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Effect of conventional and alternative products on postharvest disease control in avocados[1]

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ABSTRACT- Postharvest diseases constitute a serious problem for avocado commercialization. Thus, the present study aimed to evaluate the effect of conventional and alternative products in controlling diseases affecting 'Hass' avocados in the field and in the postharvest by carrying out physicochemical characterization of fruits subjected to postharvest treatments. In the field, besides the management adopted by the farmer, seven products were sprayed three times during fruiting for evaluation. Postharvest products were diluted in water or in oxidized polyethylene wax and shellac. Water treatments with potassium phosphite, Soil-Set®, chlorine dioxide, thyme essential oil, sodium bicarbonate, lemon grass essential oil and thiabendazole reduced the incidence of diseased fruits, and anthracnose, the main disease, was controlled with sodium bicarbonate, lemon grass essential oil and thiabendazole. Greater soluble solids content was found for control (water), chlorine dioxide, acibenzolar-S-methyl and thiabendazole. For the products that reduced anthracnose, there was no correlation between the disease and the physicochemical parameters, evidencing that the disease control is not associated with delayed ripening. For wax treatments, diseases were not controlled, and the fruits presented lower titratable acidity with thyme essential oil, sodium bicarbonate, control (wax), acibenzolar-S-methyl and lemon grass essential oil. Control and thyme essential oil were highlighted for maintaining the green coloration of the fruit skin for the shortest period. Under field conditions, azoxystrobin, thiabendazole, difenoconazole+azoxystrobin and acibenzolar-S-methyl+azoxystrobin reduced the occurrence of diseased fruits, while anthracnose control was only obtained with azoxystrobin.
Index terms: Rot, *Persea americana*, *Colletotrichum*, control disease.

Efeito de produtos convencionais e alternativos no controle de doenças pós-colheita do abacate

RESUMO- Um dos grandes problemas na comercialização de abacates é a incidência de doenças pós-colheita. Objetivou-se avaliar o efeito de produtos convencionais e alternativos no controle de doenças em abacates 'Hass', em condições de campo e em pós-colheita, realizando a caracterização físico-química nos frutos submetidos aos tratamentos pós-colheita. No campo, em adição ao manejo do produtor, foram avaliados sete produtos, pulverizados três vezes durante a frutificação. Os produtos em pós-colheita foram diluídos em água ou em cera de polietileno oxidada e goma laca. Os tratamentos em água com fosfito de potássio, Soil-Set®, dióxido de cloro, óleo essencial de tomilho, bicarbonato de sódio, óleo essencial de capim-limão e tiabendazol reduziram a incidência de frutos doentes, sendo a antracnose, principal doença, controlada com bicarbonato de sódio, óleo essencial de capim-limão e tiabendazol. Maior teor de sólidos solúveis foi constatado nos tratamentos água, dióxido de cloro, acibenzolar-S-metílico e tiabendazol. Os produtos que reduziram a antracnose não apresentaram correlação entre a incidência da doença com os parâmetros físico-químicos, evidenciando que o controle não está associado ao atraso no amadurecimento. Nos tratamentos em cera, não ocorreu controle das doenças, sendo observado menor acidez titulável com óleo essencial de tomilho, bicarbonato de sódio, controle (cera), acibenzolar-*S*-metílico e óleo essencial de capim-limão. Os tratamentos controle e óleo essencial de tomilho destacaram-se pela menor manutenção da coloração verde da casca dos frutos. Em condições de campo, os produtos azoxistrobina, tiabendazol, difenoconazol+azoxistrobina e acibenzolar-S-metílico+azoxistrobina reduziram a ocorrência de frutos doentes, sendo que o controle da antracnose ocorreu apenas com azoxistrobina.
Termos para indexação: podridão, *Persea americana*, *Colletotrichum*, manejo fitossanitário.

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Introduction

Avocado varieties commercially grown in Brazil can be grouped into exportation or domestic consumption types. Those preferred for domestic consumption generally have bigger fruits with low oil content. For exportation, the most frequently cultivated varieties are ‘Hass’ and ‘Fuerte’, the fruits of which show small size and high oil content. ‘Hass’ avocado production has increased in the last years, being especially destined for the European market. The fruit of this variety presents oval to pyriform shape and average mass between 180 and 300 grams; its thick and rough skin is green before and immediately after harvest but changes to dark brown when ripe (SCHAFFER et al., 2013).

