PHYSICAL, CHEMICAL AND SENSORY CHANGES OF REFRIGERATED YELLOW PITAHAYA TREATED PREHARVEST WITH 1-MCP

CAMBIOS FISICOS, QUIMICOS Y SENSORIALES DE PITAHAYA AMARILLA REFRIGERADA TRATADA EN PRECOSECHA CON 1-MCP

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ABSTRACT: The effect of application of 0, 200 and 400 μg L^{-1} aqueous solution of 1-methylcyclopropene (1-MCP) on preharvest yellow pitahaya (Selenicereus megalanthus Haw) was assessed. Changes in weight loss, total change of color, total sugars, titratable acidity, ascorbic acid and sensory analysis were measured. The pitahaya was stored under refrigeration (10 °C and 85% relative humidity for 29 days). Two types of packaging were used (export cartons and perforated plastic crates, used in the domestic market). Results showed that during storage, the chilled yellow pitahaya presented significant variations in all response variables. However, the application of aqueous solutions of 1-MCP before harvesting, produces significant beneficial effects on the chemical, physical and sensory properties of yellow pitahaya and extends their shelf life by 5 days.

KEYWORDS: Selenicereus megalanthus, 1-methylcyclopropene, shelf life.

RESUMEN: El efecto de la aplicación de soluciones acuosas de 0, 200 y 400 μg L^{-1} de 1-metilciclopropeno (1-MCP) en pitahaya amarilla en precosecha (Selenicereus megalanthus Haw) fue evaluado. Se midieron los cambios en pérdida de peso, cambio total de la coloración, azucares totales, acidez titulable, ácido ascórbico y análisis sensorial. La pitahaya fue almacenada bajo refrigeración (10°C y 85% de humedad relativa por 29 días). Dos tipos de empaque (Cajas para exportación y canastillas plásticas usadas en el mercado local) fueron utilizadas. Los resultados mostraron que durante el almacenamiento, la pitahaya amarilla refrigerada presento variaciones significativas en todas las variables de respuesta. Sin embargo, la aplicación de soluciones acuosas de 1-MCP antes de la cosecha, produce efectos benéficos significativos en las propiedades químicas, físicas y sensoriales de pitahaya amarilla y extiende su vida útil por un período de 5 días.

PALABRAS CLAVE: Selenicereus megalanthus, 1-metilciclopropeno, vida útil.

1. INTRODUCTION

The pitahaya is a cactus native to tropical and subtropical America and is one of several promising fruit for cultivation [1]. The fruit of this cactus species is popular in Europe and the U.S. for its appearance, exotic taste and properties. This fruit is native to Mexico, Central America and South America and is cultivated in Southeast Asia; it contains essential fatty acids such as oleic, linoleic and linolenic acids and cis-vaccenic acid [2].Within this species, there are 4 types of fruit: red, cherry, yellow and white [3]. The yellow and white pitahaya contain high amounts of phenolic compounds and ascorbic acid. Their consumption may be associated with nutraceutical properties of the food generated by their effect on free radicals, reducing the risk of chronic diseases [4]. In addition, it is a polyphenol-rich fruit and a good source of antioxidants [3].

However, the yellow pitahaya is a tropical fruit that undergoes physiological damage associated with cold [5], including the browning and necrosis of the peel, which causes postharvest loss; the browning of the fruit is related to the action of polyphenol oxidase and peroxidase, and the necrosis is related to the presence of reactive oxygen species [6]. Therefore, to avoid cold injury, temperatures between 3 and 6 °C have been recommended, and complementary techniques have been evaluated to increase the benefit of refrigeration, such as modified atmospheres, heat treatment and the use of chemicals [7]. Packaging also plays an important role in limiting cold injury to the fruit [8].

In addition to cold injury, the loss of fruit quality during storage has been associated with the production of ethylene and the respiration of the fruit. The greater the production of ethylene, the greater the speed at which the ripening and senescence reactions progress [9]. Compounds such as cyclopropenes, including 1-methylcyclopropene (1-MCP), are used to block the action of ethylene based on their link with the membrane receptors [10, 11, 12]. In yellow pitahaya stored at 27 ° C, 200 µg applications of L^{-1} 1-MCP after harvest extended the shelf life of the fruit by 3 days [13]. The preharvest application of 1-MCP (Harvista TM technology) to biological products has led to retention of firmness, good color development [14, 15, 16] and lower production of ethylene [15], indicating that its application in the field is a way of extending the shelf life of the fruit. The response to the compound depends on the cultivar, the storage conditions, the temperature, the duration of the treatment and the stage of maturity [17].

Therefore, research is required to evaluate the application of composites and packaging to promote the conservation of the yellow pitahaya fruit during cold storage, mitigating the effects of cold injury. The aim of this study was to evaluate the effect of preharvest application of two different concentrations of 1-MCP on the physical, chemical and sensory changes of yellow pitahaya stored under refrigeration in plastic crates and in export cartons. The physical changes were measured in terms of weight loss, and color; the chemical changes were measured in terms of total sugars, titratable acidity and ascorbic acid; and the sensory changes were measured by sensory analysis.

