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Ripening of sapodilla fruits (*Manilkara zapota* [L.] P. Royen) treated with 1-methylcyclopropene after refrigeration

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An experiment was conducted during the year 2010 to evaluate the effect of the treatment with 1-methylcyclopropene (1-MCP) on the ripening process of sapodilla fruits, after refrigeration. The fruits were exposed to 0 and 1 µL/L of 1-MCP for 24 h in airtight chambers at 25°C, after which they were stored at 16°C for four periods of refrigeration (0, 11, 18 and 25 days). At the end of each refrigeration period, the samples were allowed to ripe at 25°C. The results demonstrated the effectiveness of 1-MCP in significantly delaying (P≤0.05) the ripening process of sapodilla fruits and extending the post-harvest life to 28 days. It was possible to observe a reduction and delay in the climacteric maximums of ethylene and respiration, and a delay in the maximum activity of the pectin methyl esterase enzyme (PME), while weight loss was also reduced. In general, the quality characteristics of ripe fruits were maintained, except for a significant increase in the total soluble solids content of the fruits treated. These results indicate that the treatment with 1-MCP, combined with refrigeration, is an adequate alternative for increasing the shelf life of sapodilla with the aim of facilitating its commercialization.

Key words: Sapodilla, 1-methylcyclopropene, ripening, post-harvest, shelf life, refrigeration.

INTRODUCTION

The sapodilla (*Manilkara zapota* (L.) P. Royen) is a fruit species native to the tropical Americas which is said to have originated from southern Mexico. The fruit is sweet with a pleasant aroma and is greatly appreciated by a significantly large group of consumers (Balerdi and Shaw, 1998; Ma et al., 2003). India is the main producer of sapodilla, with a production of 1,346,000 tons (Indian Horticulture Database, 2010). The production of this fruit in Mexico is estimated at 20,000 tons, mainly from the states of Campeche, Yucatán and Veracruz (SAGARPA, 2011).

Physiologically, sapodilla fruits exhibit a climacteric

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behavior in postharvest (Lakshminarayana, 1979); ripening occurs rapidly and is characterized by a significant increase in the respiration rate and ethylene production, all of which classify it as a highly perishable fruit with a short shelf life, making its commercialization more difficult. Depending on the variety and the agro-climatic conditions of production, the fruit ripens at 26°C between 8 and 10 days after harvesting (Morais et al., 2006). Any increase in the shelf-life of this product, therefore, would contribute to an improvement in its commercialization.

The fact that the sapodilla is highly perishable due to its climacteric nature, has made it necessary to study technologies of postharvest management that prolong its shelf life and favor its commercialization in more distant markets (Ganjyal et al., 2003). Ethylene action inhibitors, 1-methylcyclopropene (1-MCP) has been found to delay the ripening process and the onset of senescence in fruits. In their study, Sisler and Serek (1997) reported that 1-MCP, when used at very low concentrations (0.0025-1.0 µL/L), blocks the ethylene receptors, preventing the physiological action of this phytohormone on plant tissue. It has been demonstrated that this compound influences the physiological responses of the fruit during ripening, which include ethylene production, respiratory intensity, tissue softening, weight loss and degradation of the cell wall (Blankenship and Dole, 2003; Watkins, 2006). The activity of 1-MCP has been studied in a wide range of fruits with the objective of delaying the ripening process, prolonging shelf life and maintaining quality; for example, in apples (Kashimura et al., 2010), papaya (Manenoi et al., 2007), pears (Calvo and Sozzi, 2009), plums (Luo et al., 2009) and mangosteen (Piriyavinit et al., 2011).

As a plausible alternative for prolonging the shelf-life of sapodilla, this study evaluated the effect on the ripening process of fruits treated with 1-MCP following a period of refrigeration.

MATERIALS AND METHODS

Fruit procurement

Five hundred and forty (540) sapodilla fruits were harvested in November, 2010 from an orchard located in the municipality of Cansahcab, Yucatan. The quality of fruits was selected based on the stage of physiological maturity. Maturity was determined by the absence of latex (Sulladmath and Reddy, 1990) and a less grainy texture of the peel (Araújo et al., 2001). At the time of harvest, the fruits were averaged of the following characteristics: average weight 200 g, a length of 10 cm, firmness 196 N and acidity of 0.27 g of malic acid/100 g of fresh pulp. The samples were then transported to the laboratory for analyses.

Treatment of fruits with 1-MCP

135 sapodilla fruits were placed into airtight chambers (0.07 m^3) and exposed to 1 µL/L of 1-MCP (SmartFresh, Rohm and Haas, USA) for 24 h at 25°C. Moreover, 135 fruits were placed in the similar airtight chambers with the same temperature and treatment time conditions but without the 1-MCP treatment (0 µL/L of 1-MCP for 24 h at 25°C). The respective dose was calculated based on product weight and container volume, considering that 1.6 g of powder releases 1.0 µL/L of 1-MCP in 1.0 m^3. The compound, previously weighed, was dissolved in a flask with 25 mL of distilled water at 40°C (Akbudak et al., 2009) and the mixture was shaken until the powder had dissolved completely. Subsequently, each flask was placed inside each airtight chamber containing the fruit to release the vapour of 1-MCP. The period between harvesting and the initiation of the treatments was two days.

