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Post-harvest conservation of *Passiflora alata* fruits under ambient and refrigerated condition

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Abstract

Brazil is the world's largest producer of passion fruit, a perishable fruit with reduced post-harvest shelf life, which limits its commercialization. For sweet passion fruit, *Passiflora alata*, there is little information about its postharvest conservation and shelf life under different storage conditions. Thus, the objective of the present study was to determine the post-harvest conservation of *P. alata* fruits packed on styrofoam trays rapped with 10 µm PVC film and HDPE 30 µm thick, coated with 18% carnauba wax and without any packaging; stored under ambient conditions (25 °C and 70% relative humidity) and refrigerated (10 °C and 90% relative humidity) for 14 days. The best results were obtained with *P. alata* fruits packaged on styrofoam trays rapped with 10 µm PVC flexible film and kept under refrigeration in a cold room at a temperature of 10 °C and relative humidity between 85% and 90% for a period of 10 to 14 days. Fruits of *P. alata*, for commercialization "*in natura*", kept under ambient conditions, should not be packaged and have a shelf life of up to seven days.

Keywords: sweet passion fruit; temperature; packaging; wax; color.

Practical Application: *Passiflora alata* fruit kept under refrigeration (10 °C/R.H. between 85% and 90%), and packaged on styrofoam trays rapped with 10 µm PVC flexible film, have a shelf life of 14 days. Under ambient conditions, should not be packaged and have a shelf life of up to seven days.

1 Introduction

Brazil is one of the main diversity centers of the genus *Passiflora*, from where genetic resources of great importance have been obtained, characterized and used in the Brazilian Passiflora Breeding Program (Cerqueira-Silva et al., 2016). The species *P. alata* Curtis is native to Brazil, where it finds excellent ecological conditions for its development. Its fruit, rich in minerals and vitamins, is appreciated for the quality of its pulp, pleasant aroma and taste, as well as its pharmacological properties. Sweet passion fruit is consumed "in natura", due to its tasty and sweet pulp (Lawinscky et al., 2014). Thus, the cultivation in Brazil is directed to the high valued fresh fruit market (Osipi et al., 2011).

There is little information on the quality and post-harvest conservation of *P. alata* fruits produced and marketed in the Federal District of Brazil (Junqueira et al., 2003). Presently, most of the studies are focused on yellow passion fruit (*Passiflora edulis* Sims) and, more recently, on *Passiflora setacea* (Mota et al., 2003; Mota et al., 2006; Rinaldi et al., 2017a). Thus, more detailed studies on the post-harvest conservation of *P. alata* fruits are needed, in order to provide information that can help producers in the best strategy for commercialization and increase of its shelf life.

Several post-harvest studies aiming at defining the best storage temperature for *Passiflora* spp. fruits have been carried out, where the temperature varied between 6.5 °C and 12 °C and relative humidity between 85 and 90% (Arjona et al., 1992; Silva et al., 1999; Zapata, 1987; Rinaldi et al., 2017b). Arjona et al. (1992), reported a 30-day shelf life for yellow passion fruit (*Passiflora edulis*) stored at 10 °C and 85% relative humidity. For *Passiflora alata* fruits, the temperature of 10 °C and 90% relative humidity were recommended during storage (Rinaldi et al., 2017c). At post-harvest, physical and chemical changes in fruits can be reduced by the use of plastic packaging with passive or active modification of the internal atmosphere (Arruda et al., 2011b). PVC film is practical and inexpensive, and has been widely used in the storage of fruits and vegetables, especially when associated with a refrigerated environment (Cia et al., 2010).