Avocado is a climacteric fruit which becomes ripe a few days after harvest due to a series of events such as increased respiratory activity, greater ethylene production, modified lipid content and altered texture, involving mesocarp cell degradation, starch content reduction and glucose and fructose level increase (SEYMOUR; TUCKER, 1993). In Brazil, avocados produced for the external market are routinely waxed. Wax application improves the appearance of fruits and extends their conservation by diminishing both the transpiration rate and the metabolic activity (DARVAS et al., 1990).

The avocado tree is affected by several diseases both in the pre and in the postharvest period. Anthracnose, caused by *Colletotrichum gloeosporioides* complex, is considered the main postharvest disease, occurring in all avocado-producing countries (SCHAFFER et al., 2013). Over 90% anthracnose incidence was observed for ‘Hass’ avocados cultivated under conditions favorable to the disease in Australia (WILLINGHAM et al., 2006). In a packinghouse in São Paulo State, Brazil, 68.7% sampled ‘Hass’ avocados were detected with anthracnose after 15 days of storage (FISCHER et al., 2011). This infection occurs during fruit development in the field and remains quiescent until ripening due to the physiological conditions imposed by the host, so that fruits are apparently healthy at harvest but symptoms manifest during storage and commercialization. Characteristic symptoms in the fruits appear as small, circular, dark dots. The lesions tend to evolve, reaching part of the fruit or completely necrosing it (PICCININ et al., 2016).

Besides anthracnose, several other diseases can affect avocados in the postharvest (SCHAFFER et al., 2013). A survey of rots affecting ‘Hass’ avocados in the state of São Paulo indicated that Lasiodiplodia rot, which is caused by *Lasiodiplodia theobromae*, and Fusicoccum rot, which is caused by *Fusicoccum* spp., reached 4 and 3%, respectively (FISCHER et al., 2011). Of the 15 isolates of *Fusicoccum* spp. from avocado trees, 11 were identified as *F. parvum* (*Neofusicoccum parvum*) and the remaining ones as *F. aesculi* (FIRMINO et al., 2016). Symptoms due to Lasiodiplodia or Fusicoccum rot are similar; they are characterized by dark necrosis in the peduncle region, spreading to the whole fruit, besides grayish mycelium production on the surface of the necrotic fruit. The infections occur in the field through lenticels and wounds and disease development generally occurs after harvest and fruit softening (PHILLIPS et al., 2010).

Control of postharvest diseases in an orchard is based on application of balanced fertilization, clear pruning to remove dead, debilitated and diseased branches, and application of fungicides two or three times between flowering and fruiting (PICCININ et al., 2016). However, even after rigorous application of the recommended fungicides, fruits free from anthracnose are difficult to obtain (DARVAS, 1981).

Several procedures can be adopted to control diseases by means of postharvest fruit treatment; they include chemical, physical and biological methods which can act directly on the pathogens and/or on the fruit physiology, delaying ripening and increasing resistance (BENATO, 1999). The fungicides thiabendazole, strobilurin and prochloraz are efficient in controlling postharvest rots (EVERETT et al., 2005; FISCHER et al., 2011). Powell (1988) tested wax, with and without the fungicide prochloraz, in the postharvest treatment of avocados and noted that it drastically reduced anthracnose, especially when associated with the fungicide. Nevertheless, due to increasing restrictions on the use of fungicides in the postharvest, some countries like France do not allow postharvest treatment with prochloraz (SCHAFFER et al., 2013). Alternative methods that are feasible to the small farmer and that were already tested in the postharvest showing certain efficiency for fruiting plants include application of phosphites (FERRAZ et al., 2016), chlorine (FISCHER et al., 2011), acibenzolar-S-methyl (DANTAS et al., 2004; PESSOA, 2009), Agro-Mos® (phosphorylated mannanoligosaccharide-based product) (DANTAS et al., 2004; PESSOA, 2009), sodium bicarbonate (HASAN et al., 2012) and essential oils (MOURA et al., 2012; SELLAMUTHU et al., 2013). Association between essential oils and wax-based coating was effective for pathogen control in avocados (REGNIER et al., 2010). The advantage of treating fruits with alternative products is that they do not leave undesirable residues and do not pose risks to the human health or to the environment; thus, they can be an additional tool in the integrated control of diseases.

In view of the lack of information about the management of diseases in avocados, the aim of this study was to evaluate the effect of conventional and alternative products on rot control under field conditions and in the postharvest, as well as on the physicochemical characteristics of fruits subjected to postharvest treatments.

