DOI: 10.5965/223811712212023037

*Revista de Ciências Agroveterinárias 22 (1): 2023*
*Universidade do Estado de Santa Catarina*

# Different storage conditions and 1-methylcyclopropyl in pitaya post-harvest conservation

*Diferentes condições de armazenamento e 1-metilciclopropeno na conservação pós-colheita de pitaia*

**Raquel Carlos Fernandes*[1] (ORCID 0000-0002-0973-3871), Jéssica Mayumi Anami[1] (ORCID 0000-0002-2177-7519), Bruno Pansera Espíndola[2] (ORCID 0000-0002-0789-5199), Marcos André Nohatto[2] (ORCID 0000-0002-0820-330X), Cristiano André Steffens[1] (ORCID 0000-0003-0936-8656)**

[1]Universidade do Estado de Santa Catarina, Lages, SC, Brasil. * Author for correspondence: raaquel-carlos@hotmail.com
[2]Instituto Federal Catarinense,Santa Rosa do Sul, SC, Brasil.

*Submission: 25/07/2022 | Acceptance: 16/09/2022*

**ABSTRACT**

Fast perishability of dragon fruit requires that strategies be adopted to extend its post-harvest shelf life, in order to reduce losses, maintain quality and increase the financial return of economic activity. The objective of this work was to evaluate the effect of storage conditions in combination with the application of 1-methylcyclopropene (1-MCP) on the quality maintenance of red dragon fruit. The treatments evaluated were cold storage (CS; 21 kPa $O_2$ + 0.03 kPa $CO_2$), controlled atmosphere (CA; 2 kPa $O_2$ + 5 kPa $CO_2$) and modified atmosphere (MA; 40 µm thick low-density polyethylene bags) combined or not with the application of 1-MCP (300 nL.L$^{-1}$), with four replications per treatment. The fruits of all treatments were stored for 20 days at 13 ± 2°C and relative humidity (RH) of 90 ± 5%, followed by 3 days of exposure at ambient conditions (20 ± 3°C and RH of 70 ± 5%). After the shelf life, CA and MA maintained fruits with a higher hue angle. The treatment of 1-MPC added to CA and MA provided greater force for pulp penetration. CS, AC and MA, added to the treatment with 1-MCP, are promising technologies to be used in the storage of dragon fruit.

**KEYWORDS:** *Hylocereus undatus;* dragon fruit; post-harvest; storage; controlled atmosphere; modified atmosphere.

**RESUMO**

A rápida perecibilidade dos frutos de pitaia exige que sejam adotadas estratégias para prolongar sua vida útil em pós-colheita, a fim de reduzir perdas, manter a qualidade e aumentar o retorno financeiro da atividade econômica. O objetivo deste trabalho foi avaliar o efeito de condições de armazenamento em combinação com a aplicação de 1-metilciclopropeno (1-MCP) sobre a manutenção da qualidade de pitaia vermelha. Os tratamentos avaliados foram armazenamento refrigerado (AR; 21 kPa $O_2$ + 0,03 kPa $CO_2$), atmosfera controlada (AC; 2 kPa $O_2$ + 5 kPa $CO_2$) e atmosfera modificada (AM; bolsas de polietileno de baixa densidade de 40 µm de espessura) combinados ou não com a aplicação de 1-MCP (300 nL.L$^{-1}$), com quatro repetições por tratamento. Os frutos de todos os tratamentos foram armazenados durante 20 dias a 13 ± 2°C e umidade relativa (UR) de 90 ± 5% seguidos de 3 dias de exposição em condições ambiente (20 ± 3°C e UR de 70 ± 5%). Após o período de prateleira, AC e AM mantiveram frutos com maior ângulo hue. O tratamento de 1-MPC somado a AC e AM proporcionou maior força para penetração da polpa. O AR, a AC e a AM, somadas ao tratamento com 1-MCP, são promissoras tecnologias a serem empregadas no armazenamento de pitaia.

**PALAVRAS-CHAVE:** *Hylocereus undatus*; fruta-do-dragão; pós-colheita, armazenamento; atmosfera controlada; atmosfera modificada.

