Conservation of 'Pedro Sato' guavas under treatment with 1-methylcyclopropene

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Abstract – The search for techniques that extend shelf life of guava (*Psidium guajava*) fruits, and reduce its postharvest losses is desirable. The objective of this work was to evaluate the effects of concentrations of competitive ethylene antagonist 1-methylcyclopropene (1-MCP) on conservation of 'Pedro Sato' guava fruits. Treatments consisted of 0, 100, 300 or 900 nL L^{-1} of 1-MCP for 3 hours followed by storage at 25ºC, and 10ºC with 90±5% RH. The application of 900 nL L^{-1} 1-MCP for 3 hours was efficient in delaying loss of skin color, and in keeping fruit firmness at both storage temperatures. The 300 nL L^{-1} of 1-MCP concentration was efficient in delaying skin color loss only when fruits were stored at 10ºC. The effect of 1-MCP was quite significant on the reduction of rot incidence at both storage temperatures. The respiratory rate was lower in fruits treated with 300 and 900 nL L^{-1} of 1-MCP during storage at 25ºC. The product was efficient in delaying the ripening of fruits, and the concentration of 900 nL L^{-1} showed the best effect.

Index terms: *Psidium guajava*, temperature, conservation, postharvest.

Conservação de goiabas 'Pedro Sato' tratadas com 1-metilciclopropeno

Resumo – A pesquisa de técnicas que ampliem o período de conservação da goiaba (*Psidium guajava*) e reduzam as perdas pós-colheita é importante, por causa de sua perecibilidade. O objetivo deste trabalho foi avaliar os efeitos e concentrações do antagonista competitivo do etileno, 1-metilciclopropeno (1-MCP), na conservação de goiabas 'Pedro Sato'. Os frutos foram tratados com 0, 100, 300 e 900 nL L^{-1} de 1-MCP durante três horas, e armazenados a 25ºC e a 10ºC com 90±5% UR. A aplicação de 900 nL L^{-1} de 1-MCP foi eficiente em retardar a perda de coloração da casca e em manter a firmeza dos frutos, nas duas temperaturas de armazenamento. A concentração de 300 nL L^{-1} de 1-MCP retardou a perda de coloração da casca, quando os frutos foram armazenados a 10ºC. O efeito do 1-MCP foi bastante significativo em diminuir a incidência de podridões, nas duas temperaturas de armazenamento. A taxa respiratória foi menor nos frutos tratados com 300 e 900 nL L^{-1} de 1-MCP, durante o armazenamento a 25ºC. O 1-MCP foi eficiente em retardar o amadurecimento dos frutos e a concentração de 900 nL L^{-1} produziu o melhor resultado.

Termos para indexação: *Psidium guajava*, temperatura, conservação, pós-colheita.

Introduction

Guava is a highly perishable fruit that shows intense metabolic activity. Guava fruit becomes fully ripe between three and five days at room temperature (Gongatti Neto et al., 1996). Due to such perishability, the control of fruit ripening is fundamental for increasing shelf life after harvest. The main factors depreciating postharvest quality in guava are fast loss of green color, excessive softening, high rot incidence and loss of turgidity (Jacomino et al., 2001).

Storage under low temperatures has been considered the most efficient method to maintain quality of most fruits and vegetables due to its effects on reducing respiration rate, transpiration, ethylene production, ripening, senescence and rot development (Hardenburg et al., 1986). In climacteric fruits, like most guava varieties, the reduction of temperature delays the climacteric peak and, consequently, ripening (Kader, 1992).

The recent finding that 1-methylcyclopropene (1-MCP) interferes with ethylene link to its binding site represents a new and powerful tool for postharvest management of climacteric fruits (Sisler & Serek, 1997). It has been demonstrated that the inhibition of the ethylene action delays ripening and senescence in several species of fruits, such as custtard apple (Benassi et al., 2003), guava (Bassetto et al., 2002), papaya (Jacomino

et al., 2002), peach (Kluge & Jacomino, 2002), apple (Rupasinghe et al., 2000), avocado (Feng et al., 2000), banana (Sisler & Serek, 1997; Golding et al., 1998; Jiang et al., 1999), strawberry (Ku & Wills, 1999) and tomato (Sisler & Serek, 1997).