After the treatment, a group of untreated fruit and fruit treated with 1-MCP were stored at 16°C (with refrigeration) for 11, 18 and 25 days, while the remaining fruit were kept at 25°C for ripening (without refrigeration). After each period of refrigeration, fruit were removed from storage and kept at 25°C until the ripening process was complete. The experiment was conducted with two replications. During the ripening period at 25°C, respiration rate, ethylene production, percentage of ripe fruits, percentage of weight loss and firmness were determined daily to reach the ripening of sapodilla, while the activity of the pectin methyl esterase enzyme (PME) was measured every second day.

When the fruits reached ripeness-consumption stage (this being characterized by the time the fruits were soft to the touch), a group of untreated fruit and fruit treated with 1-MCP were removed in order to measure titratable acidity, total soluble solids, reducing sugars, color and luminosity of the pulp.

Ethylene production and respiration rate

Respiration and ethylene production were measured daily using the same fruits of each treatment. Three fruits from each replication were sealed for 2 h at 25°C in 2 L plastic containers prior to gas sampling. A 2 mL gas sample was withdrawn by a syringe through a rubber septum and analyzed by a gas chromatograph (Varian Star model 3400, Walnut Creek, CA, USA). Carbon dioxide and ethylene were determined using a thermal conductivity detector (TCD) and flame ionization detector (FID) respectively, with a Porapak Q column. Injector and detector temperatures were both set at 250°C, and an isothermal program was run at 30°C. Helium was used as the carrier gas at a flow rate of 1 mL/min. Based on areas of standard gasse, concentrations of carbon dioxide and ethylene were calculated. Respiration rate was expressed as mL/kg/h while ethylene production rate was expressed as µL/kg/h.

Ripening and physico-chemical characteristics

The determination of ripeness for consumption was based on changes in firmness (softening) and was characterized as the moment at which the fruit was soft to the touch (Téllez et al., 2009). The result was expressed in percentage of ripe fruits.

The accumulated weight losses were measured in percentage with respect to the initial weight of the fruits; ten individually weighed fruits were used each day after treatment. The measurement was made with a digital balance (OHAUS, Adventure Pro AV3102, USA) and results were expressed as percentage.

For the determination of soluble solids content (SSC, °Brix), titratable acidity (TA) and reducing sugar, five ripe fruits per replication were homogenized and the homogenates filtered through a cheese cloth to obtain clear juice. SSC was determined by a digital refractometer (Model PR-1, Atago, Tokyo, Japan) and expressed as

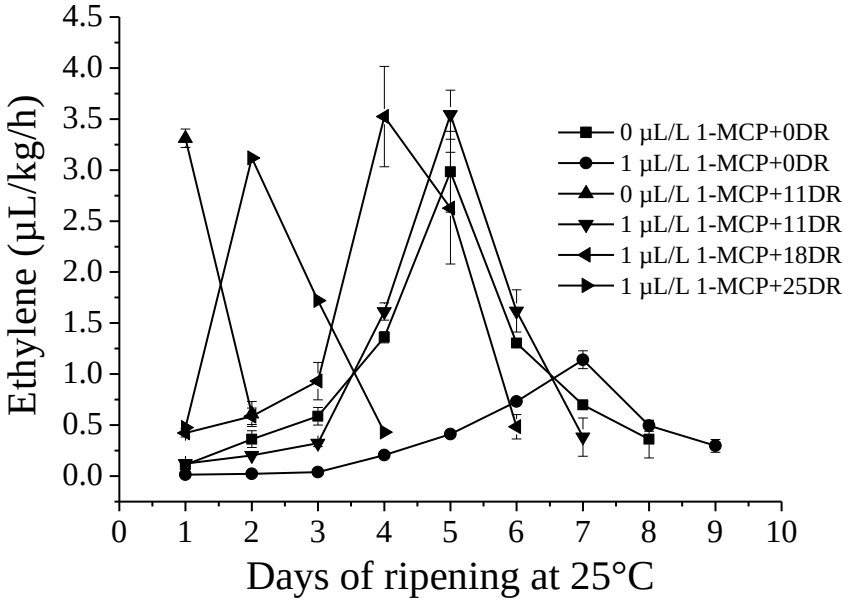

Figure 1. Ethylene production of sapodilla fruit treated with 1-MCP, refrigerated for 0, 11, 18 and 25 days at 16°C and ripened at 25°C. Average values of two replications ± standard deviation. DR: days of refrigeration.