Carnauba wax, made from the fruit of a Brazilian palm, has been used as a coating on fruits and vegetables, conferring brightness and avoiding losses through transpiration. It is atoxic and can be consumed on unpeeled fruits, also, is easily removed with water (Hagenmaier & Baker, 1994). In different reports, Mota et al. (2003) and Mota et al. (2006) showed that the use

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of carnauba wax significantly reduced the loss of fresh mass and wilting in passion fruit (*Passiflora edulis*) stored at room temperature and relative humidity. Blum et al. (2008) reported that immersion of persimmon fruits (*Diospyrus kaki*) in a solution with 12.5% carnauba wax was efficient in maintaining ascorbic acid levels and tissue firmness, allowing storage for up to 49 days. Silva et al. (1999) found that fruits of *P. alata* immersed in carnauba wax, and maintained at a temperature of 9 °C and relative humidity between 85% and 90%, also had lower loss of fresh mass and less wilting when compared to the untreated control. Junqueira et al. (2003), reported that fruits of *P. alata* stored in refrigerated environment (5 °C and 90% RH) had lower fresh mass loss and lower incidence of anthracnose, the most common post-harvest fungal disease on *P. alata*, when compared to fruits kept at room temperature (23 °C and 65% RH). However, no precise recommendation was made regarding storage duration, nor a comparison using different packaging materials, such as PVC plastic, was evaluated.

The objective of this study was to determine the post-harvest conservation of *P. alata* fruits using different packaging materials, such as PVC, HDPE and carnauba wax, and storage conditions (ambient and refrigerated) for 14 days.

2 Material and methods

Passiflora alata fruits (Cultivar BRS Mel do Cerrado) used on the experiments came from the experimental fields of Embrapa Cerrados (Planaltina, DF, Brazil). The fruits were harvested with 20% of their surface colored yellow. Harvesting was done manually in the early hours of the day in order to avoid field heat. The fruits were washed in running water with subsequent drying on paper towels. According to Rinaldi et al. (2017c) the sanitization of *P*. alata fruits is not recommended, as the use of sanitizers increases water loss, and fungal and bacterial infestation, reducing their shelf life. Afterwards, the fruits were submitted to the following treatments: (i) Manual coating with 18% carnauba wax, provided by Aruá - a postharvest technology company (São Paulo - SP); (ii) Packaging in 18cm x 23cm trays of expanded polystyrene (styrofoam), and rapped with 10 µm thick PVC film; (iii) Packaging in 19cm x 29cm plastic containers of high density polyethylene (HDPE) with a 30 µm thickness, and: (iv) Fruits washed in running water with subsequent drying on paper towels (control).

All treatments were stored in cold rooms at 10 °C and 90% relative humidity and at 25 °C with 70% relative humidity, in order to simulate the ambient condition. The storage period was 14 days.

At the beginning of storage (day zero) and at seven and 14 days, pH, titratable acidity, soluble solids and Ratio analyses were performed according to Carvalho et al. (1990). Color (L^*, a^*, b^*) was determined by HunterLab brand MiniScan® EZ spectrophotometer, with five readings per fruit. The value of L^* defines the luminosity (L^*= 0 black and L^*= 100 white) and a^* and b^* are responsible for chromaticity (+ a^* red and - a^* green), b^* (+ b^* yellow and -b^* blue). Using the module L^*, a^* and b^* we are able to calculate the increase in fruit surface darkening (browning) ($[(L^* - L^*0)^2 + (a^* - a^*0)^2 + (b^* - b^*0)^2]^{1/2}$) and hue angle (color angle, 0º red, 90º yellow, 180º green, 270º blue and 360º black). The hue angle was calculated using the formula: [tangent arc (b^*/a^*)] for the a^* positive and [tangent arc (b^*/a^*) (-1) + 90] for the a^* negative, as recommended by HunterLab (2008). For the analysis of texture it was used the Brookfield texture Analyzer, model CT3 4500. The analysis consisted of the perforation resistance test (normal test), with the standards for Trigger (strength) set at 10 g. Deformation set at 10 mm and Speed set at 10 mm/s, using the TA 17 tip with a 30 mm D cone, 45°. The results were presented in Newton (N). Fresh weight loss was also assessed by calculating the difference in weight between the initial fruit mass and the mass at the moment of the evaluation. Also, O_2 and CO_2 concentration was measured inside the packages using CheckPoint II equipment developed by PBI-Dansensor America Inc. Gas concentration measurements were performed directly inside the packages by introducing the equipment´s needle through a silicone septum adapted to the packages containing the fruits (Rinaldi et al., 2009).