Material And Methods

Postharvest disease control under field conditions

The field experiment was conducted in a six-year-old orchard of ‘Hass’ avocados located in Bauru, São Paulo State (SP), Brazil. Control treatment (a) was the standard adopted by the farmer. In the crop season 2014/15, the adopted standard was one application of trifloxystrobin+tebuconazole (0.06+0.12 g L^{-1}) at floral cluster formation (21/09/14) and three sequential applications of copper oxychloride (2 g L^{-1}) at approximately 45-day intervals (27/10/14, 15/12/14 and 29/01/15), employing a 1250 L/hectare water volume. In the following season (2015/16), the applied products were trifloxystrobin+tebuconazole (17/09/15) and copper oxychloride (26/10/15 and 28/01/16). In addition to control treatment, three applications were performed per year (crop season) on the following dates: 17/10/14, 28/11/14 and 14/01/15 in the crop season 2014/15, and 05/10/15, 23/11/15 and 18/01/2016 for crop season 2015/16, using the following products (g L^{-1}): b) difenoconazole (0.05); c) azoxystrobin (0.08); d) acibenzolar-S-methyl (0.0125); e) acibenzolar-S-methyl (0.0125) + azoxystrobin (0.08); f) difenoconazole (0.05) + azoxystrobin (0.08); g) thiabendazole (0.485) and h) calcium chloride (20). Those products and copper control treatment were sprayed interchangeably, starting when the length of fruits was approximately 2 cm. Application was done with a turbo atomizer trailed at a water volume of 1250 L/hectare.

Experimental design was in randomized blocks, containing eight treatments, four replicates and four trees per plot. In the adequate maturation stage, 15 fruits were sampled from the “shoulder height” portion of two central trees in the plot. The fruits were individualized in plastic trays and stored for 15 days, at 25ºC and 80-85% relative humidity (RH). The incidence of postharvest diseases was evaluated at every three days and data were subjected to analysis of variance, while means were compared according to Scott-Knott test at 5% significance level. Data on the incidence of stem-end rots were transformed into root x + 1.0 in order to obtain normalization and adequacy for statistical analysis. The experiment was carried out in the crop season 2014/15 and repeated in 2015/16.

Alternative postharvest disease control and physicochemical characterization of avocados

‘Hass’ avocados, harvested from a commercial orchard located in Bauru, SP, were standardized as to the absence of defects, washed under tap water with a foam sponge and neutral detergent, and immersed for 60 seconds (time taken by the fruit to pass through the packinghouse ferry) in a suspension containing the following products (g L^{-1}): a) water (control), b) acibenzolar-S-methyl (0.05) (NASCIMENTO et al., 2008), c) Agro-Mos® (phosphorylated mannanoligosaccharides-based product) (1.5) (PESSOA, 2009, PESSOA et al., 2009), d) Soil-Set® (S 3.8%, Cu 2.0%, Fe 1.6%, Mn 0.8%, Zn 3.2%, organic carbon 1.7% and amino acids as complexing agents 5.0%) (1.5), e) chlorine dioxide (0.2 active chlorine) (FISCHER et al., 2011), f) potassium phosphite (40% P_2O_5 and 20% K_2O) (1.5) (FERRAZ et al., 2016), g) sodium bicarbonate (20) (HASAN et al., 2012), and h) thiabendazole (1.94) (BRASIL, 2017). As phytotoxicity occurs when fruits are immersed for 60 seconds, essential oils of lemon grass (*Cymbopogon citratus*) (1) (MOURA et al., 2012) and white thyme (*Thymus vulgares*) (1) (SELLAMUTHU et al., 2013) were sprayed on the fruits until runoff. To potentiate the effects of suspensions and prevent toxicity by pure essential oils in direct contact with fruits, Tween 20 (0.2 g L^{-1}) was added as dispersant (DANTAS et al., 2004; PESSOA et al., 2009). The same products and their respective doses were also incorporated into oxidized polyethylene wax and shellac (Brillaqua EU Mercosur®), which were then sprayed onto the fruits until runoff; control was represented by the treatment containing only wax.

After treatment application and drying, fruits were stored at 25ºC and 80-85% RH for 12 days and evaluated for natural incidence of postharvest diseases at every three days; the disease was detected based on the symptomatology and the identification of structures of the causal agent under an optical microscope. Experimental design was completely randomized, including ten treatments diluted in water and ten treatments diluted in wax, and four replicates of five fruits per plot for each treatment.

