosporioides (Penz.) Penz. & Sacc. and Colletotrichum acutatum J.H. Simmonds on avocado fruits. *Crop Protection*, *89*, 101–104. https://doi.org/10.1016/J.CROPRO.2016.07.001

Cannon, P. F., Damm, U., Johnston, P. R., & Weir, B. S. (2012). Colletotrichum – current status and future directions. *Studies in Mycology*, *73*(1), 181–213. https://doi.org/10.3114/sim0014.

Chávez-Magdaleno, M. E., González-Estrada, R. R., Ramos-Guerrero, A., Plascencia-Jatomea, M., & Gutiérrez-Martínez, P. (2018). Effect of pepper tree (Schinus molle) essential oil-loaded chitosan bio-nanocomposites on postharvest control of Colletotrichum gloeosporioides and quality evaluations in avocado (Persea americana) cv. Hass. *Food Science and Biotechnology*, *27*(6), 1871–1875. https://doi.org/10.1007/s10068-018-0410-5

Cowan, A. K., & Wolstenholme, B. N. (2016). Avocado. In *Encyclopedia of Food and Health* (pp. 294–300). Academic Press. https://doi.org/10.1016/B978-0-12-384947-2.00049-0

Dantas, D., Pasquali, M. A., Cavalcanti-Mata, M., Duarte, M. E., & Lisboa, H. M. (2018). Influence of spray drying conditions on the properties of avocado powder drink. *Food Chemistry*, *266*, 284–291. https://doi.org/10.1016/J.FOODCHEM.2018.06.016

Dávila, J. A., Rosenberg, M., Castro, E., & Cardona, C. A. (2017). A model biorefinery for avocado (Persea americana mill.) processing. *Bioresource Technology*, *243*, 17–29. https://doi.org/10.1016/J.BIORTECH.2017.06.063

Defilippi, B. G., Ejsmentewicz, T., Covarrubias, M. P., Gudenschwager, O., & Campos-Vargas, R. (2018). Changes in cell wall pectins and their relation to postharvest mesocarp softening of "Hass" avocados (Persea americana Mill.). *Plant Physiology and Biochemistry*, *128*, 142–151. https://doi.org/10.1016/J.PLAPHY.2018.05.018

Donadon, J. R. (2009). *Distúrbio fisiológico provocado pelo frio e prevenção com tratamentos térmicos em abacates*. Universidade Estadual Paulista "Julio De Mesquita Filho."

Fischer, I. H., Moraes, M. F. de, Palharini, M. C. de A., Fileti, M. de S., Cruz, J. C. S., Firmino, A. C., Fischer, I. H., Moraes, M. F. de, Palharini, M. C. de A., Fileti, M. de S., Cruz, J. C. S., & Firmino, A. C. (2018). EFFECT OF CONVENTIONAL AND ALTERNATIVE PRODUCTS ON POSTHARVEST DISEASE CONTROL IN AVOCADOS. *Revista Brasileira de Fruticultura*, *40*(1). https://doi.org/10.1590/0100-29452018408

Fuentes Campo, A., Sancho, M. I., Melo, G., Dávila, Y. A., & Gasull, E. (2018). In vitro and in vivo inhibition of Hass avocado polyphenol oxidase enzymatic browning by paeonol, β-cyclodextrin, and paeonol:β-cyclodextrin inclusion complex. *Journal of Bioscience and Bioengineering*. https://doi.org/10.1016/J.JBIOSC.2018.11.009

George, H. L., & Christoffersen, R. E. (2016). Differential latency toward (–)-epicatechin and catechol mediated by avocado mesocarp polyphenol oxidase (PPO). *Postharvest Biology* *and Technology*, *112*, 31–38. https://doi.org/10.1016/J.POSTHARVBIO.2015.09.036

Glowacz, M., Roets, N., & Sivakumar, D. (2017). Control of anthracnose disease via increased activity of defence related enzymes in 'Hass' avocado fruit treated with methyl jasmonate and methyl salicylate. *Food Chemistry*, *234*, 163–167. https://doi.org/10.1016/J.FOODCHEM.2017.04.063

Granada, S. D., Ramírez-Restrepo, S., López-Luján, L., Peláez-Jaramillo, C. A., & Bedoya-Pérez, J. C. (2018). Screening of a biological control bacterium to fight avocado diseases: From agroecosystem to bioreactor. *Biocatalysis and Agricultural Biotechnology*, *14*, 109–115. https://doi.org/10.1016/J.BCAB.2018.02.005

Gwanpua, S. G., Qian, Z., & East, A. R. (2018). Modelling ethylene regulated changes in 'Hass' avocado quality. *Postharvest Biology and Technology*, *136*, 12–22. https://doi.org/10.1016/J.POSTHARVBIO.2017.10.002