2. MATERIALS AND METHODS

2.1. Vegetable material

An experimental lot of 500 m^2 with a harvest density of 5000 plants/Ha located in the Roldanillo municipality, Valle del Cauca, Colombia (latitude 4°24'37" north, longitude 75°93'72" west and altitude 1500 MASL was selected. Fruit at ripening stage 2 according to Colombian Technical Standard 3554 were selected [18]. The selection was random, and the technician from the *Yellow Pitahaya Producers Association – Asoppitaya* confirmed the state of maturity of the fruit.

2.2. Preparation and application of 1-MCP

A powder formulation of 1-MCP (3.8% w/w) supplied by Rohm and Haas Chemical Ltd. (Philadelphia, Pennsylvania) was used. Solutions of 10 L of 1-MCP at concentrations of 200 and 400 μgL^{-1} were prepared directly in the field using distilled water, as recommended by the manufacturer; the solution concentrations were selected based on previous studies on yellow pitahaya [13]. The 1-MCP was applied directly to fruit on the tree at a distance of 5 cm, using a manual sprayer with an operating pressure of 2 bars. Fifteen days after application, the fruit were collected, washed with distilled water for 1 minute, dried in the open air (20 minutes, at room temperature) and finally, the fruit were packed.

2.3. Packing

The fruit were packed in export cartons and in perforated plastic crates. Cartons containing 24 polypropylene compartments (Reference: BCW 930 count corrugated carton). 24 fruit in a single layer were arranged. In the perforated plastic crates (60 x 40 x 20 cm) two layers of 27 fruit each layer, were placed. The packed fruit were stored in an environmental chamber (1000L, Dies, Colombia) at 10 ± 1 °C and 85% relative humidity.

2.4. Physical properties

Nine pitahaya were collected (per treatment), and weighed daily during the first six days of storage, then weighed every three days, using a scale accurate to three decimal places (Mettler Toledo 1200 , Columbus, Ohio). Weight loss was analyzed using the relative percentage change (ΔY) relative to time zero (initial day of storage), using Equation 1:

$$\Delta Y = \left(\frac{Y_j - Y_i}{Y_i}\right) * 100 \qquad \text{(Eq.1)}$$

Where:

Y= fruit weight

i = initial sample.

j = final sample.

The color was measured using the CIE-L*a*b* color scale, in a reflection spectrum between 400-700 nm, using as reference the 10 ° observer under illuminant D65 through a colorimeter Colorflex (HunterLab, Reston, Virginia). Color parameters (L*a*b*) were measured at three equidistant points distributed on the periphery of the peel of each fruit. The total color change (ΔE) with respect to time zero was calculated using equation 2 [19]:

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad \text{(Eq.2)}$$

Where:

L*: brightness

a*: green coloration

b*: yellow coloration

2.5. Chemical properties

The total sugars (TS), total titratable acidity (TTA) and ascorbic acid were determined with the juice extracted, homogenized and filtered from the pulp of three whole pitahayas. The total sugars were determined with the Antrona method [20] using a spectrophotometer (Thermo Spectronic Genesis UV10, Boston, USA). The TTA was determined using the AOAC 942.15A official method [21] through acid-base titration using a solution of NaOH 0.1 N until a pH of 8.1 was reached; the acidity was expressed as a percentage of citric acid. The ascorbic acid was estimated by reducing yellow molybdophosphoric acid to blue molybdenum by the action of ascorbic acid, as reported in investigations of Serna et al. [22].The measurement was performed using a refractometer (RQflex 10 plus, Merck, Darmstadt, Germany) in a measuring range of 25-450 mg L^{-1} for ascorbic acid. The results were expressed in mg L^{-1} of sample.

2.6. Sensory analysis

The fruit were sensory tested by analyzing the degree of acceptance in terms of appearance. For this test, nine fruit from each treatment were collected and grouped (three fruit in each group). The samples were placed on a table and were labeled with randomly selected three-digit numbers.

For this sensory test, a three-point hedonic scale was used with 20 consumer judges to assess the level of acceptance of appearance.

2.7. Experimental design and statistical analysis

A completely randomized factorial design with three factors was used, as follows: *concentration of the solution of 1-MCP* with three levels (0, 200 and 400 µg L^{-1}), *packaging* with two levels (export cartons and the domestic market plastic crates), and s*torage time,* with 14 levels (0, 1, 2, 3, 4, 5, 6, 9, 12, 15, 18, 21, 24 and 29 days) for the variables TTA and loss of weight. And 10 levels (0, 3, 6, 9, 12, 15, 18, 21, 24 and 29 days) were used, for the variables color, TS and sensory changes. The effect of 1-MCP concentration, type of packaging and storage time was determined by analysis of variance (ANOVA) and mean comparisons with the Tukey method at 5% probability using the Minitab software version 15.1 (Minitab Inc., State College, PA, 2007). All determinations were performed in triplicate.

The following nomenclature was used: 200 and 400 to identify the concentration of 1-MCP. 0 to identify the control (untreated with 1-MCP), and LC and EX to identify the fruit packed in plastic crates for the domestic market and export cartons, respectively.

3. RESULTS AND DISCUSSION

3.1. Physical properties

The control fruit showed greater weight loss compared to the fruit treated with 1-MCP for both types of packaging (See Figure 1).

The weight loss was significantly affected ($p < 0.05$) by 1-MCP concentration, the type of packaging and the storage time. It also showed a second-order interaction effect of the concentration factor with the packing and time factors.