Physicochemical characterization was also performed on harvest day and after ten days of storage of fruits subjected to the different treatments, except Soilset®. The studied characteristics were: a) skin color, determined by performing two readings on the opposite sides of the equatorial region of the fruit in a colorimeter, expressed as hue angle (ºh); b) pulp firmness, determined by performing two readings on the opposite sides of the equatorial region of the fruit in a 8mm-tip digital penetrometer, expressed as Newton; c) soluble solids content, determined in a digital refractometer, expressed as °Brix; and d) titratable acidity content, determined by means of titration with NaOH, expressed as % citric acid (AOAC, 2005). Experimental design was completely randomized, including three replicates of four fruits per plot.

Results of diseases and physicochemical characterization of fruits were subjected to analysis of variance and means were compared according to Scott-Knott test ($p<0.05$). Data on stem-end rot incidence and weight loss at 10 days were transformed into root x + 1.0 in order to obtain normalization and adequacy for statistical analysis. Physicochemical variables were correlated with postharvest disease incidence and subsequently analyzed according to F test ($p<0.05$). The experiment was repeated once.

Results and Discussion

Postharvest disease control under field conditions

There were significant differences among treatments for incidence of diseased fruits and fruits with anthracnose (Table 1). As the crop seasons did not differ ($p>0.05$) with respect to incidence of diseased fruits, the data were analyzed together. The products azoxystrobin, thiabendazole, difenoconazole+azoxystrobin and acibenzolar-S-methyl+azoxystrobin, when added to the treatment already adopted by the farmer, reduced by 13.3 to 26.4% the number of fruits showing rot symptoms, while anthracnose control was only obtained with azoxystrobin, which led to a reduction of 34.4% in the incidence, relative to control. The mean incidence of diseased fruits and fruits with anthracnose at 15 days of storage at 25ºC and 80-85% RH was 66.5 and 56.1%, respectively. Lasiodiplodia and Fusicoccum rots were found at lower incidences, showing means of 13.1 and 1.2%, respectively, and no differences among treatments.

Anthracnose was the major disease detected; according to Darvas (1981), its control is difficult even after application of the recommended fungicides. Currently, the fungicides registered in Brazil for anthracnose control in avocado trees are the copper fungicides copper oxychloride and cuprous oxide, the mixture mancozeb+copper oxychloride and the systemic fungicides difenoconazole and thiabendazole; the latter can be applied in the field and in the postharvest (BRASIL, 2017). In Europe and South Africa, the fungicide azoxystrobin is also registered for the control of this disease in the field (PIP, 2011; HSE, 2014), which is a possibility in Brazil. Reduced occurrence of rots in 'Hass' avocados was obtained by means of eight monthly fungicide sprayings, and the best results were obtained with copper hydroxide, followed by azoxystrobin and carbendazim (EVERETT et al., 2005); however, control failure occurs due to the high frequency of rainfall, which washes the copper fungicides. According to Duvenhage (2002), anthracnose control using copper oxychloride was more effective when followed by one application of azoxystrobin, corroborating the results obtained in the present study, in which three applications of azoxystrobin were performed. In the evaluation of fungicides for anthracnose control in mango tree, azoxystrobin (75 mg L^{-1}) + paraffin mineral oil at 0.5% showed the lowest incidence of diseased fruits (SALES JÚNIOR et al., 2004).

Alternative postharvest disease control and physicochemical characterization of avocados

Fruits that received water treatments with potassium phosphite, Soil-Set®, chlorine dioxide, thyme essential oil, sodium bicarbonate, lemon grass essential oil and thiabendazole had lower disease incidence (53.4-66.5%), relative to control treatment (77.8%), which did not differ from treatments with Agro-Mos® and acibenzolar-S-methyl (Table 2). Greater fruit conservation, due to rot control and/or delayed ripening, was already reported for most of the studied products applied in the postharvest, such as thyme essential oil (SELLAMUTHU et al., 2013), chlorine dioxide and thiabendazole in avocado (FISCHER et al., 2011), potassium phosphite in guava (FERRAZ et al., 2016), sodium bicarbonate in papaya (HASAN et al., 2012), and lemon grass essential oil in passion fruit (MOURA et al., 2012) and papaya (CARNELOSSI et al., 2009). However, the efficiency of postharvest disease control with acibenzolar-S-methyl and Agro-Mos® in banana (PESSOA, 2009) and acibenzolar-S-methyl in papaya (DANTAS et al., 2004) was not confirmed in the present study in avocados.