°Brix. TA was determined by titrating 5 mL of juice with 0.1 N NaOH, to pH 8.1 and expressed as grams of malic acid per 100 g. Reducing sugars were determined following the colorimetric method described by Nelson (1944) and Somogyi (1952) and expressed as grams of glucose per 100 g of pulp.

Pulp color was measured with a Minolta portable colorimeter CR-200 (Minolta Co; Ltd., Osaka, Japan). Two measurements in the equatorial area of the pulp fruit were carried out, using ten fruits per replication. The parameters 'L*', 'a*' and 'b*' were measured and the final results were expressed as hue angle (h= arctan[b*/a*]) (McGuire, 1992).

Fruit firmness was determined on whole and unpeeled fruits using an Instron Universal Testing Instrument (Model 4422, Canton, MA, USA) fitted with a flat-plate probe (5 cm diameter) and 50 kg load cell. The force was recorded at 5 mm deformation and was determined at two equidistant points on the equatorial region of each fruit. Ten fruits per treatment were used. The mean values of the firmness were expressed as Newton (N).

Pectin methyl esterase (PME) activity in the fruit was also determined using the method of Ranganna (1979) by the reaction of a sample (4 mL) of enzymatic extract (20 g pulp + 50 mL NaOH 0.2N, pH 7.5) centrifuged (12 500 xg at 4°C for 25 min), with 30 mL of citrus pectin (1%) as substrate and adjustment of pH to 7.5, and the methoxyl groups released by the enzyme per gram of soluble solids per minute (mg methoxyl/g/min) were quantified. Five fruits per treatment were used.

Statistical analysis

For respiration rate and ethylene production two replicates per treatment were used with three fruits per each replica, while for titratable acidity, total soluble solids, reducing sugars and activity of pectin methyl esterase enzyme (PME) two replicates per treatment were used with five fruits per each replica.

For physiological loss of weight, percentage of ripe sapodilla, color, luminosity of the pulp and firmness two replicates per treatment were used with 10 fruits per each replica. The physiological loss of weight and percentage of ripe fruit were plotted with program Sigma Plot for Windows ® V. 2.01, indicating the average and standard deviation. The data obtained for the other variables were statistically analyzed by the analysis of variance (ANOVA) using a completely randomized design and the means were compared with Tukey's multiple-range test at $P<0.05$ level.

RESULTS AND DISCUSSION

Ethylene production rates

Maximum ethylene production of the fruits treated with 1-MCP, without exposure to refrigeration but with subsequent ripening at 25°C, was significantly lower in comparison with the control fruit, in which the climacteric peak of ethylene appeared on the seventh day with 1.14 µL/kg/h for the treated fruit and on the fifth day with 2.98 µL/kg/h for the control (Figure 1). This would indicate that the treatment with 1-MCP delayed the climacteric maximum by two days in the treated fruit, in comparison with the untreated fruit. The effect of 1-MCP may be a result of the compound blocking the sites of ethylene action at cell level, thereby impeding the perception of the phytohormone and the concomitant gene expression which