The experimental design was completely randomized, in a 4 x 3 x 2 factorial scheme, with four types of packages (no packaging, PVC 10µm, 30 µm HDPE, 18% wax), three periods of analysis (zero, seven and 14 days) and two storage conditions (ambient condition and 10 °C). Three replicates were used for each treatment, and each replicate consisted of three fruits of *P. alata*. We were only able to fit three fruits per package due to their size. *P. alata* fruits presented the following characteristics: average weight of 192.54 g, height of 96.20 mm and diameter of 71.36 mm. In general, the weight of *P. alata* fruits varied from 120 to 300 grams. The amount of fruits and pulp volume used for the analyzes were statistically significant. For the color analysis, three fruits were used per treatment and five readings per fruit were performed on each test date, always in the same batch of fruits from the beginning to the end of storage. The data were submitted to analysis of variance using the F test and the means compared using Tukey´s test at 5% probability of error. All statistical analyzes were performed using the software Assistat version 7.7 (Silva, 2015).

In the phytosanitary evaluation, the fruits were separated and packed, following the same design, the same treatments and storage conditions already mentioned. Evaluations of fungal incidence occurred on the first day of storage at seven and 14 days after the start of the experiment. At the end, the average incidence of fungi per replicate/per treatment/per evaluation was calculated. Statistical analysis was performed using the Tukey test ($p < 0.05$) with the aid of the software Assistat version 7.7 (Silva, 2015).

3 Results and discussion

The storage conditions and the use of packaging and wax provided significant changes in the physiological variables, which directly influenced the post-harvest shelf life of *P. alata* fruits. The same occurred in the reports of Junqueira et al. (2003) and Silva et al. (1999).

The values of pH, which ranged from 3.34 to 4.17, increased in all treatments under ambient condition after 14 days of storage. The carnauba wax treatment finished the experiment with a pH of 4.17. The other treatments, in spite of the significant increase in pH, remained below 3.9, which follows the Identity and Quality Standards (PIQ) for passion fruit pulp (*Passiflora* spp.) of the Ministry of Agriculture (Brasil, 2000) (Table 1).

The increase in pH values during the storage of vegetable products is related to the reduction in the acidity levels, which normally occurs, since the acids present in the fruit can be used in the metabolic processes taking place after harvest (Rinaldi et al., 2017a).

In fruits kept under refrigeration at 10 °C, there was no significant variation in pH over the 14 days, regardless of the treatment, and values remained between 3.34 and 3.59, therefore within the standards indicated by the PIQ (*Passiflora* spp.) (Brasil, 2000) (Table 1). Silva et al. (1999), also reported similar results after 14 days of refrigerated storage. The results of both experiments demonstrate the efficiency of this type of storage in maintaining the pH of *P. alata* fruits.

The titratable acidity values were between 1.03 and 1.78 g of anhydrous citric acid/100 mL (Table 1), showing no significant variation between the treatments maintained at the same temperature. The fruits stored at 10 °C showed the highest titratable acidity levels, which was already expected and could be explained by the greater conservation of the initial characteristics of the fruits when kept under refrigeration. Rinaldi et al. (2017b) also observed higher values of acidity in *P. setacea* fruits kept under refrigeration when compared to those maintained under ambient conditions. Acidity reduction is higher in fruits kept at higher temperatures due to higher metabolic activity (Arruda et al., 2011a).

The loss of organic acids occurs with the metabolic processes of fruit maturation and senescence, as a result of its use as a substrate in the respiratory process or due to the conversion of organic acids to sugars (Moreno et al., 2016). Although not

Table 1. Evaluation of the pH, titratable acidity and soluble solids in *P. alata* fruit during storage under two different environmental conditions.