The recommendation regarding treatment with 1-MCP generally sets an exposure time of 12 hours. However, when considering postharvest of guava fruit a fast treatment of 3 hours at most is suggested.

The purpose of this work was to evaluate the effects of 1-MCP concentrations on 'Pedro Sato' guavas treated for 3 hours, stored at room temperature and under refrigeration.

Material and Methods

'Pedro Sato' guava fruits were harvested and taken to the Crop Production Department of Esalq-USP, Piracicaba, SP, Brazil. Fruits showing no defects at maturation stage characterized by skin color change from dark to light green and weighing 165±10 g were used.

The commercial product Smartfresh, wetable powder, containing 0.14% 1-MCP active ingredient was used. Application was carried out in hermetic chambers in which fruits were exposed to 1-MCP at concentrations of 0, 100, 300 and 900 nL L^{-1} for 3 hours at 24ºC–25ºC (first experiment) and at 10ºC (second experiment). Predetermined amounts of Smartfresh were placed in flasks with lids and 20 mL of distilled water at 50ºC were added to each flask, which was shaken until complete dissolution. Then, flasks were opened inside the chambers, which were immediately closed to avoid gas losses. After treatments the chambers were opened, fruits were stored under room conditions (25ºC) for 2, 4, 6 and 8 days and put under refrigeration (10ºC) for 4, 8, 12 and 16 days.

The experimental statistical design was completely randomized in a factorial design. The factors studied were 1-MCP concentrations and storage periods. Fruits stored at 25ºC were analyzed at the end of each storage period, and those stored at 10ºC were kept at 25ºC for two days before being analyzed. For each treatment, four replications were used with four fruits per plot, totaling 512 fruits.

The variables analyzed were: a) skin and pulp colors determined with colorimeter, and results were expressed in hue angle (ºh) and chroma (C), respectively; skin color was evaluated by means of two readings on opposite sides along the fruit's equatorial region, while pulp color was assessed by means of one reading in the middle of the fruit's placental region after transversal sectioning; b) mass loss was determined by percentage difference between initial and final masses of each replication; c) pulp firmness was determined with a 8 mm-point digital penetrometer; two readings were carried out on opposite sides along fruit equatorial region, and results were expressed in Newton (N); d) total titratable acidity (TTA) was determined from 10 g of puree diluted with 90 mL of water, titrated with 0.1 N NaOH to pH 8.1 and expressed in percentage of citric acid (Carvalho et al., 1990); e) amount of ascorbic acid was determined by titration (Carvalho et al., 1990), and results were expressed in mg of ascorbic acid per 100 g of pulp; f) total soluble solids amount (TSS) was determined by direct reading of centrifuged fruit samples in a digital refractometer, and results were expressed in ºBrix; g) rot incidence was evaluated by affected fruit count, with results expressed as a percentage of affected fruits; and h) respiratory rate was determined by incubating fruits of known mass and volume in hermetic flasks of known volume; after one hour, CO_2 concentration in flasks was determined by a Check Mate 9900 O_2/CO_2 PBI Dansensor A/S, DK-4100 gas analyzer, and respiratory rate results were expressed in mL CO_2 kg^{-1} h^{-1}; five replications with three fruits per treatment were used.

A standard deviation analysis was applied to the results. Differences between two treatments exceeding two standard deviations were considered to be significant.

Results and Discussion

Fruits treated with 1-MCP and stored at 25ºC showed slower loss of green skin color than non-treated fruits (Figure 1). On the 4th day of storage, non-treated fruits presented yellow color (h^o = 102); they were on their last suitable day for commercialization, while fruits from the remaining treatments retained greenish-yellow skin color. From the 4th day of storage, there was fast loss of green color in fruits treated with 100 and 300 nL L^{-1} 1-MCP. Fruits treated with 900 nL L^{-1} 1-MCP showed the greatest retention of skin color. On the 8th day of storage these fruits were still slightly green.

Loss of green skin color is due to chlorophyll molecule breakdown by the chlorophyllase activity. The increase

in the activity of this enzyme is generally associated with ethylene production during fruit ripening (Tucker, 1993). The product binds to the ethylene binding site in cells, inhibiting ethylene action on the physiologic processes of ripening (Serek et al., 1995). Therefore, loss of green color resulting from the normal ripening process was delayed by the application of 1-MCP. Green color retention in fruits treated with 1-MCP has also been observed in plums (Abdi et al., 1998), bananas (Golding et al., 1998), tomatoes (Dupille & Sisler, 1995) and papayas (Jacomino et al., 2002).