## INTRODUCTION

The consumption of pitayas [*Hylocereus undatus* (Haw.) Britton and Rose] has increased worldwide due to its attractive appearance, nutritional value and antioxidant potential (HARDESTY 2015). This fruit has a pulp that corresponds to up to 80% of its size, and can be consumed *in natura* or processed (LIMA et al. 2014). There are several varieties of pitaya cultivated and marketed that are easily differentiated by the color of the pulp (OBENLAND et al. 2016), and may be red or white, or by the color of the bark, which can be pink or yellow (NUNES et al. 2014).

After harvest, pitaya presents a very reduced shelf life, and exposure to high temperatures during transport and storage can accelerate the senescence process, resulting in fruits with undesirable characteristics, such as deterioration of the pulp and loss of bracts color (CHAEMSANIT et al. 2018). Fruits stored at 23 °C ± 2 showed greater change in peel color when compared to those stored at 16 and 6°C, possibly due to chlorophyll degradation and betacyanin accumulation, as well as lower pulp firmness, due to the effect of temperature promoting on pectolytic activity (PUNITHA et al. 2010). In addition to the reduction of storage temperature, it is possible that the use of complementary technologies to refrigeration, such as modified atmosphere (AM), controlled atmosphere (CA) and 1-methylcyclopropene (1-MCP) enable the maintenance of the postharvest quality of fruits.

AM consists of the use of plastic packaging that causes the reduction of $O_2$ and $co_{2\ accumulation}$, due to fruit respiration and the barrier properties of the plastic film used. The use of AM is widespread in pitaya storage and brings as main advantages the prolongation of the post-harvest period and reduction of dehydration (GARCIA & ROBAYO 2008). According to FREITAS & MITCHAM (2013), the use of perforated plastic packaging has benefits in maintaining the quality of pitaya, avoiding the loss of fruit mass.

CA is used in various vegetables and consists of reducing $O_2$ and/or increasing $CO_{2\ levels}$ in storage, reducing fruit metabolic activity and optimizing postharvest life. Unlike AM, in CA the atmospheric conditions are pre-established and maintained uniformly throughout storage. The effect of the composition of the atmosphere in pitaya was investigated by HO et al. (2020), evaluating the respiratory rate of the fruits and demonstrating that $O_2$ and its concentration affects fermentation and oxidative respiration, and that $CO_2$ has a non-competitive inhibition in oxidative respiration. CA, when used with inadequate partial pressures of $O_2$ and $CO_2$, can cause fermentation of stored fruits if the concentration of $O_{2\ is}$ very low and $CO_{2\ is\ very}$ high (THOMPSON et al. 2018), negatively affecting the sensory quality of the fruits.

1-MCP, a potent inhibitor of ethylene action, can delay ripening and maintain the quality of climacteric fruits, such as pears, during storage (LWIN et al. 2021), in addition to reducing the respiratory rate and ethylene production (AMORNPUTTI et al. 2016). Although pitaya is considered a non-climacteric fruit (NERD et al. 1999, CHIEN et al. 2007), the effect of 1-MCP on the reduction in respiratory rate in yellow pitaya has already been reported (DEAQUIZ et al. 2014). Additionally, LIU et al. (2019) found lower mass loss and higher content of soluble solids in pitaya treated with 1-MCP, in relation to untreated fruits, from 24 days of refrigerated storage.

Although the effects of AM, AC and 1-MCP on pitaya quality are reported in the literature (VERA et al. 2017, BA et al. 2019, HO et al. 2021), there is no information on the combined use of AM or CA with application of 1-MCP. It is possible that CA and AM with 1-MCP allow to extend the storage period while maintaining quality.

The objective of this work was to evaluate the effect of storage conditions (refrigerated, controlled and modified atmospheres) in combination with the application of 1-methylcyclopropene (1-MCP) on the maintenance of red pitaya quality.