pH			
Ambient storage			
Treatments	Storage time (days)		
	0	7	14
Without packging	3.34 aB	3.49 aB	3.83 bA
PVC 10µm	3.34 aB	3.54 aA	3.71 bA
HDPE 30µm	3.34 aC	3.62 aB	3.84 bA
Carnauba wax 18%	3.34 aB	3.51 aB	4.17 aA
Refrigerated storage (10 °C)			
Without packging	3.34 aA	3.48 aA	3.48 aA
PVC 10µm	3.34 aA	3.45 aA	3.53 aA
HDPE 30µm	3.34 aA	3.50 aA	3.59 aA
Carnauba wax 18%	3.34 aA	3.40 aA	3.45 aA
Titratable acidity (g of citric acid/100ml)			
Ambient storage			
	0	7	14
Without packging	1.60 aA	1.60 aA	1.47 aA
PVC 10µm	1.60 aA	1.30 aA	1.35 aA
HDPE 30µm	1.60 aA	1.29 aA	1.37 aA
Carnauba wax 18%	1.60 aA	1.37 aA	1.03 aA
Refrigerated storage (10 °C)			
Without packging	1.60 aA	1.54 aA	1.76 aA
PVC 10µm	1.60 aA	1.63 aA	1.72 aA
HDPE 30µm	1.60 aA	1.65 aA	1.57 aA
Carnauba wax 18%	1.60 aA	1.78 aA	1.67 aA
Soluble solids (°Brix)			
Ambient storage			
	0	7	14
Without packging	18.57 aA	17.13 aA	15.73 aA
PVC 10µm	18.57 aA	18.00 aA	16.80 aA
HDPE 30µm	18.57 aA	16.63 aA	13.27 aB
Carnauba wax 18%	18.57 aA	16.03 aAB	14.57 aB
Refrigerated storage (10 °C)			
Without packging	18.57 aA	18.37 aA	17.17 aA
PVC 10µm	18.57 aA	18.23 aA	17.50 aA
HDPE 30µm	18.57 aA	16.30 aA	16.53 aA
Carnauba wax 18%	18.57 aA	18.03 aA	17.53 aA

Same lowercase letters in the column do not differ significantly at the 5% level in Tukey's test. Same capital letters, on the line, do not differ significantly at the 5% level in Tukey's test.

statistically significant, oscillation occurred in titratable acidity values in fruits kept under refrigeration, which may be related to the intrinsic characteristics of the sample and to other factors still unknown for this species. Alves et al. (2012) also observed variation (0.55% to 1.82% citric acid) in sweet passion fruit fruits produced in Viçosa - MG.

Yellow passion fruit (*P. edulis*) usually has high acidity levels, due to the fact that its fruits are rich in organic acids. Of the non-volatile acids present in yellow passion fruit juice, citric acid is predominant (83%), followed by malic (16%), lactic, malonic, succinic and ascorbic acid (Freitas, 2007). The chemical composition of passion fruit may vary due to a number of factors, including species, harvest time, fruit size, maturation stage, development stage, soil fertility, post-harvest handling and others (Garcia, 1980). In *P. alata* fruits, the minimum acidity limit (2.5 g 100 g^{-1}) allowed by Brazilian legislation for passion fruit juices, generally, was not observed, which was already expected since this species presents fruits with less acidity and more sugar content in their composition (Vasconcellos et al., 2001; Brasil, 2000).

The values of soluble solids ranged from 18.57 °Brix to 13.27 °Brix, and the fruits stored at 10 °C did not present significant variation, unlike the 30 μm HDPE and 18% carnauba wax treatments kept at room temperature, which presented soluble solid values statistically lower than the other treatments after 14 days of storage (Table 1). Rinaldi et al. (2017b), reported a significant decrease in soluble solids contents in setacea passion fruit during storage, both refrigerated and at room temperature. However, Arruda et al. (2011a) found that the soluble solids content of yellow passion fruit (*P. edulis*) fruits was not influenced by the time and type of storage, remaining stable throughout the experiment. However, Silva et al. (1999) reported that soluble solid contents in fruits of *P. alata* kept at 9 °C increased during the storage period, contrary to what occurred in the present report. Thus, it is possible to observe a great variation of results according to the species studied. Nevertheless, in the present study, the values of all treatments are, generally, above the minimum level required by the Ministry of Agriculture (11 °Brix) for fresh passion fruit juice (Brasil, 2000). The food industry uses soluble solids content as an indicator of fruit quality, with preference for fruits with contents above 13 °Brix (Bruckner et al., 2002). Therefore, all treatments here applied maintained the required standard at the end of the 14 days of storage.