Hernández, I., Fuentealba, C., Olaeta, J. A., Lurie, S., Defilippi, B. G., Campos-Vargas, R., & Pedreschi, R. (2016). Factors associated with postharvest ripening heterogeneity of 'Hass' avocados (*Persea americana* Mill). *Fruits*. https://doi.org/10.1051/fruits/2016016

Hershkovitz, V., Friedman, H., Goldschmidt, E. E., Feygenberg, O., & Pesis, E. (2009). Induction of ethylene in avocado fruit in response to chilling stress on tree. *Journal of Plant Physiology*, *166*(17), 1855–1862. https://doi.org/10.1016/J.JPLPH.2009.05.012

Krumreich, F. D., Borges, C. D., Mendonça, C. R. B., Jansen-Alves, C., & Zambiazi, R. C. (2018). Bioactive compounds and quality parameters of avocado oil obtained by different processes. *Food Chemistry*, *257*, 376–381. https://doi.org/10.1016/J.FOODCHEM.2018.03.048

Ladaniya, M. S., & Ladaniya, M. S. (2008). PREPARATION FOR FRESH FRUIT MARKET. *Citrus Fruit*, 229–XI. https://doi.org/10.1016/B978-012374130-1.50011-5

Maftoonazad, N., Ramaswamy, H. S., Moalemiyan, M., & Kushalappa, A. C. (2007). Effect of pectin-based edible emulsion coating on changes in quality of avocado exposed to Lasiodiplodia theobromae infection. *Carbohydrate Polymers*, *68*(2), 341–349. https://doi.org/10.1016/J.CARBPOL.2006.11.020

Martínez-Padilla, L. P., Franke, L., & Juliano, P. (2017). Characterisation of the viscoelastic properties of avocado puree for process design applications. *Biosystems Engineering*, *161*, 62–69. https://doi.org/10.1016/J.BIOSYSTEMSENG.2017.06.016

Mazhar, M., Joyce, D., Cowin, G., Brereton, I., Hofman, P., Collins, R., & Gupta, M. (2015). Non-destructive1H-MRI assessment of flesh bruising in avocado (Persea americana M.) cv. Hass. *Postharvest Biology and Technology*, *100*, 33–40. https://doi.org/10.1016/j.postharvbio.2014.09.006

Mazhar, M., Joyce, D., Hofman, P., & Vu, N. (2018a). Factors contributing to increased bruise expression in avocado (Persea americana M.) cv. 'Hass' fruit. *Postharvest Biology and*

Technology, *143*, 58–67. https://doi.org/10.1016/J.POSTHARVBIO.2018.04.015
Mazhar, M., Joyce, D., Hofman, P., & Vu, N. (2018b). Factors contributing to increased bruise expression in avocado (Persea americana M.) cv. 'Hass' fruit. *Postharvest Biology and Technology*, *143*, 58–67. https://doi.org/10.1016/J.POSTHARVBIO.2018.04.015
Menzel, C. M., & Le Lagadec, M. D. (2014). Increasing the productivity of avocado orchards using high-density plantings: A review. *Scientia Horticulturae*, *177*, 21–36. https://doi.org/10.1016/J.SCIENTA.2014.07.013
Ncama, K., Magwaza, L. S., Poblete-Echeverría, C. A., Nieuwoudt, H. H., Tesfay, S. Z., & Mditshwa, A. (2018). On-tree indexing of 'Hass' avocado fruit by non-destructive assessment of pulp dry matter and oil content. *Biosystems Engineering*, *174*, 41–49. https://doi.org/10.1016/J.BIOSYSTEMSENG.2018.06.011
Obianom, C., Romanazzi, G., & Sivakumar, D. (2019). Effects of chitosan treatment on avocado postharvest diseases and expression of phenylalanine ammonia-lyase, chitinase and lipoxygenase genes. *Postharvest Biology and Technology*, *147*, 214–221. https://doi.org/10.1016/J.POSTHARVBIO.2018.10.004
Oliveira, M. A. de, Santos, C. H. dos, Henrique, C. M., & Rodrigues, J. D. (2000). Ceras para conservação pós-colheita de frutos de abacateiro cultivar fuerte, armazenados em temperatura ambiente. *Scientia Agricola*, *57*(4), 777–780. https://doi.org/10.1590/S0103-90162000000400028
Ortiz-Viedma, J., Rodriguez, A., Vega, C., Osorio, F., Defillipi, B., Ferreira, R., & Saavedra, J. (2018). Textural, flow and viscoelastic properties of Hass avocado (Persea americana Mill.) during ripening under refrigeration conditions. *Journal of Food Engineering*, *219*, 62–70. https://doi.org/10.1016/J.JFOODENG.2017.09.014
Pedreschi, R., Muñoz, P., Robledo, P., Becerra, C., Defilippi, B. G., van Eekelen, H., Mumm, R., Westra, E., & De Vos, R. C. H. (2014). Metabolomics analysis of postharvest ripening heterogeneity of "Hass" avocadoes. *Postharvest Biology and Technology*. https://doi.org/10.1016/j.postharvbio.2014.01.024
Perato, S. M., Martínez-Zamora, M. G., Salazar, S. M., & Díaz-Ricci, J. C. (2018). The elicitor AsES stimulates ethylene synthesis, induce ripening and enhance protection against disease naturally produced in avocado fruit. *Scientia Horticulturae*, *240*, 288–292. https://doi.org/10.1016/J.SCIENTA.2018.06.030
Perkins, M. L., Joyce, D. C., & Coates, L. M. (2019). Possible contribution of impact injury at harvest to anthracnose expression in ripening avocado: A review. *Scientia Horticulturae*, *246*, 785–790. https://doi.org/10.1016/J.SCIENTA.2018.11.012
Pesis, E., Ackerman, M., Ben-Arie, R., Feygenberg, O., Feng, X., Apelbaum, A., Goren, R., & Prusky, D. (2002). Ethylene involvement in chilling injury symptoms of avocado during cold storage. *Postharvest Biology and Technology*, *24*(2), 171–181.