## MATERIAL AND METHODS

The fruits were harvested in the 2017/2018 crop, 45 days after full flowering, at a commercial maturation point, in a commercial orchard in the municipality of Santa Rosa do Sul, SC (29° 8' 15'' S, 49° 42' 45'' O) and sent to the laboratory for analysis of the initial characterization of the fruits (after harvest), homogenization of samples and application of treatments. The treatments evaluated consisted of factorial 3 [refrigerated storage (21 kPa of $O_2$ + 0.03 kPa $CO_2$), controlled atmosphere (2 kPa $O_2$ + 5 kPa $CO_2$) and passive modified atmosphere)] x 2 (with and without 1-MCP). The experimental design used was completely randomized with four replicates of five fruits.

For the application of 1-MCP, the fruits were exposed to volatilization of the product (300 nL.L-1) for 24 h at 20°C, in an airtight microchamber with a volume of 0.5 $m^3$. This dose has been evaluated in previous studies (BATISTA et al. 2009, TRINDADE et al. 2015). Subsequently, the fruits treated and not treated with 1-MCP were stored under storage conditions, as established by the treatments.

For the AM treatment, low density polyethylene (LDPE) packages were used, with a thickness of 40 µm, with eight perforations per$^{m2}$, with a diameter of 2 mm.

For CA, the fruits were packed in airtight AC microchambers, with a volume of 0.5 $m^3$. The installation of the atmosphere was performed with the injection of gaseous nitrogen from high pressure cylinders to remove $O_2$ from the inside of the microchamber until the partial pressure of 2 kPa. Then, CO2 gas was injected, from high pressure cylinders, up to the partial pressure of 5 kPa. During the installation of the atmosphere the partial pressures of $O_2$ and $CO_2$ were monitored with an electronic gas analyzer $O_2$ and $CO_2$ (Schelle, Germany). The partial gas pressures were monitored daily during storage with the same analyzer used for the installation of the atmosphere, and correction d and $O_2$ and $CO_2$ were performed when necessary.

The fruits were stored for 20 days at 13 ± 1 °C and relative humidity (RH) of 90 ± 5%. After this period they remained for another 3 days at 20 ± 3°C and RH of 70 ± 5%, to simulate shelf time, and evaluated for the color of the epidermis; forces for rupture of the epidermis and penetration of the pulp; soluble solids (SS) and titratable acidity (TA).

For the evaluation of epidermis color, we used the dimensions of luminosity (L) and *hue* angle (h°) of the reddest part (four readings per fruit), and of the residual bracts (greener region, one reading per bracts), with the aid of a colorimeter (CR 400, Konica Minolta®, Osaka, Japan). L values indicate the brightness of the epidermis, and h° values indicate the basic staining.

The rupture force of the epidermis and the resistance of the penetrating pulp (N) were obtained with the electronic texturometer (Stanley Micro System, TAXT-Plus®, Surrey, United Kingdom), equipped with a stainless steel probe of 2 mm in diameter, with a speed during the test of 1 mm.s-1 and distance of 10 mm, on two opposite sides of the fruits.

For titratable acidity (meq.100mL-1), from two transverse wedges of each fruit processed in an electric centrifuge, 10 mL was collected, which were diluted in 90 mL of distilled water. The solution used to determine acidity was NaOH (0.1N) until reaching a final pH of 8.2 by means of an automatic titrator (Schott Instruments, TitroLine® Easy, Mainz, Germany). The soluble solids (°Brix) values were obtained by digital refractometer (Atago®, PR201α, Tokyo, Japan), with sampling of fruit juice obtained in the same way as acidity analysis.

The data were submitted to variance analysis by the F test, and when significance was found, they were analyzed by the Tukey mean comparison test ($p<0.05$) with the aid of the Sisvar software (FERREIRA 2014)