The ratio SS/AT (Ratio) is an organoleptic evaluation, which represents the balance between these two variables and has a direct correlation to flavor and aroma. Generally, fruits with higher Ratio values present mild taste and better sensorial acceptance, being preferred by consumers (Barankevicz et al., 2015). The Ratio values for the present trial remained between 9.69 and 14.35, when stored at room temperature at 25 °C, and between 9.78 and 11.98, under refrigeration at 10 °C (Table 2). The lowest Ratio value was at 14 days in the 30μm HDPE treatment, and the highest value was in the 18% carnauba wax treatment also at 14 days of storage, both at room temperature. Rinaldi et al. (2017b) reported a significant Ratio increase at the end of the storage period, at, both, room temperature and under refrigeration. In the present study, the only significant variation occurred in the fruits packed in 30μm HDPE maintained under ambient conditions (Table 2). Typicaly, the higher the Ratio, the more palatable will be the juice or the fruit pulp, since the soluble solids content is high and the acidity is low (Cavalcante et al., 2016).

A vegetable product fresh weight loss (FWL) is directly related to its storage condition. Fruits stored at 10 °C and 90% relative humidity had less than 10% weight loss in all treatments, especially the fruit packed in 30 μm HDPE and 10 μm PVC, which had a significantly better performance than the untreated control and the 18% carnauba wax treatment (Table 2). At 25 °C and 70% relative humidity the FWL at 14 days of storage was above 30% in the untreated control and in the 18% carnauba wax tratment (Table 2). In the treatments with 30 μm HDPE and 10 μm PVC, the percentage after 14 days was lower than 10%, that is, similar to the same treatments under refrigeration (Table 2). The use of plastic films and refrigeration significantly decrease FWL, as both reduce the respiration rate and minimize water loss (Fonseca et al., 2000; Chitarra & Chitarra, 2005). Diminishing weight loss and fruit wrinkling is of fundamental importance, since fresh passion fruit acceptance in the market is based on weight and appearance (Rotili et al., 2013a).

Texture influences post-harvest fruit handling, because it is directly related to firmness, resistance and integrity of the fruit tissues (Cenci, 2006). Firmness is reduced during maturation, which is attributed to changes in the pectin molecules (Canteri et al., 2012), catalyzed by the enzymes pectinmethylesterase and polygalacturonase (Pinheiro, 2008). In the present work, the fruit kept under ambient conditions had a significant reduction in texture after seven days of storage, and the 10 μm PVC treatment was the only one lacking significant loss between the seventh and fourteenth day of storage (Table 2). Also, the 10 μm PVC treatment was the only one in refrigerated storage that maintained statistically uniform texture values in the first seven days (Table 2). Although, the refrigerated environment was not effective in maintaining fruit resistance after 14 days of storage, since there was a statistically significant reduction of texture in all treatments (Table 2). This result agrees with Silva et al. (1999), who also showed significant texture loss in the refrigerated storage of *P. alata* fruits.

Color determination is a crucial quality trait in food and a main parameter to stimulate purchase, especially if the products are packaged (Aday et al., 2013). The increase on tissue browning (Table 3) is directly linked to the luminosity index. Both variables are concomitant, that is, the lower the luminosity index, the higher are the levels of tissue browning on the fruit (Rinaldi et al., 2017a). The values at room temperature ranged from zero to 36.39 (Table 3). The refrigerated fruit also presented variation regarding their coloration, but this occurred in a smaller scale, and could be explained due to the decrease on metabolic activity caused by the lower temperatures (Table 3) (Fonseca et al., 2000). The untreated control and fruits coated with 18% carnauba wax had the highest browning indexes at room temperature (Table 3).

Passiflora alata has a yellowish color when harvested at its ideal maturation point. The hue angle is expressed in degrees, in which 90° corresponds to the color yellow (Tibola et al.,

Table 2. Evaluation of the Ratio, fresh weight loss and texture in *P. alata* fruit during storage under two different environmental conditions.