Anthracnose was the major disease affecting fruits and had the lowest incidence (48.9-51.3%) when fruits received water treatments with sodium bicarbonate, lemon grass essential oil and thiabendazole, relative to the remaining treatments (60.0-75.4%). Control of this disease using thiabendazole was already obtained by Fischer et al. (2011); fruits immersed for 30 seconds in 1 g L^{-1} fungicide had 13.6% anthracnose incidence, while control treatment led to 30% incidence after ten days of storage at 25ºC. Nevertheless, the efficiency of thiabendazole in controlling anthracnose in the postharvest (Table 2) was not confirmed for the treatment in the field (Table 1), where the efficiency of fungicides tends to be lower compared to tests under controlled conditions, since the environmental factors that involve the host plant and the pathogens in the field are in constant interaction.

Immersion of papayas for 15 minutes in sodium bicarbonate syrup (20 g L^{-1}) was reported to reduce by up to 60% anthracnose incidence and severity (HASAN et al., 2012), while in the present study one-minute immersion reduced the disease incidence by 35%, suggesting that a longer immersion time may lead to increased efficiency. The severity of anthracnose significantly decreased in naturally infected passion fruits immersed for one minute in lemon grass essential oil (1 g L^{-1}) (MOURA et al., 2012), as well as in papaya inoculated with *C. gloeosporioides*, at 10 g L^{-1} lemon grass oil (CARNELOSSI et al., 2009). For mango, immersion for 3 minutes in sodium bicarbonate (3%) and fumigation with lemon grass essential oil (1000 µL/3 min) did not control anthracnose (CRUZ et al., 2010); however, the disease was controlled by associating lemon grass oil (4 g L^{-1}) with thermal treatment in fruits inoculated with *C. gloeosporioides* (DUAMKHANMANEE, 2008).

Several studies have demonstrated the antimicrobial activity of natural products such as salts and essential oils, some of which induce the activity of enzymes related to the plant defense. Oranges infected with *Penicillium digitatum*, the causal agent of green mold, and treated with sodium bicarbonate had greater activity of the enzymes peroxidase (POD) and phenylalanine ammonia lyase (PAL) (YOUSSEF et al., 2014). In a recent study, the mycelial growth of *C. gloeosporioides* in avocado was totally inhibited by concentrations from 1000 µL L^{-1} lemon grass essential oil. 'Hass' avocados inoculated with the pathogen and treated with 1 and 2 ml L^{-1} oil associated with wax had lower incidence of anthracnose after 14 days of storage at 12±2ºC and increased POD activity at the highest concentration of the oil; however, when the fruits were exposed for more than three days at 22±2ºC, there was no difference among treatments (MARQUES, 2015).

Lasiodiplodia rot (2.3-12.5%) and Fusicoccum rot (0.0-17.8%) were found at lower incidences, but there was no significant difference among treatments (Table 2).

There were no significant differences in the incidence of diseases for fruits subjected to wax treatments (Table 2). In general, the incidence of diseased fruits was numerically inferior in waxed fruits, compared to fruits that did not receive wax, but there was no difference (p=0.06) in the joint analysis for water and wax treatments after 12 days of storage. According to Darvas et al. (1990), wax provides protection to the fruits and delays the ripening process, consequently delaying the development of quiescent pathogens such as that of anthracnose (POWELL, 1988, FISCHER et al., 2011).

Inoculation of *C. gloeosporioides* or *L. theobromae* in avocados treated with *Lippia scaberrima* essential oil (1 and 2 ml L^{-1}), associated with wax covering, reduced the development of diseases, compared to treatment with wax or water alone (REGNIER et al., 2010). In citrus, application of fungicides in mixture with wax is generally less efficient to control postharvest diseases, compared to application with water (ECKERT; EAKS, 1989; SMILANICK et al, 2006). To compensate such lower efficacy in combination with wax, fungicides are applied in aqueous suspensions before wax application or used at higher concentrations together with waxes (ECKERT; EAKS, 1989). Association between sodium bicarbonate (2%) and *Candida oleophila* (2x10^8 cells) in mixture with wax resulted in significantly reduced anthracnose incidence and severity in naturally infected papayas (GAMAGAE et al., 2004).

A marked increase in the incidence of anthracnose was noted at the end of storage, changing from 6.6-12.5% at nine days to 56.5-63.6% at 12 days, on average, for wax and water treatments, respectively (Figure 1). Characteristic symptoms of rots, such as anthracnose and stem-end rots, manifest in the last fruit ripening stages (PÉREZ-JIMÉNEZ, 2008). Antifungal compounds present in the skin of green fruits decrease during ripening, activating latent infections and rapidly resulting in symptoms in the fruits (NELSON, 2008).