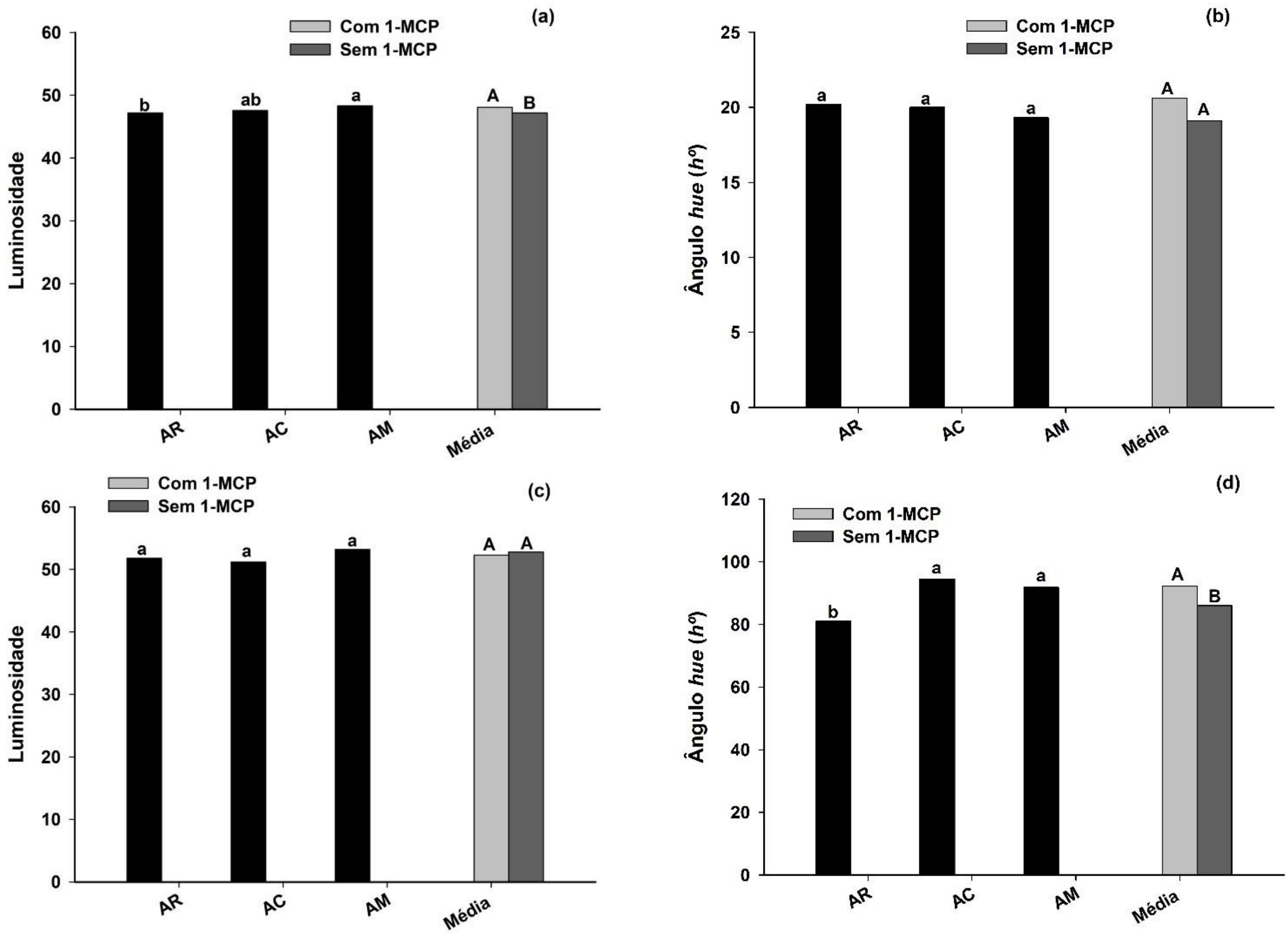
**RESULTS AND DISCUSSION**

At harvest, the fruits presented L* of 47.0 and h° of 18.0 in the reddest part of the epidermis. In bract L* of 52.0 and h° of 102.0, SST of 18.0 °Brix and AT of 9.0 meq 100 mL-1. After storage followed by three days of shelf, in the part of the epidermis covered with red color, the fruits of THE presented lower Value of L* than the fruits stored in AM. The fruits stored in CA presented intermediate results (Figure 1a). However, there was no difference between the storage conditions for h° (Figure 1b). Regarding the effect of 1-MCP on epidermis staining, there was no difference between treated and untreated fruits for h°, but it was observed that the untreated fruits, regardless of storage condition, presented lower L* value (Figure 1a and 1b). These results show that among the storage conditions, the fruits stored in AR showed lower brightness in the reddest region of the epidermis. This lower brightness was also observed in fruits not treated with 1-MCP.