Pulp was pink in the placental region at harvest (chroma = 34.5) and became intense red after ripening (chroma = 41.5 to 43.0). Chroma defines the variation in color intensity, with greater chroma values indicating more vivid colors. The fruit's pulp color was affected by the application of 1-MCP. Fruits treated with 1-MCP present slower increasing in the chroma of pulp color as

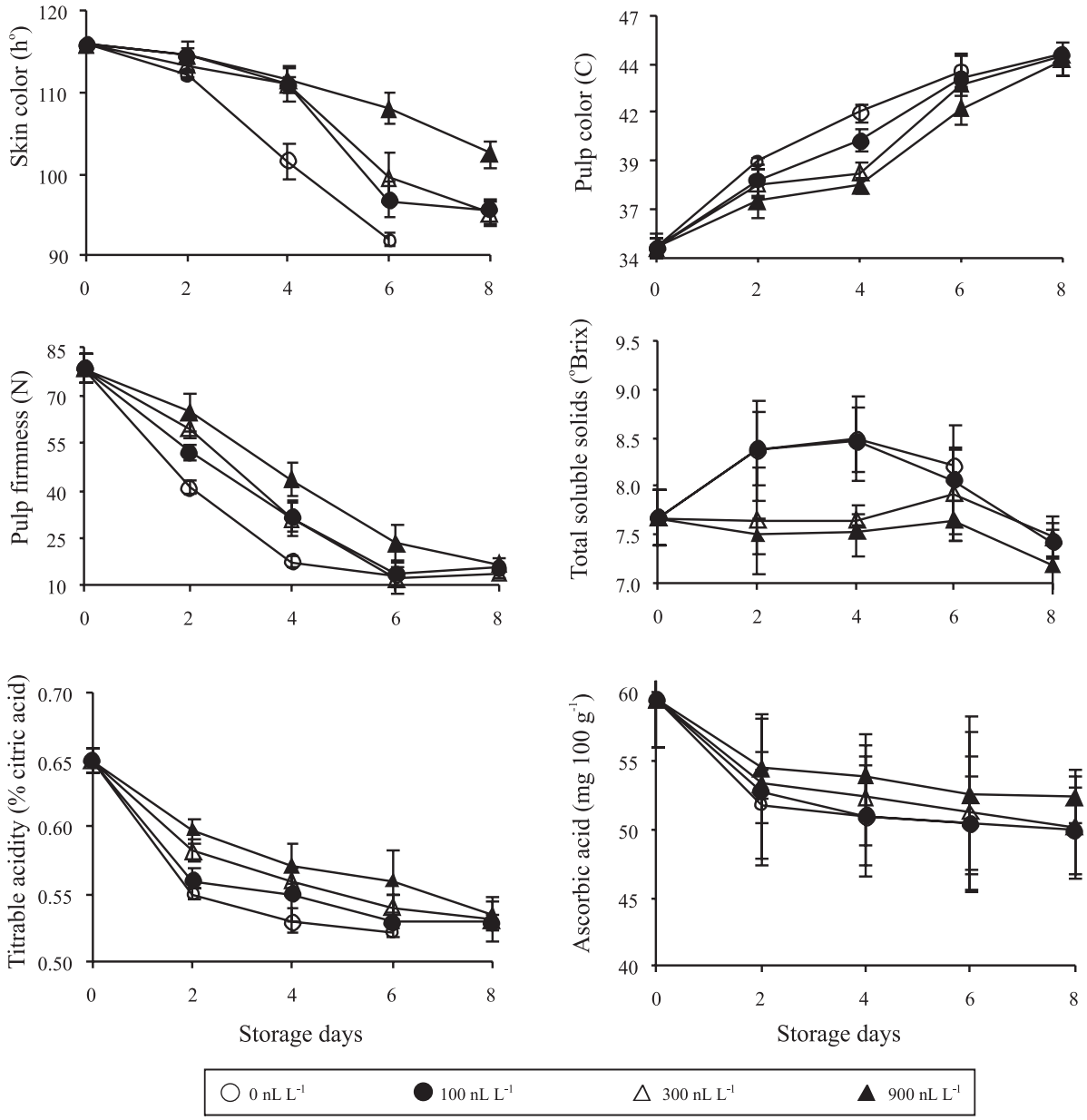

Figure 1. Physicochemical characteristics of 'Pedro Sato' guavas treated with 1-MCP for 3 hours, and stored at 25ºC.

shown in Figure 1. On the 6th day of storage, there was little difference among treatments for pulp color. New ethylene binding sites were, probably, synthesized in the pulp, promoting fruit ripening and making color more vivid (increasing chroma) (Figure 1).