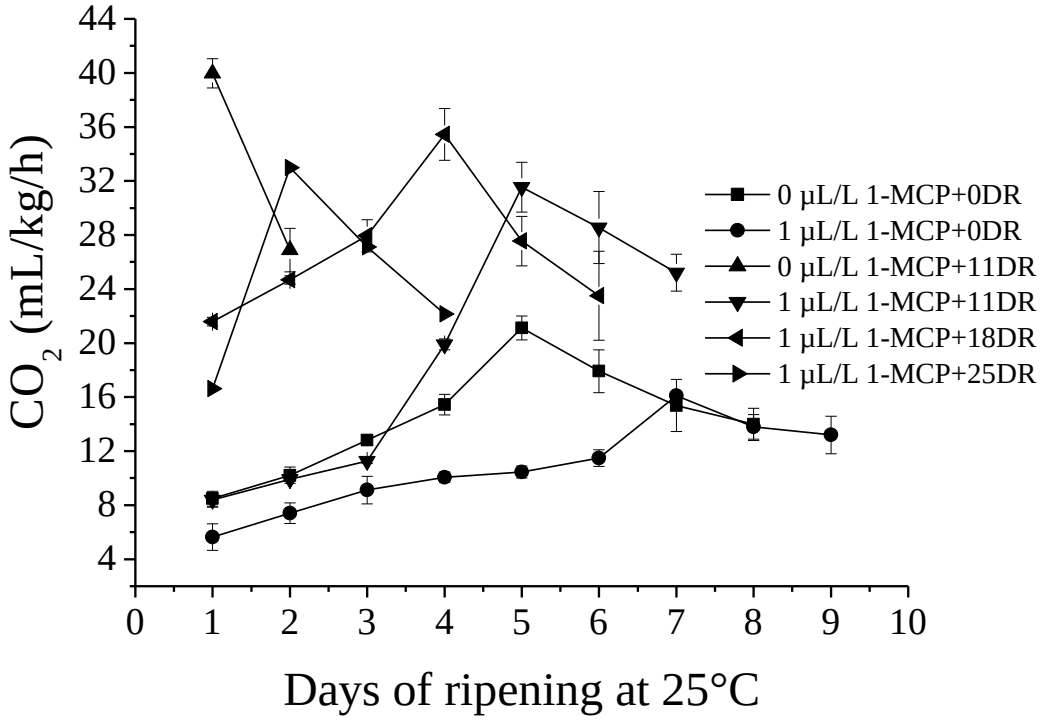

Figure 2. Production of carbon dioxide in sapodilla fruit treated with 1-MCP, refrigerated for 0, 11, 18, and 25 days at 16°C and ripened at 25°C. Average values of two replications ± standard deviation. DR: days of refrigeration.

participate in its biosynthesis (Binder and Bleecker, 2003). In this sense, other studies have shown that I-MCP not only delays the appearance of the ethylene peak in fruits such as avocado (Zhang et al., 2013), banana (Zhang et al., 2006), sapodilla (Qiuping et al., 2006) and persimmon (Luo, 2007), but also reduce ethylene production in fruit species such as pears (Villalobos-Acuña et al., 2011), apples (Watkins and Nock, 2012) and mangosteen (Piriyavinit et al., 2011).

After 11 days of storage at 16°C, a similar result was obtained for the ethylene climacteric peak in fruits treated with 1-MCP (3.54 µL/kg/h) and the control (3.31 µL/kg/h) when they were compared at 5 and 2 days of exposure to the ripening conditions (25°C), in the same order (Figure 1). In this case, the only observation was that the treatment with 1-MCP significantly delayed the climacteric maximum by 3 days, in comparison with the control.

It is important to note that the untreated fruit reached ripeness for consumption in cold storage (16°C) after 16 days, suggesting advances in the ripening process during refrigeration.

As the period of refrigeration was extended, ethylene production in the fruit treated with 1-MCP increased to 3.52 µL/kg/h (18 days at 16°C) and 3.12 µL/kg/h (25 days at 16°C) when they were transferred to the fourth and second day of ripening, respectively. From this we can assume that the treatment followed by refrigeration prolongs the shelf life of the sapodilla fruit.

These results indicate that the treatment with 1-MCP influences the climacteric maximum of ethylene, thereby prolonging the shelf life of sapodilla fruit in ripening conditions after a period in cold storage.

Respiration rates

According to the results obtained for carbon dioxide production (Figure 2), the maximum respiratory rate recorded for the fruit treated with 1-MCP without cold storage was significantly lower (16.10 mL/kg/h) on the seventh day of ripening at 25°C in comparison with untreated fruit (21.12 mL/kg/h on the fifth day), indicating that the treatment was responsible for delaying maximum respiratory intensity in the fruit by two days as compared to the respective controls.

Moreover, maximum production of carbon dioxide in treated fruit (31.55 mL/kg/h on the fifth day of ripening) after 11 days of refrigeration was lower in comparison with untreated fruit (39.97 mL/kg/h on the first day of ripening) (Figure 2). This would suggest that the compound