For the color of the bracts, there was no effect of the treatments evaluated on the attribute L* (Figure 1c). Both CA and AM kept the fruits with higher values of h° than the AR (Figure 1d). HO et al. (2021) also observed better maintenance of h° in pitaya peel stored for 50 days in AC (2 kPa $O_2$ + 5 kPa $CO_2$) when compared to other partial pressures of $O_2$ and $CO_2$ and refrigerated storage. According to THOMPSON et al. (2018), $CO_2$ has as one of the postharvest effects in CA inhibiting the effect of ethylene on fruits in general, and consequently reducing chlorophyll degradation. Am probably also caused a higher concentration of $CO_2$ n inside the package (both higher than AR), providing the same effect observed in CA. According to YANG et al. 2020, high concentrations of $CO_2$ attenuate oxidative stress and delay fruit senescence.

1-MCP, regardless of storage condition, also provided fruits with higher h° values in the bracts (Figure 1d). These results indicate that CA and AM, as well as the application of 1-MCP, provided fruits with greener bracts. The maintenance of the coloration of the bracts makes the product more attractive, as they transmit the appearance of a fresher and/or better preserved fruit. Such characteristics are sought by the consumer at the time of purchase. The effect of 1-MCP on maintaining greater brightness of the epidermis and green color of the bracts is due to the fact that this compound inhibits the action of ethylene by permanently binding to the binding site of this hormone, preventing the natural hormone itself from triggering the maturation process (DE MARTINO et al. 2006).

By preventing the action of ethylene, a slower degradation of chlorophyll of the bracts occurred, keeping them greener. The retention of green color by the action of 1-MCP has already been observed in citrus species, fruits also considered non-climacteric (JOMORI et al. 2003, KLUGE et al. 2003).




Treatments with means not followed by the same uppercase letter (with or without 1-MCP treatment) and lowercase letter (conditions storage), differ from each other by Tukey's test at 5% error probability.

Figure 1. Lightness (L*) and hue angle (ºh) of the reddest portion of the epidermis (red color) (a; b) and of the bracts (c; d) of red pitayas stored for 20 days (13 ± 2°C/RH of 90 ± 5%), under different conditions [refrigerated storage (RS; 21 kPa $O_2$ + 0.03 kPa $CO_2$), controlled atmosphere (CA; 2 kPa $O_2$ + 5 kPa $CO_2$) and modified atmosphere (MA)] combined or not with the application of 1 -methylcyclopropene (1-MCP), followed by three days at ambient conditions (20 ± 3°C and RH of 70 ± 5%).

LI et al. (2016) concluded that one of the main effects of 1-MCP on non-climacteric fruits, such as pitaya, is inhibition of green color loss and color changes in general and suggest that its application at the commercial level should be considered due to the advantages it presents over the maintenance of this quality parameter. Explanations about the effect of 1-MCP on non-climacteric fruits are still scarce, although positive effects on fruits have been observed (LI et al. 2016). According to DU et al. (2021), the delay in chlorophyll degradation by 1-MCP may be related to the effect of the product on suppressing genes involved in this metabolic pathway, and not directly to the effect of ethylene.

There was no difference between the treatments evaluated for the rupture force of the epidermis (Table 1), corroborating the results found by HO et al. (2021), who stored pitayas at 6°C for 50 days under different CONDITIONS of CA. However, AM and CA, in relation to AR, provided greater force for pulp penetration (Table 1). The reduction of partial pressures of $O_2$ and increase of $CO_2$ in the TREATMENTS AC and AM kept the fruits firmer possibly due to the reduction of metabolism, with lower activity of hydrolytic enzymes of cell wall (GOULAO & OLIVEIRA 2008, PAYASI et al. 2009). In yellow pitayas, the use of AM with plastic packaging in a refrigerated environment (10°C) was effective in delaying the ripening of fruits (GARCIA & ROBAYO 2008), which differ from the results obtained by HO et al. (2021).