Guava fruits show high reduction in firmness during ripening, which constitutes a major conservation problem; treatment with 1-MCP efficiently preserved this quality characteristic. Non-treated guavas showed 78.7 N firmness at harvest and 17.0 N on the 4th day of storage. Fruits treated with 100 or 300 nL L^{-1} reached values around 17.0 N firmness on the 6th day of storage and those treated with 900 nL L^{-1} on the 8th day (Figure 1).

Firmness of fruit pulp is determined by cohesion among pectins, and in ripening evolution pectinolytic enzymes turn insoluble into soluble pectin and promote fruits softening, which is one of the ripening processes most sensitive to ethylene (Lelièvre et al., 1997). Firmness increasing of fruits treated with 900 nL L^{-1} 1-MCP is probably associated with reduction in the activity of pectinolytic enzymes induced by smaller ethylene action. Similar results were observed in apple (Fan et al., 1999), banana (Jiang et al., 1999) and papaya (Jacomino et al., 2002).

Soluble solids amount was lower in fruits treated with 300 and 900 nL L^{-1} 1-MCP (Figure 1), due to the fact that 1-MCP probably delays fruit ripening. The amount of sugars usually increases along with fruit ripening through biosynthesis processes or degradation of polysaccharides (Chitarra & Chitarra, 1990). Lower amounts of soluble solids in fruits treated with 1-MCP were also verified in other studies (Watkins et al., 2000; Botrel, 2002).

The amount of organic acids usually decreases during ripening, because they are substrates of respiration (Wills et al., 1981). In general, amount of citric acid decreased during storage, which was more evident in fruits not receiving 1-MCP. In treated fruits, the higher was the regulator concentration, the greater was the retention of acidity (Figure 1).

Ascorbic acid amount ranged from 50 mg 100 g^{-1} to 53 mg 100 g^{-1} of pulp and was not influenced by 1-MCP (Figure 1).

The percentage of fruit rot during storage at 25ºC was affected by 1-MCP treatment (Figure 2). *Colletotrichum gloeosporioides* was the most frequent fungus. Non-treated fruits showed high percentage of rot (above 30%) on the 4th day of storage. High percentages of rot were observed from the 6th day of storage in fruits treated with 100 or 300 nL L^{-1} 1-MCP, and from the 8th day of storage in fruits treated with 900 nL L^{-1} 1-MCP. In guava, postharvest rot increases along with ripening (Jacomino, 2001). Although 1-MCP is not a fungicide and does not have protective nor eradicating effect on pathogens, it shows indirect benefits in fungi control of fruit decaying by delaying ripening.

Only fruits treated with 900 nL L^{-1} 1-MCP showed a considerable reduction in the respiratory rate at 25ºC, presenting values between 44 mL and 66 mL kg^{-1} h^{-1} CO_2 (Figure 3). Fruits from the remaining treatments

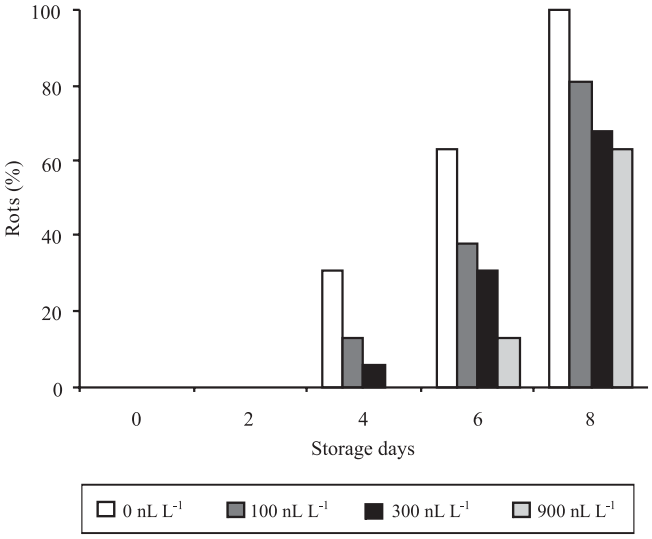

Figure 2. Rot incidence in 'Pedro Sato' guavas treated with 1-MCP for 3 hours, and stored at 25ºC.