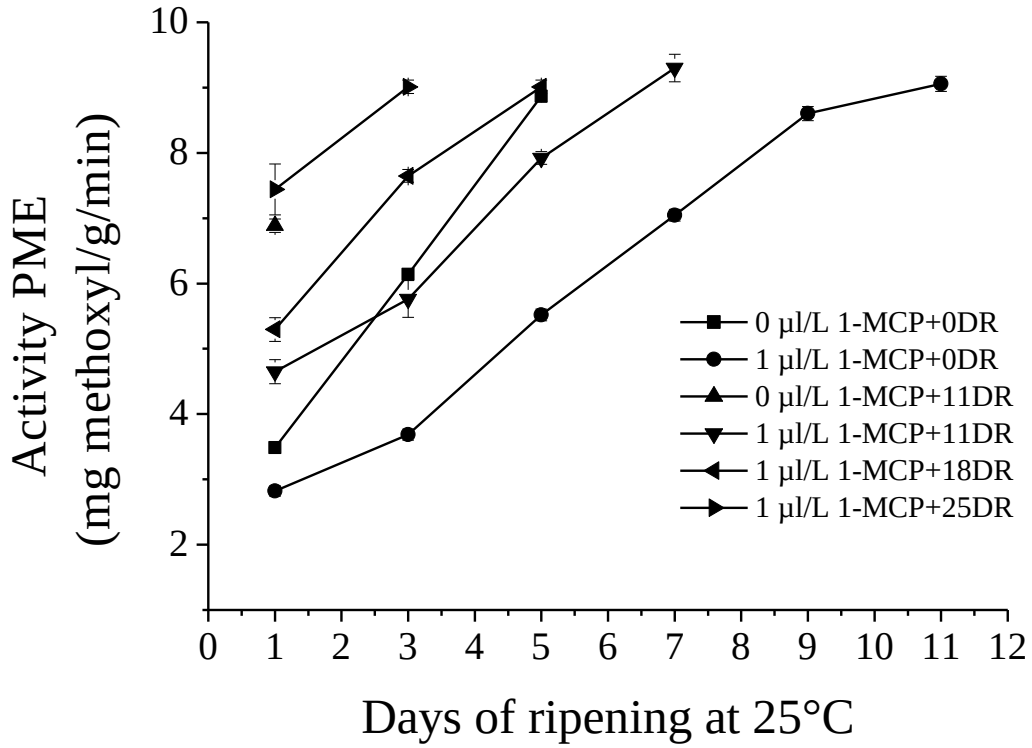

Figure 3. Activity of the pectin methyl esterase enzyme (PME) in sapodilla fruit treated with 1-MCP, refrigerated for 0, 11, 18 and 25 days at 16°C and ripened at 25°C. Average values of two replications ± standard deviation. DR: days of refrigeration.

caused a reduction in carbon dioxide production and a delay of 4 days in the maximum respiratory rate, in comparison with the control. The evidence appears to indicate that changes in the respiratory intensity of the fruit are dependent on ethylene action (Golding et al., 1998), which is linked to fruit and vegetable deterioration; therefore, a delay or reduction in the respiration rate prolongs the shelf life of fruits (Perera et al., 2003), a situation which is similar to that of this work. The reduction of respiratory intensity in fruit and vegetables due to the action of 1-MPC has been observed in a number of studies for example in banana (Zhang et al., 2006), avocado (Jeong et al., 2002), sapodilla (Qiuping et al., 2006) and persimmon fruit (Luo, 2007). Moreover, the maximum respiration of avocados was delayed for 6 days and reduced in magnitude by approximately 40% due to the treatment with 1-MCP (Blankenship and Dole, 2003).

After the extended refrigeration period, treated fruits showed similar values of respiratory maximums; 35.44 mL of carbon dioxide/kg/h (18 days at 16°C) on day four of the ripening period and 32.8 mL of carbon dioxide/kg/h (25 days at 16°C) on day two, resulting in a longer shelf life for sapodilla fruit.

These results suggest, therefore, that treatment with 1-MCP had an effect on the respiratory metabolism of sapodilla fruits after cold storage, thereby prolonging their shelf life and facilitating their commercialization.

Enzymatic activity of pectin methyl esterase (PME)

It is true that the fruit softening process is a consequence of the de-esterification of the pectin catalyzed by PME, followed by a depolymerization catalyzed by PG (Abu-Goukh and Bashir, 2003). In this sense, as can be seen in Figure 3, the maximum PME activity in fruits treated with 1-MCP (9 mg methoxyl/g/min on day 11 of ripening), without cold storage and directly exposed to ripening at 25°C, was similar to controls (9.1 mg methoxyil/g/min on day 5 of ripening). However, this maximum PME activity was delayed (6 days) in treated fruit, in comparison with untreated fruit. It is interesting to note that this maximum enzymatic activity coincided with the fruits reaching ripeness for consumption, which would suggest that the treatment was able to delay the ripening process of the sapodilla fruit. Selvaraj and Pal (1984) and Bautista-Reyes et al. (2005) also found increased PME activity in sapodilla during the ripening process, which reached its maximum when the fruit was ripe for consumption. Moreover,