Significant differences between the control, the 200-LC and the 400-LC treatments were observed after day 9 of storage ($p < 0.001$). A similar behavior was present in the fruit packed in export cartons. During storage, the 400-EX treatment exhibited less weight loss than the 400-LC and control-LC.

At the end of storage (day 29), the control-EX and control-LC treatments exhibited weight losses of 28.3 and 27.9% respectively; in the 200-EX and 200-LC, the weight losses were 21.4 and 20.4%, respectively, and for the treatments 400-EX and 400-LC, the weight losses were 21.4 and 21.7%, respectively.

The weight losses recorded for the refrigerated control fruit are higher than the losses reported for the same fruit stored at 25 °C, where weight losses between 15 and 17% after 15 days of storage were recorded [13].

As in the yellow pitahaya, other studies have reported that the 1-MCP application produced a decrease in weight loss during storage for Chinese chives [23], plums [24, 25] and tomatoes [26].

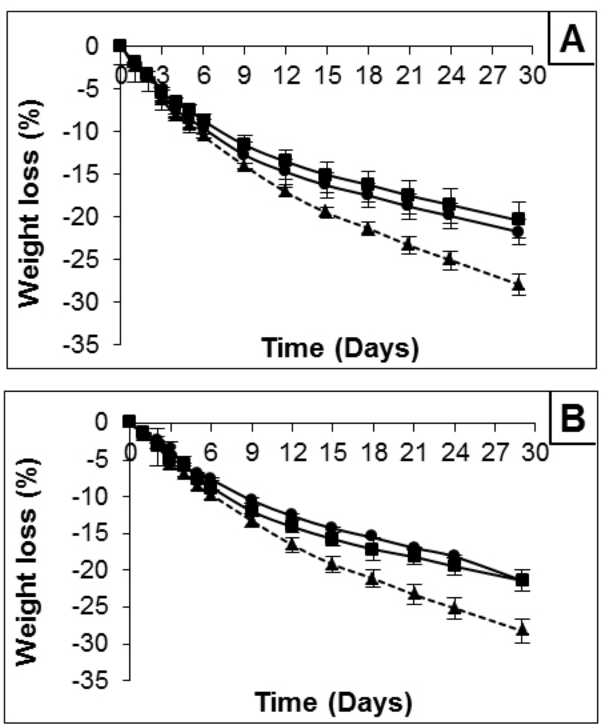

Figure1. Effect of 1-MCP on the weight loss of yellow pitahaya packed in plastic crates (A) and export cartons (B). Vertical bars represent the standard deviation from the mean value. Δ control; ■treatment with 200 μgL^{-1}of 1-MCP; ●treatment with 400 μgL^{-1}of 1-MCP.

The fruit treated with 1-MCP showed a higher total color change from the control, and this effect was more pronounced in the fruit packed in export cartons (see Figure 2). The fruit packed in plastic crates had a higher total color change than the fruit packed in export cartons.

In the fruit packed in plastic crates, there was a total color change of 17.6, 20.1 and 21% for the treatments CONTROL-LC, 200-LC and 400-LC, respectively, at the end of storage. These differences were not statistically significant. In the fruit packed in export cartons, the application of 1-MCP resulted in a greater total color change in the fruit, and this effect was enhanced by the higher concentration of 1-MCP (see Figure 2). In this packaging, the differences among the treatments CONTROL-EX, 200-EX and 400-EX were statistically significant. There was also an interaction effect between the type of packaging and the storage time. Researchers found that mango samples stored in cardboard carton, present lower color changes than samples of the fruit without packaging [27]. Kasim et al., [28], evaluated the effect of packaging on the color changes of broccoli treated with 1-MCP, and they found that the broccoli packaged with less thickness (8.5μm), is more susceptible to color changes than the broccoli in thicker packaging (14μm). In addition, they found that chlorophyll degradation of broccoli was delayed in all 1-MCP-treated packages for up to 14 days in storage.

At the end of storage, the largest color changes occurred in the 400-EX treatment (17.8%), followed by the EX-200 (16.7%). The lowest total color change was obtained in the control (10.5%).

With 1-MCP applied before harvest, the metabolic process of color change was accelerated, as the magnitude and sensitivity of the ethylene response increases when the number of receptors decreases. This behavior is similar to the behavior observed in pears, where concentrations of 0.4 and 0.8 μLL^{-1} applied after harvest generated greater changes in brightness and color [29].

3.2. Chemical properties

The TS values of yellow pitahaya are presented in Figure 3. In general, the TS are correlated with the total soluble sugar (TSS), which exhibit an oscillatory behavior with increases and decreases throughout the storage. All the evaluated factors exerted a significant effect on TS, and second- and third-order interaction effects were recorded.

Similar results are observed in mangosteen stored at 25 ° C [30], where the application of 1-MCP has a significant effect on the TSS.

In the fruit packed in export cartons (Figure 3B), the lowest value of the TS was registered on the sixth day of storage (4.45%) for the control-EX treatment. This effect could be generated by an increased metabolism of sugars generated by the concentration of ethylene and the lack of air generated by the packing characteristics, in interaction with the absence of treatment with 1-MCP. Hailu et al., [31] determined the effect of packing on the quality of bananas and found that the rate of increase of total sugars is faster in unpackaged samples (control) that in packaged samples. This is due to the decrease in respiration rate caused by the barrier effect of the package reducing gas exchange. According Rathore et al. [27], the increase in the percentage of total sugars is mainly due to splitting of starch into amylase, and simple sugars such as sucrose, fructose and glucose.