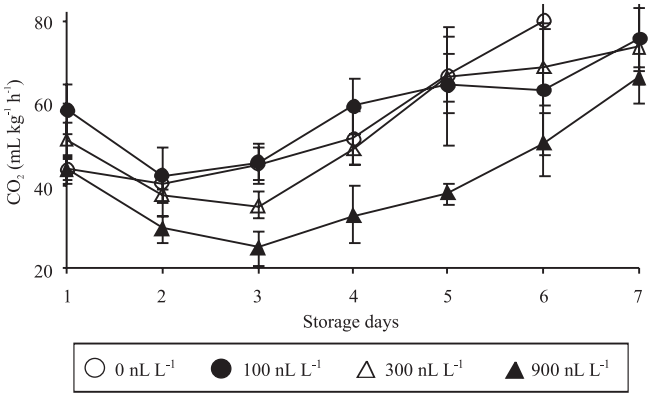

Figure 3. Respiratory rate of 'Pedro Sato' guavas treated with 1-MCP for 3 hours, and stored at 25ºC.

showed similar respiratory activity among them with values between 51 mL and 80 mL kg^{-1} h^{-1} CO_2. When applied at the right time 1-MCP blocks ethylene binding sites and prevents the ethylene effects, such as the increase in respiratory rate (Serek et al., 1995). Conservation of a vegetable product is inversely related to the respiratory rate and, in many cases, also to ethylene production rate (Kader, 1994). The reduction in respiratory rate accounts for better conservation in fruits treated with 900 nL L^{-1} 1-MCP. Lower respiratory rates in fruits treated with 1-MCP were also observed by other authors (Abdi et al., 1998; Golding et al., 1998; Fan et al., 1999; Jiang et al., 1999; Jacomino et al., 2002).

As for fruits stored at 10ºC, little reduction in green skin color was observed while they were under refrigeration (Figure 4). After being transferred to room conditions (25ºC), non-treated fruits or fruits treated with 100 nL L^{-1} showed evident loss of green color, which intensified with lengthening of the storage period. Treatments 300 and 900 nL L^{-1} effectively retained the green color of fruits, so that even after two days in room conditions guavas were predominantly green, presenting average values for hº from 107 to 110, regardless refrigerated storage period.

Storage under low temperatures reduces enzymatic activities (Hardenburg et al., 1986). Therefore, the loss of green color, resulting from normal ripening process, was delayed in refrigerated storage and because of 1-MCP application. The retention of skin color in fruits treated with 1-MCP and stored in refrigerated conditions was also verified in pears (Fan et al., 2002).

Treatment with 1-MCP efficiently delayed loss of pulp firmness during 10ºC/25ºC refrigerated storage only at 900 nL L^{-1} concentration (Figure 5). Fruits treated with 100 nL L^{-1} or 300 nL L^{-1} showed fast loss of firmness not differing from non-treated fruits on the 8th day of storage. Fruits treated with 900 nL L^{-1} showed higher firmness than other treatments during all storage periods. Greater firmness in fruits, treated with 900 nL L^{-1} 1-MCP, is probably associated with reduction in the activity of pectinolytic enzymes induced by lower ethylene activity, and low storage temperature (Lelièvre et al., 1997).

Total titratable acidity was influenced by 1-MCP. Fruits treated with 1-MCP showed greater amounts of citric acid than non-treated ones, regardless 1-MCP concentration used (Figure 5).