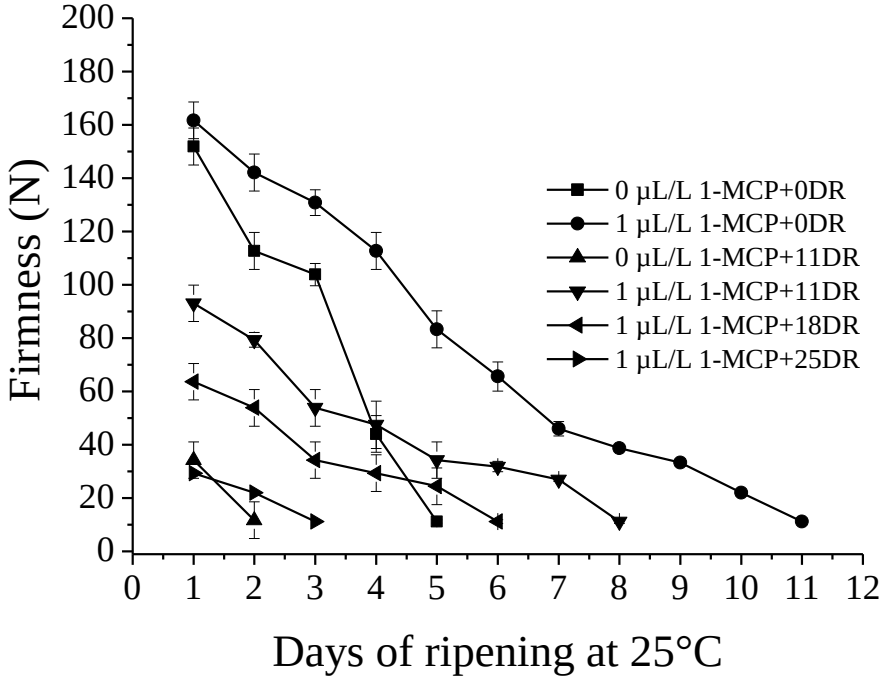

Figure 4. Firmness of sapodilla fruit treated with 1-MCP, refrigerated for 0, 11, 18 and 25 days at 16°C and ripened at 25°C. Average values of two replications ± standard deviation. DR: days of refrigeration.

after 11 days at 16°C and a subsequent ripening period at 25°C, the treated fruits also required more time to reach maximum PME activity (9.3 mg methoxyl/g/min on the seventh day) as compared to the controls (6.9 mg methoxyl/g/min on the first day) (Figure 3). The evidence suggests that 1-MCP was able to prolong shelf life by delaying ripening. Similarly, Jeong et al. (2002) found that the maximum PME activity was delayed in avocados treated with 1-MCP, in comparison with the control, while, Morais et al. (2008) observed that the treatment with 300 nL/L of 1-MCP in sapodilla resulted in a significant delay of maximum PME activity, when compared the untreated fruit.

Furthermore, after 18 and 25 days in refrigeration, the fruits treated with 1-MCP showed similar values for maximum PME activity on reaching ripeness for consumption (Figure 3).

These results demonstrated that the treatment with 1-MCP exerted considerable influence on the maximum activity of the PME enzyme, thereby prolonging the shelf life of sapodilla with the aim of facilitating the commercialization of this species.

Firmness

The firmness of treated and untreated fruits, without exposure to refrigeration, decreased to values of 11.27 N at 11 and 5 days of ripening, respectively, from which we can assume that loss of firmness was delayed for up to six days in treated fruit in comparison with untreated fruit (Figure 4). It is important to note that the value of firmness (11.27 N) coincided with the fruit reaching ripeness for consumption. A similar response was observed after 11 days in refrigeration. This situation would suggest that the delay in loss of firmness of the treated fruits with 1-MCP may be due to the inhibition of hydrolysis in enzymes such as polygalacturonase (PG), cellulase and pectin methyl esterase (Jeong et al., 2002). Excessive loss of firmness is known to be one of the main limiting factors of the post harvest shelf life of climacteric fruits (Skog et al., 2003). It has been reported that 1-MCP maintains firmness in climacteric fruits (Blankenship and Dole, 2003), a situation which, in the case of the sapodilla, is confirmed by the number of days required to reach a firmness in relation to ripeness for consumption. In other studies, 1-MCP has been shown to delay the loss of firmness in Mexican plum and summer squash (Osuna-García et al., 2011; Massolo et al., 2013).

Similarly, Morais et al. (2008) found that sapodilla fruit treated with 300 nL/L of 1-MCP, presented a slower rate of softening in comparison with untreated fruit.