Considering the physicochemical characterization of 'Hass' avocados on harvest day, the mean value of soluble solids was 7.83 ºBrix, titratable acidity was 0.082 % citric acid, skin color was 123.55 ºh and pulp firmness was >196 Newton. After 10 days of storage at 25ºC, with fruit ripening, titratable acidity increased while firmness and skin color values decreased, regardless of the treatment (Table 3). Soluble solids content slightly varied, positively for control treatment in water (8.10) and negatively for control treatment in wax (7.68). In general, these results are similar to those found by Fischer et al. (2011) for 'Hass' and 'Fuerte' avocados.

During ripening, wax application promoted greater maintenance of fruit color and pulp firmness and decreased weight loss, evidencing the delay in the ripening process, as already reported by Fischer et al. (2011) and Marques (2015). Maftoonazad et al. (2007) also observed greater firmness in 'Hass' avocados treated with pectin-based wax. Pulp firmness is determined based on the cohesion strength between pectins, and ripening in avocados leads to the action of pectinolytic enzymes, especially cellulase, polygalacturonase and pectin methylesterase, which transform insoluble into soluble pectin and promote fruit softening (SEYMOUR; TUCKER, 1993). The modified gaseous atmosphere created by wax application reduces the activity of these enzymes and promotes fruit firmness retention during storage (MAFTOONAZAD et al., 2007).

Ripening in avocados is directly related, among other factors, to increased oil levels, the production of which consumes carbohydrates, especially soluble ones (SANCHES et al., 2008). However, a factor that can eventually explain the maintenance and the increase in solids during storage is the release of hexoses, due to polysaccharide degradation, at levels similar (in the case of level maintenance) or superior (in the case of level increase) to that of sugar consumption by avocados in respiration and oil production. Another factor that may have contributed to the increased soluble solids is weight loss, which may have helped concentrate sugars. As to titratable acidity contents, Oliveira et al. (2000) also observed decreased pH in 'Fuerte' avocados on the 4th day of storage at 25ºC, which indicates an increase in acidity.

As to the effect of different products diluted in water on the physicochemical characteristics of fruits, there were no significant differences among treatments for titratable acidity, pulp firmness, skin color and weight loss after five days (Table 3). Higher soluble solids content (8.10-8.75) was found for the treatments water (control), chlorine dioxide, acibenzolar-S-methyl and thiabendazole, compared to the remaining treatments (7.00-7.80). The treatment with sodium bicarbonate had greater weight loss (5.24%) after 10 days, relative to the remaining treatments.

Wax treatments and water treatments had no significant differences for pulp firmness and weight loss of fruits after five days (Table 3). Differently from water, wax treatments showed no differences for soluble solids, and there was lower titratable acidity (0.098-0.107) for treatments with thyme essential oil, sodium bicarbonate, control (wax), acibenzolar-S-methyl and lemon grass essential oil, compared to the remaining treatments (0.114-0.132); similarly, the treatments control and thyme essential oil were highlighted for maintaining the green coloration of the fruit skin for the shortest period, showing the lowest angle (ºhue).

As in the present study, 'Hass' avocados treated with lemon grass essential oil (1 ml L^{-1}) in association with carnauba wax and plant resin (Aruá® BR-A2 Tropical) have shown higher color angle (ºh) and no differences in the features weight loss, pulp firmness, titratable acidity and soluble solids, relative to waxed fruits at the end of storage (MARQUES, 2015). In mangoes treated with sodium bicarbonate and lemon grass essential oil, titratable acidity reduced during the 21 days of storage under environmental conditions, while soluble solids had an increase, which was significant only on the first week of storage for the treatment with lemon grass essential oil (CRUZ et al., 2010). The natural ripening process of papayas was not affected by the presence of sachets with lemon grass essential oil, according to the analysis of physicochemical parameters of weight loss, skin color, firmness, total soluble solids/titratable acidity ratio and pH (ESPITIA et al., 2012). Papayas treated with lemon grass essential oil and immediately inoculated with *C. gloeosporioides* had lower total soluble solids content and pH but greater weight loss, relative to the inoculated fruits (CARNELOSSI et al., 2009).