Retention of fruit ripening due to refrigerated storage and due to the use of 1-MCP promoted lower incidence of fruit rots. Fruits kept at 10ºC showed low rot incidence. Some rot incidence was observed only in the treatment without 1-MCP on the 16th day of storage (incidence <15%). When fruits treated with 1-MCP remained at 25ºC for two days, rot percentage was low (<20%) until the 12th day of storage, while non-treated fruits showed 63% of rot incidence (Figure 5). Jacomino et al. (2002) also observed lower rot incidence in papayas

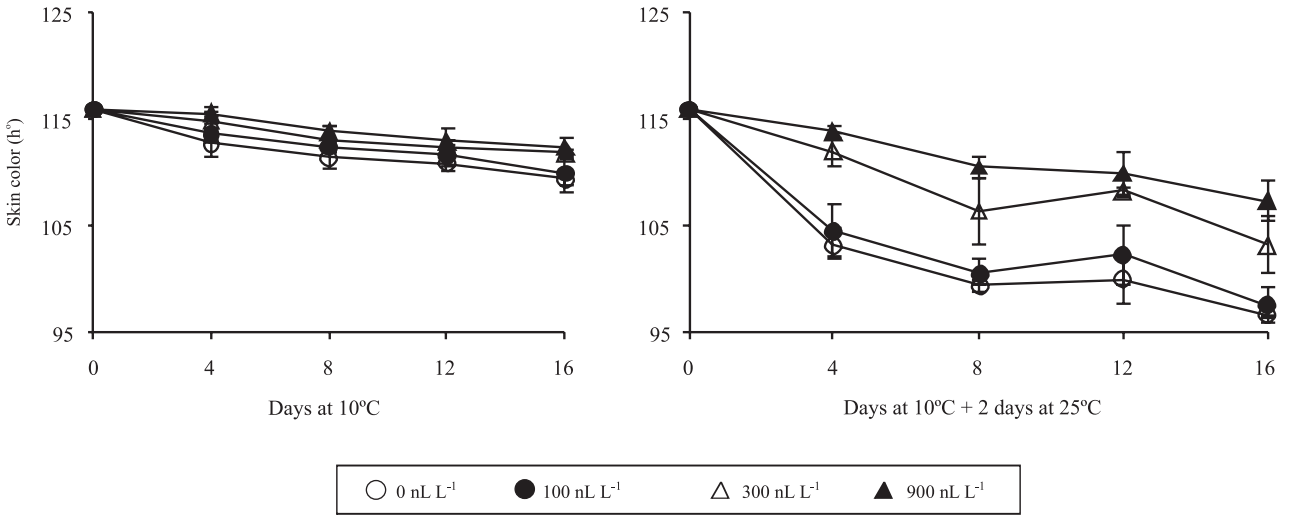

Figure 4. Skin color of 'Pedro Sato' guavas treated with 1-MCP for 3 hours, and stored at 10ºC and at 10ºC + 2 days at 25ºC.

treated with 1-MCP. *Colletotrichum gloeosporioides* was identified as the main fungus causing rot in guavas.

Pulp color, soluble solids amount and vitamin C amount were not influenced by 1-MCP at 10ºC/25ºC storage temperatures (Figure 5).

Fruits stored at 10ºC showed little variation in respiratory rate along the storage period, with values ranging from 10 mL to 15 mL kg^{-1} h^{-1} CO_2 regardless treatment (Figure 6). Such values were much lower than those observed for fruits kept at 25ºC.