Treatments	Storage time (days)		
Ratio			
Ambient storage			
	0	7	14
Without packging	11.61 aA	11.01 aA	10.72 bA
PVC 10µm	11.61 aA	13.87 aA	12.50 abA
HDPE 30µm	11.61 aAB	13.22 aA	9.69 bB
Carnauba wax 18%	11.61 aA	11.99 aA	14.35 aA
Refrigerated storage (10 °C)			
Without packging	11.61 aA	11.98 aA	9.78 aA
PVC 10µm	11.61 aA	11.19 aA	10.20 aA
HDPE 30µm	11.61 aA	10.03 aA	10.58 aA
Carnauba wax 18%	11.61 aA	10.37 aA	10.53 aA
Fresh weight loss (%)			
Ambient storage			
	0	7	14
Without packging	0.00 aC	12.03 aB	33.17 aA
PVC 10µm	0.00 aB	4.23 bAB	8.53 bA
HDPE 30µm	0.00 aA	0.85 bA	2.16 bA
Carnauba wax 18%	0.00 aC	12.60 aB	36.03 aA
Refrigerated storage (10 °C)			
Without packging	0.00 aC	4.58 aB	8.58 aA
PVC 10µm	0.00 aC	1.38 bB	2.73 bA
HDPE 30µm	0.00 aA	0.18 cA	0.41 cA
Carnauba wax 18%	0.00 aC	3.92 aB	7.64 aA
Texture (N)			
Ambient storage			
	0	7	14
Without packging	20.34 aA	9.43 bB	3.09 bC
PVC 10µm	20.34 aA	10.65 abB	9.92 aB
HDPE 30µm	20.34 aA	12.96 abB	2.09 bC
Carnauba wax 18%	20.34 aA	14.56 aB	3.25 bC
Refrigerated storage (10 °C)			
Without packging	20.34 aA	11.44 aB	10.42 aB
PVC 10µm	20.34 aA	18.76 aA	14.35 aB
HDPE 30µm	20.34 aA	17.19 aB	11.94 aC
Carnauba wax 18%	20.34 aA	17.80 aB	12.57 aC

Same lowercase letters in the column do not differ significantly at the 5% level in Tukey's test. Same capital letters, on the line, do not differ significantly at the 5% level in Tukey's test.

2005). In the present study, the highest observed value was 74.36^0 shortly after harvest (zero storage days) (Table 3). During the storage period, the hue angle did not present estatistically significant variations among the different treatments in both environments (Table 3). These results do not comply with the report by Rinaldi et al. (2017b), which observed a significant reduction on hue angle values in *P. setacea* fruit stored at ambient conditions (25 °C). The hue angle values obtained in the present experiment suggest that *P. alata* fruit presented a reddish yellow color during storage.

Oxygen and carbon dioxide concentrations inside the 10 µm PVC and 30 µm HDPE packages provide information on the gas exchange between the fruit and the environment around them. If fruits are submitted to conditions of low O_2 concentration and high concentrations of CO_2, this can result in fruit tissue stress, which may manifest itself through different symptoms, such as irregular maturation, physiological disorders, fermentation and rotting (Kader et al., 1989).

Cia et al. (2010), observed very small changes in the atmosphere (O_2 and CO_2) of PVC packaging during refrigerated storage of grapes, and its non-interference with the metabolism of the fruit, when compared to other plastic films, such as polyethylene. Unlike the report by Cia et al. (2010) in the present study, the concentrations of O_2 and CO_2 varied significantly in both cases over the entire storage period under both refrigerated and ambient conditions (Table 4). This variation did not have deleterious action on the fruits, it showed that both packages were permeable to these gases, which allowed gas exchanges with the environment, avoiding the occurrence of physiological imbalances that could have a negative effect on the quality of the fruits during the 14 days of storage (Oliveira et al., 2014; Rinaldi et al., 2017b).

Table 3. Evaluation of the fruit browning and hue angle in *P. alata* fruit under two different storage conditions.

Treatments	Storage time (days)		
Browning			
Ambient storage			
	0	7	14
Without packging	0.00 aC	25.38 aB	36.39 aA
PVC 10µm	0.00 aB	18.97 bA	23.60 bA
HDPE 30µm	0.00 aC	21.64 abB	28.98 bA
Carnauba wax 18%	0.00 aC	23.05 abB	36.12 aA
Refrigerated storage (10 °C)			
Without packging	0.00 aC	15.52 bB	22.11 aA
PVC 10µm	0.00 aB	18.14 abA	22.34 aA
HDPE 30µm	0.00 aC	15.14 bB	28.10 aA
Carnauba wax 18%	0.00 aB	21.86 aA	24.07 aA
Hue angle (°h)			
Ambient storage			
	0	7	14
Without packging	74.63 aA	59.36 aB	55.43 aB
PVC 10µm	74.63 aA	65.40 aB	62.95 aB
HDPE 30µm	74.63 aA	65.71 aB	60.68 aB
Carnauba wax 18%	74.63 aA	63.16 aB	59.82 aB
Refrigerated storage (10 °C)			
Without packging	74.63 aA	67.52 aB	63.52 aA
PVC 10µm	74.63 aA	70.08 aA	68.33 aA
HDPE 30µm	74.63 aA	71.32 aA	61.75 aB
Carnauba wax 18%	74.63 aA	68.23 aB	65.91 aB