Correlation analysis between the incidence of diseases and the physicochemical parameters of 'Hass' avocados was carried out only for anthracnose in fruits subjected to different water treatments in the postharvest, since for the remaining diseases, as well as for wax treatments, there was no effect on control. There was a correlation ($p \leq 0.05$) between the incidence of anthracnose and the physicochemical parameters for acibenzolar-S-methyl, considering titratable acidity ($r=0.96$), pulp firmness ($r=-0.99$) and weight loss after 10 days ($r=-0.98$), and thyme essential oil and Agro-Mos®, considering the parameter skin color ($r=-1.00$ and -0.98, respectively); however, these products did not control anthracnose. Lemon grass essential oil, thiabendazole and sodium bicarbonate, which reduced the incidence of anthracnose, did not show correlation of this disease with the evaluated physicochemical parameters, evidencing that its control is not associated with delayed ripening.

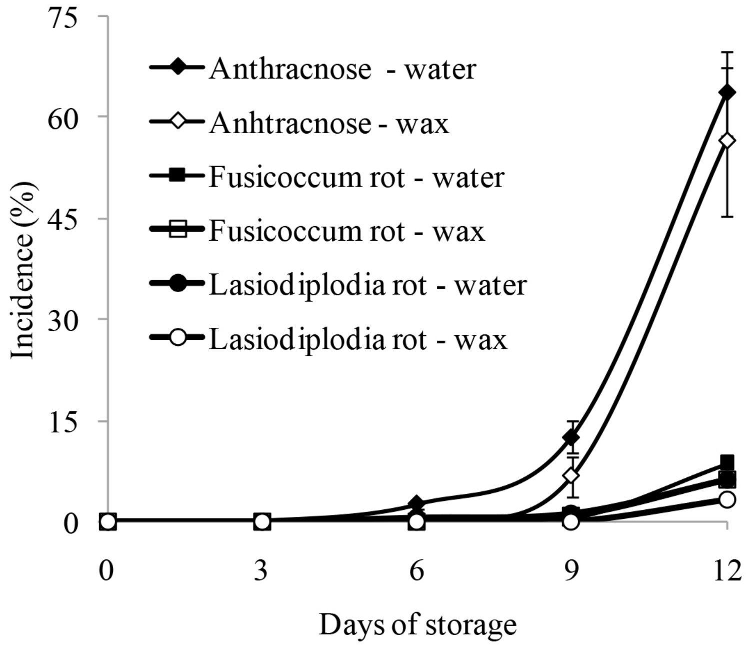

Figure 1. Progress incidence (%) of diseases in 'Hass' avocado subjected to postharvest treatments, in water or wax, during 12 days of storage at 25ºC and 80-85% relative humidity. Vertical bars represent the standard deviation of means.

Table 1. Incidence (%) of postharvest diseases in 'Hass' avocados subjected to different treatments under field conditions after 15 days of storage at 25ºC and 80-85% relative humidity. Average harvests of 2014/15 and 2015/16.

Treatments	Diseased	Diseases		
	Fruits	Anthracnose	Lasiodiplodia rot[1]	Fusicoccum rot[1]
Azoxystrobin	53.7 a	41.1 a	13.3 [ns]	1.3 [ns]
Thiabendazole	63.0 a	52.3 b	11.4	2.0
Difenoconazole+azoxystrobin	63.1 a	55.3 b	11.7	1.1
Acibenzolar-S-methyl+azoxystrobin	63.3 a	58.1 b	9.7	0.7
Difenoconazole	68.0 b	56.1 b	13.9	1.6
Control (adopted by the farmer)	73.0 b	62.7 b	11.8	1.2
Acibenzolar-S-methyl	74.0 b	61.2 b	17.1	0.8
Calcium chloride	74.3 b	62.3 b	15.7	1.2
C.V. (%)	13.0	14.6	16.2	26.8

*Means followed by the same letter in the column do not differ statistically from each other at 5% significance level, according to Scott-Knott test. [ns] = not significant ($p \leq 0.05$). [1]Statistical analysis with the original data transformed into root x + 1.0.

Table 2. Incidence (%) of postharvest diseases in 'Hass' avocados subjected to different postharvest treatments, in water or wax, after 12 days of storage at 25ºC and 80-85% relative humidity.