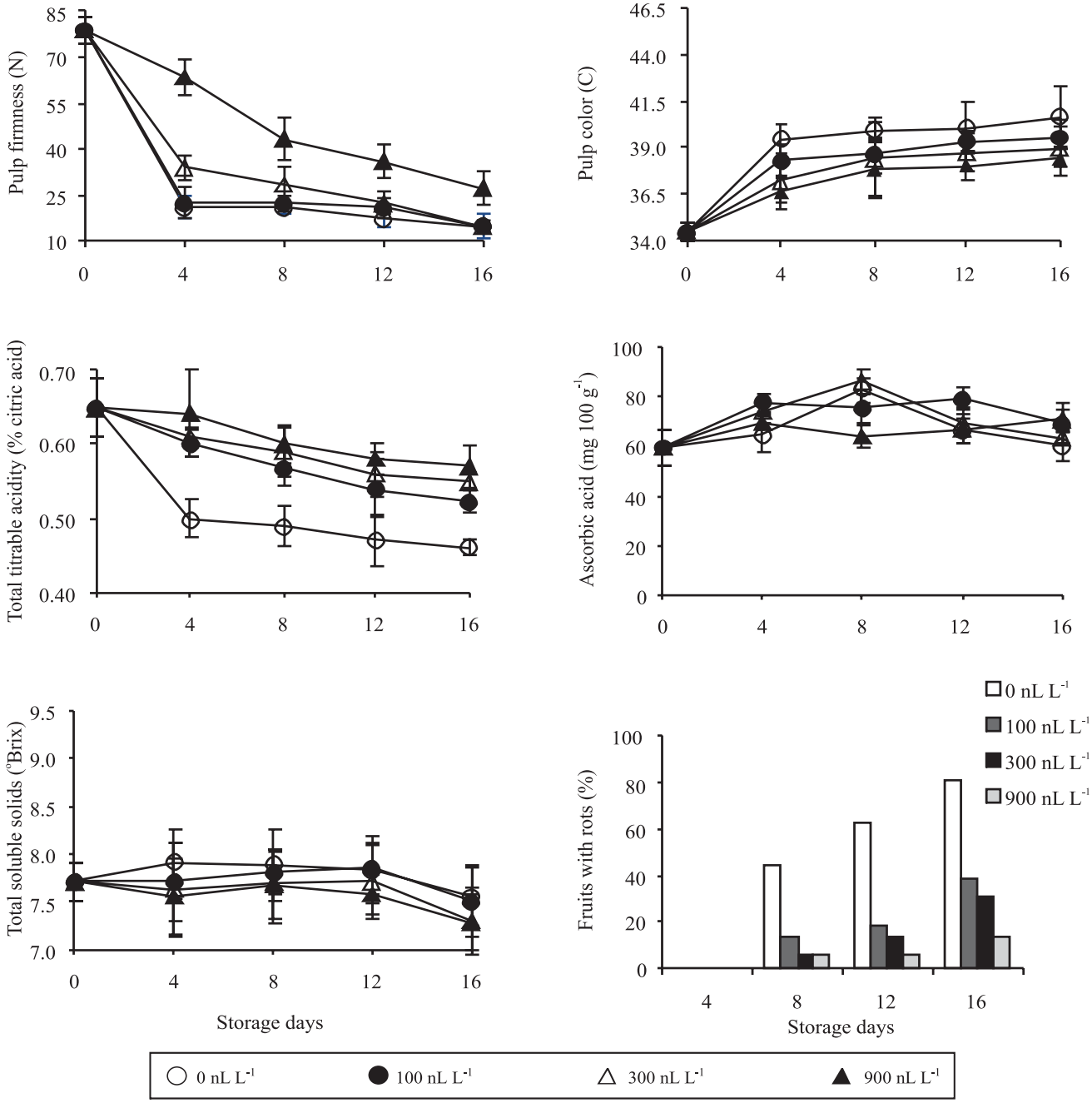

Figure 5. Physicochemical characteristics of 'Pedro Sato' guavas treated with 1-MCP for 3 hours, and stored at 10ºC + 2 days at 25ºC.

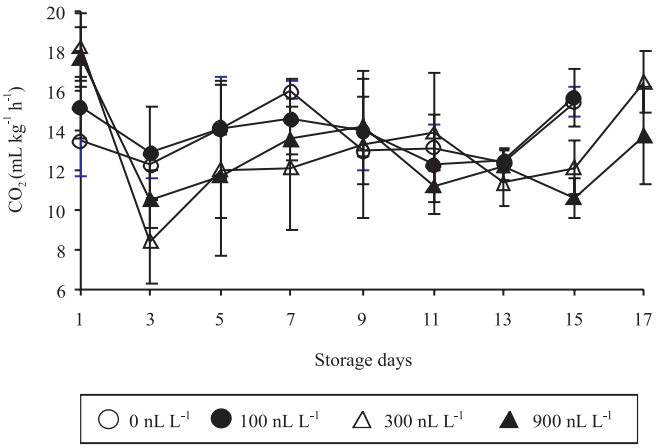

Figure 6. Respiratory rate of 'Pedro Sato' guavas treated with 1-MCP for 3 hours, and stored at 10ºC.

Conclusions

1. Treating fruits with 1-MCP for 3 hours is efficient in delaying ripening in guavas fruits.

2. The concentration 900 nL L^{-1} 1-MCP is efficient in delaying ripening under 10ºC and 25ºC storage temperatures.

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