In minimally processed yellow pitahaya [22], lower TS values have been reported, ranging between 3.41 and 7.79%. However, these differences were generated by the fermentation of sugars within the packaging.

The oscillating variations obtained in the TS can be explained by the metabolism of the fruit, associated with the consumption of energy as ATP and other compounds, to maintain homeostasis of the fruit [30]. These processes include the conversion of starch into glucose and fructose and their use through metabolic pathways as substrates for respiration [32].

The application of 1-MCP exerted significant effects on the TSS in pineapple stored under refrigeration [33], jujube [34] and loquat [7].

Figure 4 shows the behavior of TTA during storage of the 1-MCP-treated and the control yellow pitahaya during refrigerated storage. The acidity was affected by the different concentrations of 1-MCP, the type of packaging and the storage time, and there were further interaction effects between the factors studied.

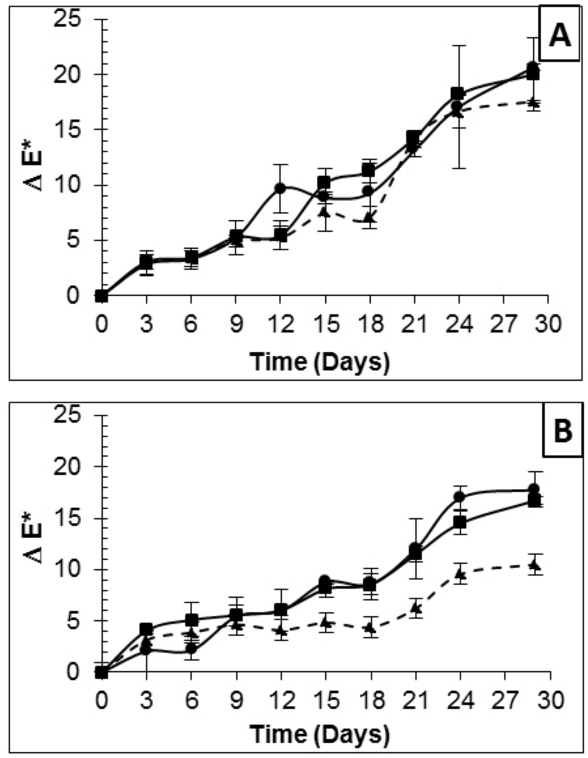

Figure 2. Effect of 1-MCP on color changes of yellow pitahaya packed in plastic crates (A) and export cartons (B). Vertical bars represent the standard deviation from the mean value ▲ control; ■ treatment with 200 μg L-1 of 1-MCP; ● treatment with 400 μg L-1 of 1-MCP.

An oscillatory behavior and a tendency of the TTA to decrease during storage were observed in all treatments. Oscillating variations can be generated by the metabolism of organic acids [35] that are consumed in oxidative reactions during maturation [36] and the synthesis of citric acid from glucose in the Krebs cycle [37].

Similar results are reported in mamey subjected to 1-MCP treatments, with significant differences in titratable acidity observed when using wax and 1-MCP applications [40]. With the application of 1-MCP, the TTA was maintained for both apple [39] and jujube [34].

The acidity values determined in this work are lower than those obtained by Rodriguez et al. [40], who found changes in acidity from 1.5 to 2.5% on day 15 in pitahaya harvested at maturity stage 3 and stored at 19 °C; when the fruit was stored at 8 °C, the acidity ranged from 1.3 to 3% on day 23 of storage [40].

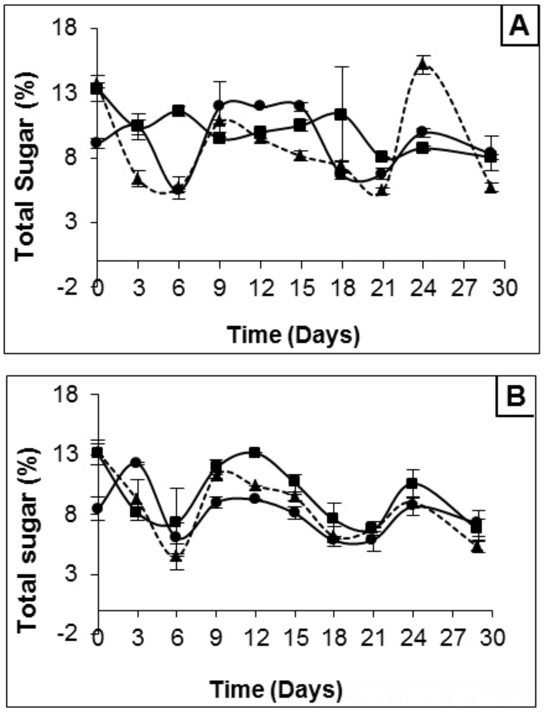

Figure 3. Effect of 1-MCP on the total sugars of yellow pitahaya packed in plastic crates (A) and export cartons (B). Vertical bars represent the standard deviation from the mean value ▲ control; ■ treatment with 200 μg L-1 of 1-MCP; ● treatment with 400 μg L-1 of 1-MCP.