On the other hand, the firmness of treated fruit decreased

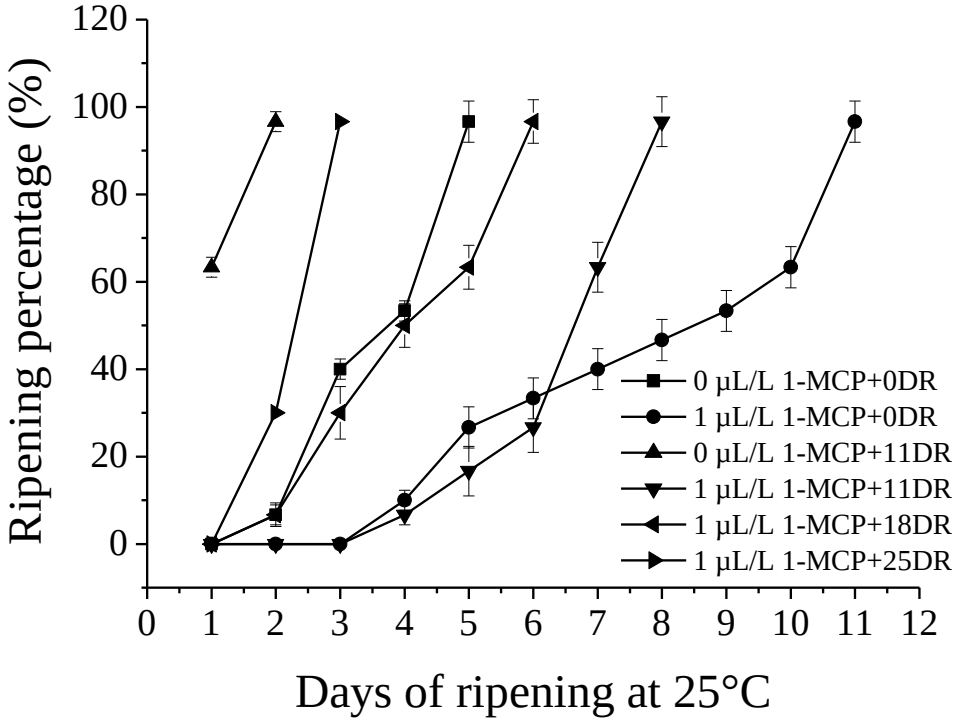

Figure 5. Percentage of ripe sapodilla fruit treated with 1-MCP, refrigerated for 0, 11, 18 and 25 days at 16°C and ripened at 25°C. Average values of two replications ± standard deviation. DR: days of refrigeration.

to 11.27 N on the sixth and third day of ripening, after 18 and 25 days in refrigeration, respectively. This result indicates that, as the period of refrigeration was extended, the loss of firmness in the fruit was correspondingly faster during the ripening period at 25°C (Figure 4).

In general, the fruit treated with 1-MCP maintained higher values of firmness during the ripening process in comparison with untreated fruit; however, at the end of the ripening period similar values of firmness were obtained with no significant differences. In this sense, one of the advantages of maintaining higher values of firmness is that this reduces the risk of mechanical damage to the fruit (Perez-Vicente et al., 2002), which is one of the most important causes of quality loss in fruit production (Amorim et al., 2008).

Ripening of sapodilla

The fruits treated with 1-MCP, without exposure to refrigeration, required more time to reach ripeness for consumption at 25°C (11 days), in comparison with untreated fruit (5 days), with no changes in the percentage of ripening (91.6-95.8%) (Figure 5). This evidence indicates that 1-MCP significantly delayed ripening up to six days.

After 11 days of refrigeration, the fruit treated with 1-MCP showed a delay in ripening of 6 days when compared with the untreated fruit, confirming the efficiency of the compound in delaying the ripening process of sapodilla. In relation to this, 1-MCP is a compound that is capable of preventing ethylene action and has also shown to be effective in reducing the post harvest deterioration rate of fruits (Menniti et al., 2004), and thus represents an enormous potential for extending the shelf life of a diversity of fruits. Moreover, it has also proved effective in delaying ripening in pears (Liu et al., 2005), sapodilla (Morais et al., 2006), banana (Pelayo et al., 2003), jujube (Li et al., 2011) and papaya (Moya-León et al., 2004).

After extending the refrigeration period to 18 and 25 days, the treated fruit reached ripeness for consumption on the sixth and third days at 25°C, respectively. Thus, we can affirm that the treatment and refrigeration prolonged the shelf life of this fruit up to 28 days (Figure 5).

Physiological loss of weight

Figure 6 shows that the treatment with 1-MCP in fruit samples that were not refrigerated resulted in a reduction in weight loss on the third (4.55%) and fifth day (7.91%) of ripening at 25°C, in comparison with untreated fruit (5.43% for day 3 and 9.24% for day 5). Similarly, after 11

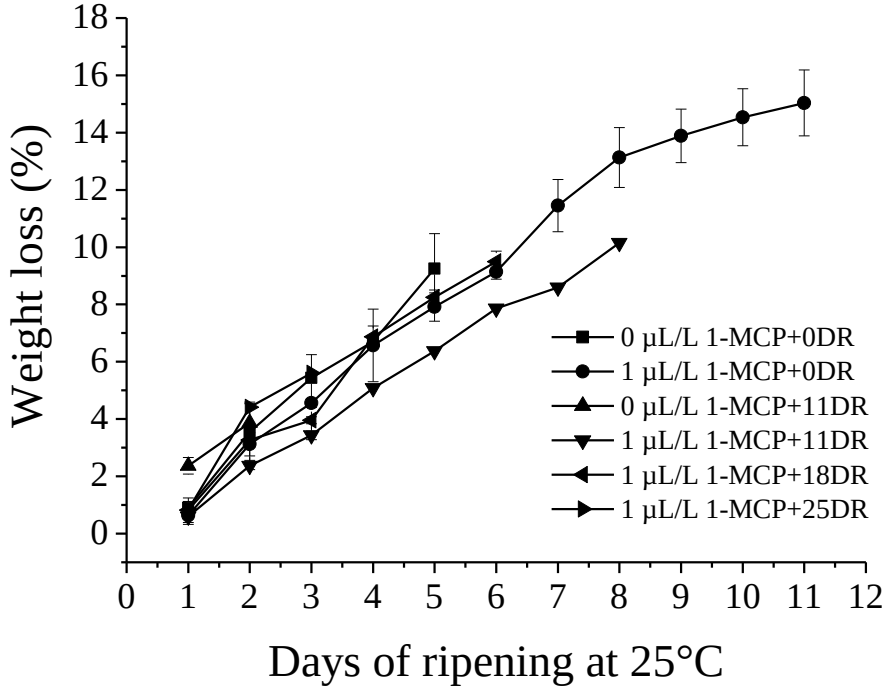

Figure 6. Percentage of weight loss in sapodilla fruit treated with 1-MCP, refrigerated for 0, 11, 18 and 25 days at 16°C and ripened at 25°C. Average values of two replications ± standard deviation. DR: days of refrigeration.