1-MCP, in relation to untreated fruits, regardless of storage condition, maintained greater strength for pulp penetration, but no differences were observed evaluating epidermis rupture. The greater firmness of red pitaya the ones treated with 1-MCP and maintained AR was also observed by LIU et al. (2019). Several authors have observed this behavior of 1-MCP, reducing metabolism and maintaining the quality of pears (EKMAN et al. 2004, TRINCHERO et al. 2004).

Table 1. Forces of epidermis rupture (N) and pulp penetration (N) of stored red pitayas (13 ± 2 °C/RH of 90 ± 5%) for 20 days, under different conditions [refrigerated storage (RS; 21 kPa $O_2$ + 0.03 kPa $CO_2$), controlled atmosphere (CA; 2 kPa $O_2$ + 5 kPa $CO_2$) and modified atmosphere (MA)] combined or not with the application of 1-methylcyclopropene (1-MCP), followed by three days at ambient conditions (20 ± 3 °C and RH of 70 ± 5%).

| | Rupture force of the epidermis (N) | | | Force for pulp penetration (N) | | |
|---|---|---|---|---|---|---|
| | With 1- MCP | Without 1- MCP | | With 1- MCP | Without 1- MCP | |
| AR | 10.0 | 10.1 | 10.0a | 0.890 | 0.834 | 0.864b |
| AC | 10.2 | 9.2 | 9.7a | 1.057 | 1.009 | 1.033a |
| AM | 9.6 | 9.8 | 9.7a | 1.024 | 1.039 | 1.032a |
| Mean | 9.9A | 9.7A | | 0,992A | 0.961B | |
| CV (%) | 4.1 | 7.2 | | 3.2 | 4.0 | |

Treatments with means not followed by the same letter, uppercase horizontally and lowercase vertically, differ from each other by Tukey's test at 5% error probability.

The storage in AM and CA, in relation to AR, provided lower ssT content (Table 2). However, HO et. al. (2021) did not observe any difference for SS between AR and CA, in pitaya stored for 50 days. It is possible that the difference in results between the results of the present study and those obtained by HO et al. (2021) is due to the storage time and/or genetic material used. The application of 1-MCP in relation to the untreated fruits, regardless of the storage condition, caused fruits with lower SST content (Table 2) and the treatments that provided lower SST content showed fruits with greater strength for pulp penetration, which indicates a slower ripening. JIANG et al. (2002), working with longan (*Dimocarpus longan* Lour.), associated the reduction in SS content with the lowest degradation of pectin, cellulose and other polysaccharides present in the cell wall of the fruits.

Table 2. Total soluble solids (ºBrix) and titratable acidity (meq of malic acid.100mL$^{-1}$) of stored red pitayas (13 ± 2 °C/RH of 90 ± 5 %) for 20 days, under different conditions [refrigerated storage (RS; 21 kPa $O_2$ + 0.03 kPa $CO_2$), controlled atmosphere (CA; 2 kPa $O_2$ + 5 kPa $CO_2$) and modified atmosphere (MA)] combined or not with the application of 1-methylcyclopropene (1-MCP), followed by three days at ambient conditions (20 ± 3 °C and RH of 70 ± 5%).

| | Soluble Solids (°Brix) | | | Titratable Acidity (malic acid meq.100mL$^{-1}$) | | |
|---|---|---|---|---|---|---|
| | With 1- MCP | Without 1- MCP | Mean | With 1- MCP | Without 1- MCP | Mean |
| AR | 13.2 | 14.0 | 13.6a | 4.9 | 5.0 | 5.0a |
| AC | 11.6 | 12.0 | 11.8b | 4.4 | 4.5 | 4.4b |
| AM | 11.5 | 12.4 | 11.9b | 4.9 | 5.1 | 5.0a |
| Mean | 12.1B | 12.8A | | 4.7A | 4.9A | |
| CV (%) | 5.1 | 2.9 | | 3.9 | 3.8 | |

Treatments with means not followed by the same letter, uppercase horizontally and lowercase vertically, differ from each other by Tukey's test at 5% error probability.