A reduction in the content of ascorbic acid was observed during storage of yellow pitahaya, except for the CONTROL-EX treatment (see Figure 5).

Generally, treatment with 1-MCP maintained the ascorbic acid levels stable during the first days of storage ($p < 0.05$). The 400-LC treatment had the highest variability, with values of ascorbic acid levels between 120 and 240 mg L^{-1}. At the end of storage, no significant differences between the 200-EX and 400-EX treatments were found.

The increase in the ascorbic acid levels may be generated by biosynthesis, as precursors may be generated by the degradation of the pectin in the cell wall [41]. Reductions in ascorbic acid levels during senescence are observed; because it is a natural antioxidant, it is consumed to repair oxidative damage in cells [7]. A similar behavior, with marked increases and decreases, was obtained for loquat [7] and jujube [7]. The packing did not have a significant effect on the yellow pitahaya ascorbic acid levels ($p > 0.05$).

The application of 1-MCP reduced the loss of ascorbic acid in jujube [42], Chinese chives [23] and minimally processed yellow pitahaya [22].

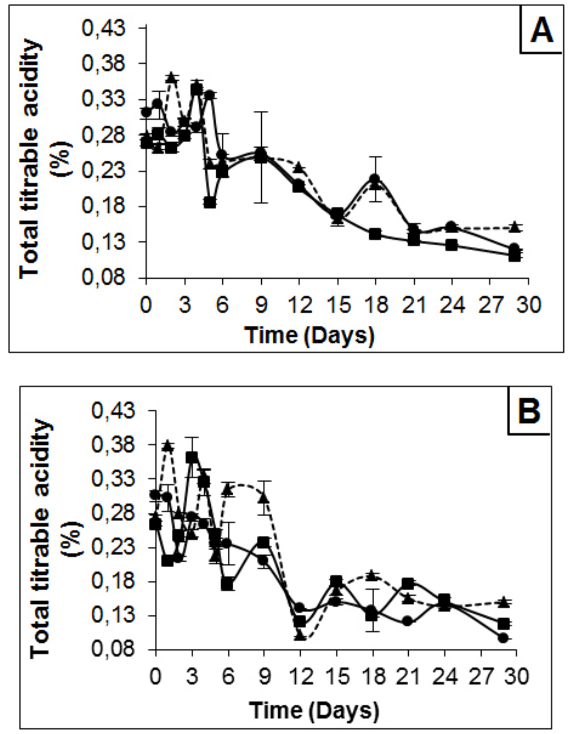

Figure 4. Effect of 1-MCP on the total titratable acidity of yellow pitahaya packed in plastic crates (A) and export cartons (B). Vertical bars represent the standard deviation from the mean value Δ control; ■ treatment with 200 μg L^{-1} of 1-MCP; ● treatment with 400 μg L^{-1} of 1-MCP.

3.3. Sensory analysis

The acceptability of the appearance of yellow pitahaya during storage is shown in Table 1. It is noted that the fruit packed in export cartons had a higher acceptance rate compared to the fruit packed in plastic crates. This effect could be generated by the greater change in total color, which generates yellow colors associated with fruit ready for consumption [43, 44].

The control fruit showed a lower acceptance rate compared to the fruit treated with 1-MCP, and, in general, the 400-EX treatment was associated with the highest acceptance. This effect may be generated by the acceleration of the color change of the pericarp of the fruit produced by the application of 1-MCP.

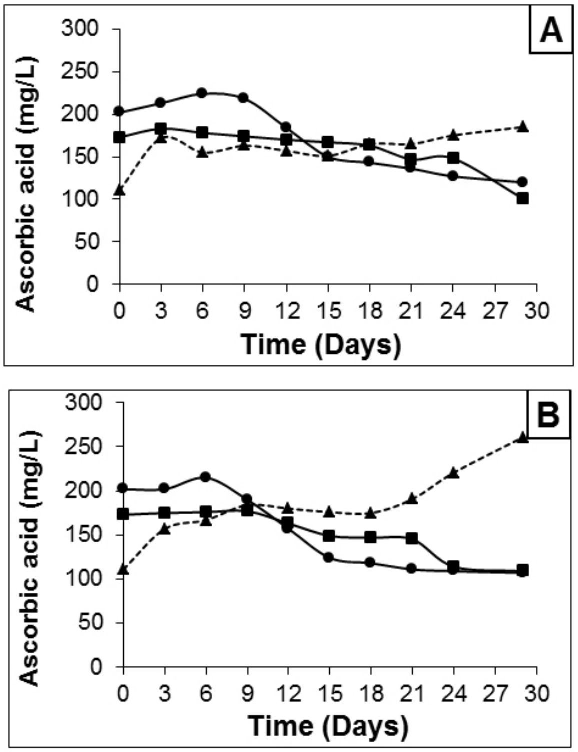

Figure 5. Effect of 1-MCP on the ascorbic acid levels of yellow pitahaya packed in plastic crates (A) and export cartons (B). Vertical bars represent the standard deviation from the mean value Δ control; ■ treatment with 200 µg L^{-1} of 1-MCP; ● treatment with 400 µg L^{-1} of 1-MCP.