days of refrigeration, the fruit treated with 1-MCP also showed a reduction in weight loss on day 1 (0.59%) and 2 (2.36%) of ripening at 25°C, as compared to untreated fruit (2.37% for day 1 and 3.87% for day 2). When the treated fruit reached ripeness for consumption, weight loss was greater in comparison with untreated fruit, indicating that the treatment with 1-MCP only reduced weight loss for short periods during the ripening process at 25°C.

In another result, the fruits which were treated and refrigerated at 16°C for 18 days presented lower values of weight loss on day 2 (3.27%) and on day 3 (4.42%) of ripening, as compared to treated fruits which were refrigerated for 25 days (4.42% on day 2 and 5.60% on day 3), indicating that weight loss increased as the refrigeration period was extended for treated fruits with 1-MCP (Figure 6).

It is important to point out that results obtained in other studies suggest that the effect of 1-MCP on weight loss may differ. In some cases, it was observed that 1-MCP had no effect on weight loss, as reported by Franco-Rosa et al. (2013) for orange. In contrast, Osuna-García et al. (2011) reported that 1-MCP reduced weight loss in Mexican plum.

The results of this study indicate that the post harvest application of 1-MCP to sapodilla fruit had an influence on the reduction of weight loss but only for short periods during the ripening process at 25°C.

Effect of 1-MCP on the main physico-chemical characteristics of sapodilla

When treated and untreated fruits reached ripeness for consumption at 25°C, after refrigeration for 0, 11, 18 and 25 days, no statistically significant differences were observed in titratable acidity (0.11-0.12 g of malic acid/100 g), reducing sugars (9.9-10.0 g of glucose/100 g), pulp color measured as hue angle (79.5-80.3°hue) and lightness (50.0-50.8 L*) (Table 1). In relation to this, a number of studies have reported that 1-MCP does not affect the evolution of acidity in fruits such as apples and oranges (Salvador et al., 2003; Franco-Rosa et al., 2013). It does not affect the change in color of fruits such as apricots, plums and berries (Dong et al., 2002; Gong et al., 2002). Treatment with 1-MCP has also been shown to have no effect on sugar content in summer squash (Massolo et al., 2013), indicating that 1-MCP does not affect sugar metabolism (Salvador et al., 2003).

On the other hand, the total soluble solids content of treated fruit was significantly higher (between 21.0 and 21.5 °Brix) when compared with that of untreated fruit (19.5 °Brix) (Table 1). This increase in soluble solids

brought about by 1-MCP has also been observed in papaya (Hofman et al., 2001). We might infer, therefore, that this effect on treated fruits could be attributed to their low respiration rate; however, we must keep in mind that it also depends on the cultivation and storage conditions (Blankenship and Dole, 2003).

The results obtained in this study indicate that the only significant effect of the post harvest application of 1-MCP to sapodilla was an increase in the total soluble solids content (°Brix) of treated fruit, without affecting the other physico-chemical characteristics of sapodilla pulp. The similar values observed for the characteristics evaluated in ripe fruit, both treated and untreated, indicate that, although 1-MCP delays the physiological activity of sapodilla fruit, the ripening process undergoes virtually no modifications, resulting in a fruit product with normal characteristics of quality.

Conclusions

In general, we can conclude that the treatment with 1-MCP (1 µL/L) and subsequent refrigeration at 16°C resulted in a prolongation of the post harvest shelf life of sapodilla fruit of up to 28 days (25 days at 16°C and 3 additional days in ripening conditions at 25°C). Furthermore, the treatment with 1-MCP significantly reduced the climacteric maximum and respiration rate of mature fruit at 25°C after refrigeration and also delayed the onset of their respective maximums, from 1 to 7 days.

In the fruit treated with 1-MCP, maximum activity of the PME enzyme was reached over a longer period of time, in comparison with untreated fruit, while the treated fruit also maintained greater values of firmness. However, when the fruit reached ripeness for consumption, the values of PME activity and firmness were similar in all the treatments.

The ripening process of both treated and untreated fruits proceeded normally and in a similar fashion, the only details of note is that 1-MCP significantly reduced physiological loss in weight over short periods during ripening and provoked a slightly significant increase in total soluble solids, from which we can affirm that 1-MCP, combined with refrigeration, is an adequate alternative for increasing the shelf life of sapodilla with the aim of facilitating its commercialization.

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