There was no effect of 1-MCP on TA, and among storage conditions, CA presented fruits with lower TA content (Table 2). These data differ from other studies, which state that fruits stored in CA may present higher acidity, probably explained by a reduction in acid consumption by decreasing krebs cycle activity (AMPOFO-ASIAMA et al. 2014, MBONG VICTOR et al. 2017) or generating acid when fruits are stored in high $CO_{2\ conditions}$ (GIRARD & LAU 1995). SMRKE et al. 2021 observed significantly higher levels of organic acids in blueberries stored under conditions of 5, 15 and 25% $CO_2$ compared to the normal atmosphere at 30 days of storage. The lower acidity of fruits stored in CA may be associated with a metabolic alteration, which possibly preferentially used organic acids as a substrate for cellular respiration (AMARANTE et al. 2013).

**CONCLUSION**

In general, the 1-MCP combined with AC and AR technologies resulted in pitayas best quality after storage. The combination of 1-MCP with AM and AC (2 kPa of $O_2$ + 5 kPa of $CO_2$) provided greater force of penetration of the pulp, but did not interfere in the rupture force of the epidermis. The application of 1-MCP did not influence the titratable acidity and decreased the total soluble solids. Among the storage conditions, AR resulted in higher content of total soluble solids, and AM and CA resulted in fruits with higher hue angle.

**REFERENCES**

AMARANTE CVT et al. 2013. Qualidade e potencial de conservação pós-colheita dos frutos em cultivares brasileiras de goiabeira-serrana. Revista Brasileira de Fruticultura 35: 990-999.

AMORNPUTTI S et al. 2016. 1-Methylcyclopropene (1-MCP) inhibits ethylene production of durian fruit which is correlated with a decrease in ACC oxidase activity in the peel. Postharvest Biology and Technology 114: 69-75.

AMPOFO-ASIAMA J et al. 2014. The metabolic response of cultured tomato cells to low oxygen stress. Plant Biology 16: 594-606.

BA L et al. 2019. Effect of modified atmosphere packaging on the storage quality of pitaya fruit. Food Research and Development 40: 32-37.

BATISTA PF et al. 2009. Associação de 1-MCP com ceras de carnaúba na conservação de goiabas 'Paluma'. Revista Brasileira de Ciências Agrárias 4: 22-26.

CHAEMSANIT S et al. 2018. Effect of peppermint oil on the shelf-life of dragon fruit during storage. Food Control 90: 172-179.

CHIEN PJ et al. 2007. Quality assessment of low molecular weight chitosan coating on sliced red pitayas. Journal of Food Engineering 79: 736-740.

DEAQUIZ YA et al. 2014. Ethylene and 1-MCP affect the postharvest behavior of yellow pitahaya fruits (*Selenicereus megalanthus* Haw.). Agronomía Colombiana 32: 44-51.

DE MARTINO G et al. 2006. 1-MCP controls ripening induced by impact injury on apricots by affecting SOD and POX activities. Postharvest Biology and Technology 39: 38-47.

DU Y et al. 2021. Synergistic inhibitory effect of 1-methylcyclopropene (1-MCP) and chlorine dioxide ($ClO_2$) treatment on chlorophyll degradation of green pepper fruit during storage. Postharvest Biology and Technology 171: 111363-111372.

EKMAN JH et al. 2004. Interactions between 1-MCP concentration, treatment interval and storage time for 'Bartlett' pears. Postharvest Biology and Technology 31: 127-136.

FERREIRA DF. 2014. SISVAR: sistema de análise de variância. Versão 5.3. Lavras: DEX.

FREITAS ST & MITCHAM EJ. 2013. Quality of pitaya fruit (*Hylocereus undatus*) as influenced by storage temperature and packaging. Scientia Agricola 70: 257-262.

GARCIA MC & ROBAYO P. 2008. Evaluation of the use of passive modified atmospheres and low temperatures on the conservation of yellow pitahaya. Corpoica–Ciencia 9: 30-39.

GIRARD B & LAU OL. 1995. Effect of maturity and storage on quality and volatile production of ''Jonagold'' apples. Food Research International 28: 465-471.

GOULAO LF & OLIVEIRA CM. 2008. Cell wall modifications during fruits ripening: when a fruit is not the fruit. Trends in Food Science & Technology 19: 4-25.