A similar trend was recorded for mangosteen [45], in which the application of 1-MCP produced superior sensory attributes.

The physical appearance of the treated fruit was evaluated during storage by recording signs of senescence as evidence of losses in the shelf life. The criteria were the onset of browning, fallen stems and the softening of the peel. Rodriguez et al. [40] reported that fruit harvested at maturity stage 3 and stored at 19 °C was maintained for 15 days. Serna et al. [13] reported a shelf life of 12 days for yellow pitahaya stored at 27 °C.

Table 1. Effect of 1-MCP on the acceptance of yellow pitahaya packed in plastic crates

Time (Days)	**0**	**3**	**15**	**18**	**21**	**24**	**29**
CONTROL LC							
I like	40	65	50	20	65	50	45
I am indifferent	40	30	30	20	20	15	35
I don´t like	20	5	20	60	15	35	20
LC-200							
I like	55	55	15	25	0	5	0
I am indifferent	35	35	45	45	20	15	5
I don´t like	10	10	40	30	80	80	95
LC-400							
I like	50	55	25	75	50	20	15
I am indifferent	40	30	55	15	25	55	30
I don´t like	10	15	20	10	25	25	55
CONTROL EX							
I like	45	60	25	30	90	5	5
I am indifferent	30	20	50	25	10	20	10
I don´t like	25	20	25	45	0	75	85
EX-200							
I like	45	75	30	25	70	60	50
I am indifferent	30	20	30	45	20	30	30
I don´t like	25	5	40	30	10	10	20
EX-400							
I like	30	65	70	90	85	70	55
I am indifferent	45	20	20	10	10	25	25
I don´t like	25	15	10	0	5	5	20

After harvesting the fruit, a series of changes will be generated because of the decrease of the water content and the dry matter from the plant through the xylem and phloem [46], increasing the levels of the hydrolytic enzymes that cause the metabolism and senescence of the components of plants and fruit [47]. The application of 1-MCP inhibits ethylene production [48, 49] and the binding of the molecule to the receptor [29], and it therefore acts as a chemical adjuvant that competes with the active sites for ethylene, reducing the hydrolytic enzyme levels and slowing the changes of the maturation process, such as changes in sugars, starches and other organic acids that lead to the senescence of the fruit [49].

The export packaging provides further support to the fruit and causes less damage to the peel and less cell damage; however, it decreases aeration and favors the concentration of ethylene and the resulting increase in temperature and enzyme action, leading to increased metabolic processes that reduce the fruit shelf life. The perforated plastic crates facilitates aeration, but there is an increased risk of injury to the fruit (caused by direct contact between them), which damages the peel and promotes the degradation of the fruit.

4. CONCLUSION

Preharvest application of 1-MCP in yellow pitahaya, has positive effect on their physical, chemical and sensory properties, extending its shelf life for up to five days (21%). The 1-MCP can be used to transport yellow pitahaya in international marketing.

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REFERENCES

[1] Braga, V., Amato, R., Ramos, J.D., Arcanjo de Araujo, N. and Reis Silva, F.O., Fenologia reprodutiva de pitaia vermelha no município de Lavras, MG, Ciência Rural, 41(6), pp. 984-987, 2011.

[2] Ariffin, A., Bakar, J., Tan, C., Rahman, R., Karim, R. and Loi, C., Essential fatty acids of pitaya (dragon fruit) seed oil, Food Chemistry, 114(2), pp. 561-564, 2009.

[3] Dembitsky, V.M.S., Poovarodom, H., Leontowicz, M., Leontowicz, S. and Vearasilp, S., Trakhtenberg and S. Gorinstein. The multiple nutrition properties of some exotic fruits: Biological activity and active metabolites, Food Res. Int., 44(7), pp. 1671-1701, 2011.

[4] Beltran, M.C., Oliva-Coba, T.G., Gallardo-Velasquez, T. and Osorio-Revilla, G., Ascorbic acid, phenolic content and antioxidant capacity red, cherry, yellow and white types of pitahaya cactus fruit (*Stenocereus stellatus* Riccobono), Agrociencia, 43, pp. 153-162, 2009.

[5] García, M.C. and Robayo, P., Evaluación del uso de atmósferas modificadas pasivas y temperaturas bajas en la conservacion de pitahaya amarilla (*Selinicereus megalanthus* Shuman), Revista Corpoica - Ciencia y Tecnología Agropecuaria, 9(1), pp. 30-39, 2008.

[6] Baquero, L.E., Castro, J.A. and Narváez, C.E., Catalasa, peroxidasa y polifenoloxidasa en pitahaya amarilla (*Acanthocereus pitajaya*): Maduración y senescencia, Acta Biológica Colombiana, 10(2), pp. 49-59, 2005.

[7] Kazuhiro-Edagi, F., Fumi-Sasaki, F., Sestari, I., Monteiro-Terra, F.A., Giro, B. and Kluge, R.A., 1-metilciclopropeno e salicilato de metíla reduzem injúrias por frio em néspera 'Fukuhara' refrigerada, Ciência Rural, 41(5), pp. 910-916, 2011.

[8] Wang, C.Y. and Qi, L., Modified atmosphere packaging alleviates chilling injury in cucumbers, Postharvest Biol. Technol, 10, pp. 195-200, 1997.