https://doi.org/10.1016/S0925-5214(01)00134-X

Quevedo, R., Ronceros, B., Garcia, K., Lopéz, P., & Pedreschi, F. (2011). Enzymatic browning in sliced and puréed avocado: A fractal kinetic study. *Journal of Food Engineering*, *105*(2), 210–215. https://doi.org/10.1016/J.JFOODENG.2011.02.012

Ramírez-Gil, J. G., Gilchrist Ramelli, E., & Morales Osorio, J. G. (2017). Economic impact of the avocado (cv. Hass) wilt disease complex in Antioquia, Colombia, crops under different technological management levels. *Crop Protection*, *101*, 103–115. https://doi.org/10.1016/J.CROPRO.2017.07.023

Rivera, S. A., Ferreyra, R., Robledo, P., Selles, G., Arpaia, M. L., Saavedra, J., & Defilippi, B. G. (2017). Identification of preharvest factors determining postharvest ripening behaviors in 'Hass' avocado under long term storage. *Scientia Horticulturae*, *216*, 29–37. https://doi.org/10.1016/J.SCIENTA.2016.12.024

Sarkhosh, A., Vargas, A. I., Schaffer, B., Palmateer, A. J., Lopez, P., Soleymani, A., & Farzaneh, M. (2017). Postharvest management of anthracnose in avocado (Persea americana Mill.) fruit with plant-extracted oils. *Food Packaging and Shelf Life*, *12*, 16–22. https://doi.org/10.1016/J.FPSL.2017.02.001

Siddique, S. S., Hardy, G. E. S. J., & Bayliss, K. L. (2018). Advanced technologies for controlling postharvest diseases of fruit. *Acta Horticulturae*. https://doi.org/10.17660/ActaHortic.2018.1194.29

Tesfay, S. Z., Bertling, I., & Bower, J. P. (2011). Effects of postharvest potassium silicate application on phenolics and other anti-oxidant systems aligned to avocado fruit quality. *Postharvest Biology and Technology*, *60*(2), 92–99. https://doi.org/10.1016/J.POSTHARVBIO.2010.12.011

Tesfay, S. Z., Magwaza, L. S., Mbili, N., & Mditshwa, A. (2017). Carboxyl methylcellulose (CMC) containing moringa plant extracts as new postharvest organic edible coating for Avocado (Persea americana Mill.) fruit. *Scientia Horticulturae*, *226*, 201–207. https://doi.org/10.1016/J.SCIENTA.2017.08.047

Vargas-Ortiz, M., Servent, A., Salgado-Cervantes, M., & Pallet, D. (2017). Stability of the lipid fraction of avocado puree obtained by flash vacuum-expansion process. *Innovative Food Science & Emerging Technologies*, *41*, 109–116. https://doi.org/10.1016/J.IFSET.2017.02.016

Woolf, A. B., Cox, K. A., White, A., & Ferguson, I. B. (2003). Low temperature conditioning treatments reduce external chilling injury of 'Hass' avocados. *Postharvest Biology and Technology*, *28*(1), 113–122. https://doi.org/10.1016/S0925-5214(02)00178-3