HARDESTY S. 2015. Pitahaya or Dragon Fruit—A New, Water Efficient Crop for Southern California Farmers. Disponível em: https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=18929. Acesso em: 19 mai. 2022.

HO PL et al. 2020. Modelling respiration rate of dragon fruit as a function of gas composition and temperature. Scientia Horticulturae 263: 109138-109148.

HO PL et al. 2021. Effect of controlled atmosphere storage on the quality attributes and volatile organic compounds profile of dragon fruit (*Hylocereus undatus*). Postharvest Biology and Technology 173: 111406-111418.

JIANG Y et al. 2002. Postharvest biology and handling of longan fruit (*Dimocarpus longan* Lour.). Postharvest Biology and Technology 26: 241-252.

JOMORI MLL et al. 2003. Cold storage of 'Tahiti'lime treated with 1-methylcyclopropene. Scientia Agricola 60: 785-788.

KLUGE RA et al. 2003. Intermittent warming in 'Tahiti'lime treated with an ethylene inhibitor. Postharvest Biology and Technology 29: 195-203.

LI L et al. 2016. Effects of the ethylene-action inhibitor 1-methylcyclopropene on postharvest quality of non-climacteric fruit crops. Postharvest Biology and Technology 111: 322-329.

LIMA CA et al. 2014. Avaliação de características físico-químicas de frutos de duas espécies de pitaya. Revista Ceres 61: 377-383.

LIU R et al. 2019. Synergistic effect of 1-methylcyclopropene and carvacrol on preservation of red pitaya (*Hylocereus polyrhizus*). Food Chemistry 283: 588-595.

LWIN HP et al. 2021. Metabolism and cold chain performance of 'Chuhwangbae' Asian pears as impacted by 1-MCP treatment. Scientia Horticulturae 288: 110357-110370.

MBONG VICTOR BM et al. 2017. Metabolic profiling reveals a coordinated response of isolated lamb's (*Valerianella locusta* L.) lettuce cells to sugar starvation and low oxygen stress. Postharvest Biology and Technology 126: 23-33.

NERD A et al. 1999. Ripening and postharvest behaviour of fruits of two Hylocereus species (Cactaceae). Postharvest Biology and Technology 17: 39-45.

NUNES EN. et al. 2014. Pitaia (*Hylocereus* sp.): Uma revisão para o Brasil. Gaia Scientia 8: 90-98.

OBENLAND D et al. 2016. Impact of storage conditions and variety on quality attributes and aroma volatiles of pitahaya (*Hylocereus* spp.). Scientia Horticulturae 199: 15-22.

PAYASI A et al. 2009. Biochemistry of fruit softening: an overview. Physiology and Molecular Biology of Plants 15: 103-113.

PUNITHA V. et al. 2010. Effect of storage temperatures on the physiological and biochemical properties of *Hylocereus polyrhizus*. Acta Horticulturae 875: 137-144.

SMRKE T et al. 2021. Modified Atmospheric $CO_2$ Levels for Maintenance of Fruit Weight and Nutritional Quality upon Long-Term Storage in Blueberry (*Vaccinium corymbosum* L.) ‘Liberty’. Horticulturae 7: 478-492.

THOMPSON AK et al. 2018. Controlled atmosphere storage of fruit and vegetables. 3.ed. Boston: CABI.

TRINCHERO GD et al. 2004. Inhibition of ethylene action by 1-methylcyclopropene extends postharvest life of 'Bartlett' pears. Postharvest Biology and Technology 32: 193-204.

TRINDADE DCG et al. 2015. Ação do 1-metilciclopropeno na conservação pós-colheita de manga ‘Palmer’ em diferentes estádios de maturação. Pesquisa Agropecuária Brasileira 50: 753-762.

VERA J et al. 2017. 1-MCP Microbubbles Influence in Fruit Color and Quality of Dragon Fruit. Agricultural Science Journal 48: 237-240.

YANG M et al. 2020. Impact of elevated $O_2$ and $CO_2$ atmospheres on chemical attributes and quality of strawberry (*Fragaria*× *ananassa* Duch.) during storage. Food Chemistry 307: 125550-125565.