[9] Brackmann, A., Both,V., Vilela-Pinto, J.A., Weber, A. and Pivotto-Pavanello, A., Absorçào de 1-metilcidopropeno aplicado em macas 'Royal Gala' armazenadas em atmosfera refrigerada juntamente com madeira,Ciência Rural, 39(6), pp. 1676-1681, 2009.

[10] Blankenship, S.M. and Dole, J.M., 1-Methylcyclopropene: a review, Postharvest Biol. Technol, 28(1), pp. 1-25, 2003.

[11]. Watkins, C.B., The use of 1-methylcyclopropene (1-MCP) on fruits and vegetables, Biotechnol. Adv., 24(4), pp. 389-409, 2006.

[12] Tatsuki, M., Hayama, H., Yoshioka, H. and Nakamura, Y., Cold pre-treatment is effective for 1-MCP efficacy in 'Tsugaru' apple fruit, Postharvest Biol. Technol, 62(3), pp. 282-287, 2011.

[13]. Serna, L., Torres,L.S. and Ayala, A.A., Efecto del empaque y del 1-MCP sobre características físicas, químicas y fisiológicas de pitahaya amarilla, Biotecnología en el Sector Agropecuario y Agroindustrial, 9, In press, 2012.

[14] Defilippi, B., Campos, R. and Manríquez, D., Uso de 1-Metilciclopropeno (1-MCP) en precosecha retarda avance de madurez en manzana, Aconex, 96, pp. 5-8, 2008.

[15] Elfving, D.C., Drake, S.R., Reed, A.N. and Visser, D.B., Preharvest Applications of Sprayable 1-Methylcyclopropene in the orchard for management of apple harvest and postharvest condition, Hort Science, 42(5), pp. 1192-1199, 2007.

[16] Serna, L., Torres,L.S. and Ayala, A.A., Changes in mechanical properties of minimally-processed yellow pitahaya treated with 1-mcp. Dyna, 79 (174), pp. 71-78.

[17] Watkins, C.B., Overview of 1-Methylcyclopropene Trials and Uses for edible horticultural crops, HortScience, 43(1), pp. 86-94, 2008.

[18] ICONTEC, NTC 3554, Frutas frescas[in Fresh fruits]: Pitahaya1996, National Federation of Coffee Growers of

Colombia (Federación Nacional de Cafeteros de Colombia).

[19] Manresa, A. and Vicente, I., El color en la industria de alimentos, Universitary E. La Habana City (E. Universitaria Ciudad de la Habana), Cuba, 2007.

[20] DuBois, M., Gilles, K.A., Hamilton, J.K., Rebers, P.A. and Smith, F., Colorimetric Method for Determination of Sugars and Related Substances, Anal. Chem., 28(3), pp. 350-356, 1956.

[21] AOAC, Official methods of analysis of the Association of Official Analytical Chemists in 942.15A Fruits and fruit products - Acidity (Titratable) of Fruit Products. 2000, Association of Official Analytical Chemists: Arlington, Virgininia, USA. p. 11.

[22] Serna, L., Segura, D.F. and Ayala, A.A., Effect of the inmersion in 1-MCP on the physicochemical and physiological properties of minimally processed yellow pitahaya fruit (*Selenicereus megalanthus* How), Acta Agronómica, 60(3), In press, 2011.

[23] Wu, C., Du, X., Wang, L., Wang, W., Zhou, Q. and Tian. X., Effect of 1-methylcyclopropene on postharvest quality of Chinese chive scapes, Postharvest Biol. Technol, 51(3), pp. 431-433, 2009.

[24] Manganaris, G.A., Crisosto, C.H., Bremer, V. and Holcroft, D., Novel 1-methylcyclopropene immersion formulation extends shelf life of advanced maturity 'Joanna Red' plums (Prunus salicina Lindell), Postharvest Biol. Technol, 47(3), pp. 429-433, 2008.

[25] Valero, D., Martinez, D., Valverde, J., Guillen, F. and Serrano, M., Quality improvement and extension of shelf life by 1-methylcyclopropene in plum as affected by ripening stage at harvest, Innov. Food Sci. Emerg. Technol, 4(3), pp. 339-348, 2003.

[26] Guillén, F., Castillo, S., Zapata, P.J., Martínez, D. Valero, D. and Serrano, M., Efficacy of 1-MCP treatment in tomato fruit, Postharvest Biol. Technol, 42(3), pp. 235-242, 2006.

[27] Rathore, H.A., Masud, T., Raza, A. and Rizwan, M., Potential techniques of interactive packaging in cardboard carton and their effect on overall quality characteristics such as sugars, colour, texture, taste and flavor of Chaunsa white variety of mango at ambient temperature during storage. Pak. J. Nutr., 9(4),pp. 343 – 351, 2010.

[28] Kasim, R., Kasim, M.U. and Erkal, S., The effect of packaging after 1-MCP treatment on color changes and chlorophyll degradation of broccoli (Brassica oleracea var. italica cv. Monopoly). J. Food Agric. Environ., 5(3), pp. 48 – 51, 2007.

[29] Trinchero, G.D., Sozzi, G.O., Covatta, F. and Fraschina, A.A., Inhibition of ethylene action by 1-methylcyclopropene extends postharvest life of "Bartlett" pears, Postharvest Biol. Technol, 32(2), pp. 193-204, 2004.