Same lowercase letters in the column do not differ significantly at the 5% level in Tukey's test. Same capital letters, on the line, do not differ significantly at the 5% level in Tukey's test.

Table 4. Evaluation of the oxigen and carbon dioxide percentage inside packaged treatments and anthracnose incidence on *P. alata* fruit during storage under two different environmental conditions.

Treatments	Storage time (days)		
Oxigen (O_2%)			
Ambient storage			
	0	7	14
PVC 10µm	21.00 aA	5.40 bC	10.73 aB
HDPE 30µm	21.00 aA	11.03 aB	8.17 bB
Refrigerated storage (10 °C)			
PVC 10µm	21.00 aA	13.37 aB	13.57 bB
HDPE 30µm	21.00 aA	9.73 bB	18.33 aA
Carbon dioxide (CO_2%)			
Ambient storage			
	0	7	14
PVC 10µm	0.03 aC	6.87 aA	4.87 bB
HDPE 30µm	0.03 aC	6.60 aB	8.97 aA
Refrigerated storage (10 °C)			
PVC 10µm	0.03 aB	3.03 bA	3.87 aA
HDPE 30µm	0.03 aC	6.03 aA	2.17 bB
Anthracnose incidence (%)*			
Ambient storage			
	0	7	14
Without packging	0.00 aA	0.00 aA	11.00 aA
PVC 10µm	0.00 aA	33.00 cB	66.00 cC
HDPE 30µm	0.00 aA	33.00 cB	66.00 cC
Carnauba wax 18%	0.00 aA	11.00 bAB	33.00 bB

Same lowercase letters in the column do not differ significantly at the 5% level in Tukey's test. Same capital letters, on the line, do not differ significantly at the 5% level in Tukey's test.
* There was no fungal infestation on refrigerated fruit.

As for the phytosanitary evaluation, fruits kept at 10 °C did not show symptoms of infestation by any post-harvest pathogens during the 14 days of storage (Benato et al., 2002; Junqueira et al., 2003; Muniz et al., 2003; Arruda et al., 2011a). The result confirms the reports of Junqueira et al. (2003), Arruda et al. (2011a), Rotili et al. (2013a), Rotili et al. (2013b) and Rinaldi et al. (2017b) who also reported a significant reduction in the incidence of post-harvest pathogens in sweet, yellow, and setacea passion fruit stored under refrigeration, regardless of whether they were wrapped in plastic films or not.

The most common fungal disease in post-harvest passion fruit is anthracnose, caused by *Colletototricum* spp. (Silva & Durigan, 2000). In the treatments kept at room temperature, it was verified that the fruit without packaging presented the lowest percentage of anthracnose incidence, 11%, with carnauba wax having the second best performance, with 33% (Table 4). The fruit packed in 10 μm PVC and 30 μm HDPE showed the highest incidences of anthracnose, concluding that the use of plastic packaging at ambient conditions favors the proliferation of fungal pathogens. Rinaldi et al. (2017b) and Barros et al. (1994) reported similar results, stating that plastic packaging, at room temperature, increased moisture around the fruit, favoring the development of post-harvest diseases.

4 Conclusion

It is not recommended to keep *P. alata* fruit under ambient condition, but, if it is the option available, they should not be packaged and have a short shelf life, as there are significant losses of fresh weight and texture after seven days. For the refrigerated condition, at 10 °C, the 10 μm PVC packaging is recommended, as it showed low fresh weight loss and no fungal infestation, after 14 days of storage, and better texture preservation, after 7 days of storage.

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