Treatments	Diseased	Diseases		
(Water)	Fruits	Anthracnose	Lasiodiplodia rot[1]	Fusicoccum rot[1]
Thiabendazole	53.4 a	51.3 a	2.3 [ns]	6.6 [ns]
Lemon grass essential oil	56.8 a	47.2 a	9.1	2.8
Sodium bicarbonate	60.2 a	48.9 a	11.4	9.1
White thyme essential oil	62.5 a	62.5 b	12.5	0.0
Chlorine dioxide	64.4 a	60.0 b	6.6	4.4
Soil-Set®	65.0 a	65.0 b	4.5	0.0
Potassium phosphite	66.5 a	62.1 b	4.4	9.1
Agro-Mos®	77.8 b	71.2 b	4.5	17.8
Water (control)	77.8 b	73.5 b	4.5	6.6
Acibenzolar-S-methyl	84.5 b	75.4 b	8.9	11.2
C.V.(%)	15.4	18.9	42.4	30.9
(Wax)				
Thiabendazole	42.2 [ns]	40.0 [ns]	0.0 [ns]	6.8 [ns]
Lemon grass essential oil	52.8	46.2	10.8	13.4
Potassium phosphite	55.3	53.0	4.5	6.8
Chlorine dioxide	58.0	53.4	4.5	2.3
Sodium bicarbonate	60.0	60.0	2.3	0.0
Wax (control)	61.9	61.9	2.1	2.3
Agro-Mos®	62.7	58.1	0.0	8.5
White thyme essential oil	64.6	60.2	0.0	6.4
Acibenzolar-S-methyl	64.6	58.0	4.5	6.6
Soil-Set®	66.5	66.5	4.4	4.4
C.V.(%)	22.3	23.6	43.2	47.3

*Means followed by the same letter in the column do not differ statistically from each other at 5% significance level, according to Scott-Knott test. [ns] = not significant ($p \leq 0.05$).[1]Statistical analysis with the original data transformed into root x + 1.0.

Table 3. Physical-chemical characteristics of 'Hass' avocados subjected to different postharvest treatments, in water or wax, after ten days of storage at 25ºC and 80-85% relative humidity.

Treatments	Soluble solids (ºBrix)	Titratable acidity (% citric acid)	Flesh firmness (N)	Skin color (ºh)	Weight loss (%)	
					5 days	10 days[1]
Water (control)	8.10 b	0.107 ns	19.89 ns	67.33 ns	2.79 ns	4.55 a
Chlorine dioxide	8.78 b	0.126	25.15	79.2	2.66	4.18 a
Acibenzolar-S-methyl	8.65 b	0.122	16.24	88.18	2.65	4.40 a
Potassium phosphite	7.65 a	0.151	64.12	82.59	2.66	4.42 a
White thyme essential oil	7.80 a	0.130	23.05	76.51	2.75	4.50 a
Lemon grass essential oil	7.00 a	0.137	20.87	72.43	2.67	4.43 a
Thiabendazole	8.23 b	0.120	75.80	85.23	2.74	4.47 a
Agro-Mos®	7.32 a	0.117	59.36	78.52	2.70	4.69 a
Sodium bicarbonate	7.28 a	0.156	36.01	79.0	2.99	5.24 b
C.V.(%)	5.76	26.67	32.26	8.48	14.27	19.39
Wax (control)	7.68 ns	0.100 a	62.94 ns	77.21 a	2.09 ns	3.52 ns
Chlorine dioxide	7.18	0.114 b	89.72	96.27 b	2.18	3.84
Acibenzolar-S-methyl	7.28	0.106 a	60.16	98.60 b	2.29	3.72
Potassium phosphite	7.28	0.126 b	93.49	89.77 b	2.14	3.51
White thyme essential oil	8.22	0.098 a	74.44	84.51 a	2.03	3.57
Lemon grass essential oil	7.57	0.107 a	104.31	95.27 b	2.04	3.63
Thiabendazole	7.68	0.132 b	63.20	88.78 b	2.12	3.50
Agro-Mos®	7.12	0.115 b	72.53	89.90 b	2.38	4.14
Sodium bicarbonate	7.75	0.099 a	98.54	94.41 b	2.19	3.66
C.V.(%)	5.45	10.99	22.52	6.27	24.49	19.85

*Means followed by the same letter in the column do not differ statistically from each other at 5% significance level, according to Scott-Knott test. ns = not significant ($p \leq 0.05$). [1]Statistical analysis with the original data transformed into root x + 1.0.

Conclusion

Field management of anthracnose can be obtained with three applications of azoxystrobin/year, alternating with copper oxychloride. In the postharvest, disease control is achieved by spraying the fruit with lemon grass essential oil or by immersing the fruits in sodium bicarbonate and thiabendazole diluted in water, which has no relationship with the delay in fruit ripening.

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