[30] Piriyavinit, P., Ketsa, S. and van Doorn, W.G., 1-MCP extends the storage and shelf life of mangosteen (Garcinia mangostana L.) fruit, Postharvest Biol. Technol, 61(1), pp. 15-20, 2011.

[31] Hailu, M., Workneh, T.S. and Belew, D., Effect of packaging materials on the quality of banana cultivars. Afr. J. Agr. Re. 7(7), pp. 1226-1237, 2012.

[32] Lima, F.V., Saavedra, J., Marcos, E.M. and Kluge, R.A., Pós-colheita de lichia 'Bengal' tratada com etileno e 1-metilciclopropeno, Ciência Rural, 41(7), pp. 1143-1149, 2011.

[33] Paliyath, G. and Murr, D.P., Biochemistry of fruits, In: Postharvest biology and technology of fruits, vegetables, and flowers, Iowa, USA, 497, 2008.

[34] Selvarajah, S., Bauchot, A.D. and John, P., Internal browning in cold-stored pineapples is suppressed by a postharvest application of 1-methylcyclopropene, Postharvest Biol. Technol, 23, pp. 167-170, 2001.

[35] Davies, J.N. and Maw, G.A., Metabolism of citric and malic acids during ripening of tomato fruit, J. Sci. Food Agric., 23, pp. 969-976, 1972.

[36] Camargo, L., Moreno, R., Da Silva, V.X., Lopes, R. and Ruffo, S., Dano de frio em limas-ácidas Tahiti, colhidas em diferentes épocas e submetidas a tratamentos térmicos e bioquímicos, Revista Brasilera de Fruticultura, 30(2), pp. 377-384, 2008.

[37] Sweetman, C., Deluc, L.G., Cramer, G.R., Ford, C.M. and Soole, K.L., Regulation of malate metabolism in grape berry and other developing fruits, Phytochemistry, 70(11-12), pp. 1329-44, 2009.

[38] Ergun, M., Sargent, S.A., Fox, A.J., Crane, J.H. and Huber, D.J., Ripening and quality responses of mamey sapote fruit to postharvest wax and 1-methylcyclopropene treatments, Postharvest Biol. Technol, 36(2), pp. 127-134, 2005.

[39] Fan, X., Mattheis, J.P. and Blankenship, S., Development of Apple Superficial Scald, Soft Scald, Core Flush, and Greasiness Is Reduced by MCP, J. Agric. Food Chem., 47(8), pp. 3063-3068, 1999.

[40] Rodríguez, D.A., Patiño, M.P., Miranda, D., Fischer, G. and Galvis, J.A., Efecto de dos índices de madurez y dos temperaturas de almacenamiento sobre el comportamiento en poscosecha de la pitahaya amarilla) (*Selenicereus megalanthus* Haw), Revista Facultad Nacional de Agronomía Medellín, 58(2), pp. 2827-2837, 2005.

[41] Agius, F., Gonzalez, R., Caballero, J.L., Munoz, J., Botella, M.A. and Valpuesta, V., Engineering increased vitamin C levels in plants by overexpression of a D-galacturonic acid reductase, Nat. Biotechnol, 21(2), pp. 177-81, 2003.

[42] Zhang, Z., Tian, S., Zhu, Z., Xu, Y. and Qin, G., Effects of 1-methylcyclopropene(1-MCP) on ripening and resistance of jujube (Zizyphus jujuba cv. Huping) fruit against postharvest disease, LWT - Food Sci. Technol. 45(1), pp. 13-19, 2012.

[43] Mayor, L., Cunha, R.L. and Sereno, A.M., Relation between mechanical properties and structural changes during osmotic dehydration of pumpkin, Food Res. Int. 40(4), pp. 448-460, 2007.

[44] Muliawan, E.B. and Hatzikiriakos, S.G., The effect of refrigerated storage on the rheological properties of three commercial mozzarella cheeses, Int. J. Food Eng. 4(4), pp. 1-19, 2008.

[45] Gamrasni, D., Ben-Arie, R. and Goldway, M., 1-Methylcyclopropene (1-MCP) application to Spadona pears at different stages of ripening to maximize fruit quality after storage, Postharvest Biol. Technol, 58(2), pp. 104-112, 2010.

[46] Leonardi, C., Baille, A. and Guichard, S., Predicting transpiration of shaded and non-shaded tomato fruits under greenhouse environments, Sci. Hortic., 84, pp. 297-307, 2000.

[47] Adams-Phillips, L., Barry, C. and Giovannoni, J., Signal transduction systems regulating fruit ripening, Trends Plant Sci., 9(7), pp. 331-8, 2004.

[48] Dal Cin, V., Rizzini, F.M., Botton, A. and Tonutti, P., The ethylene biosynthetic and signal transduction pathways are differently affected by 1-MCP in apple and peach fruit, Postharvest Biol. Technol, 42(2), pp. 125-133, 2006.

[49] Khan, A.S. and Singh Z., 1-MCP application suppresses ethylene biosynthesis and retards fruit softening during cold storage of 'Tegan Blue' Japanese plum, Plant Sci., 176(4), pp. 539-544, 2009.