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Effects of 1-Methylcyclopropene Treatments on Ripening and Quality of Harvested Sapodilla Fruit

*Zhong Qiuping[1,2], Xia Wenshui[1] and Yueming Jiang[3]**

[1]School of Food Science and Technology, Southern Yangtze University, 214036 Wuxi Jiangsu Province, PR China

[2]Food Department, South China University of Tropical Agriculture, 571737, Danzhou Hainan Province, PR China

[3]South China Botanic Garden, The Chinese Academy of Sciences, Guangzhou Leyiju 510650, PR China

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Summary

Sapodilla fruits were exposed to the ethylene action inhibitor 1-methylcyclopropene (1-MCP) at 0, 40 or 80 nL/L for 24 h at 20 °C. Fruits were then stored at 20 °C and 85–95 % relative humidity and later assessed for quality and ripening characteristics. 1-MCP treatments delayed the increases in the rates of respiration and ethylene production by 6 days. Treatments also delayed by 6 days the increase in polygalacturonase activity. Decreases in ascorbic acid, titratable acidity and chlorophyll content that are normally seen with ripening were delayed. Changes in the content of soluble solids were also slowed compared to untreated fruit. The application of 1-MCP was an effective technology for ripening inhibition and quality maintenance of harvested sapodilla fruit.

Key words: 1-methylcyclopropene, sapodilla fruit, ripening, postharvest, quality

Introduction

Sapodilla (*Manilkara zapota* L.) is a tropical fruit with unique taste and medical functions (*1–3*). In recent years, production of sapodilla fruit has increased greatly (*4*). As it ripens and decays rapidly within 7–9 days at ambient temperature, the fruit is only intended for local markets, due to the lack of effective postharvest technologies (*4*). Thus, development of postharvest technology related to quality maintenance is an essential issue for market expansion of sapodilla fruit.

1-methylcyclopropene (1-MCP) is an effective inhibitor of ethylene action and binds irreversibly to ethylene receptors (*5*). Under ambient temperature and normal pressure conditions, 1-MCP is a gas with the formula of C_4H_6 with a molecular mass of 54. 1-MCP can delay ripening onset of fruits, such as avocado, banana, mango, nectarine, papaya, peach, plum and strawberry, and reduce physiological disorders and quality loss (*6–14*). Application of 1-MCP can potentially extend shelf life and maintain quality of harvested fruits.

To our knowledge, this is the first report on the use of 1-MCP for postharvest treatment of sapodilla fruit. The objective of this research was to evaluate the effects of 1-MCP treatments on ripening inhibition and quality maintenance of harvested sapodilla fruits.

Materials and Methods

Plant materials

Mature sapodilla (*Manilkara zapota* L. cv. Fupiguo) fruits at 90 % maturation with 15.4 % total soluble solids (TSS) were harvested in April 2004 from the XiuDa orchard in Danzhou, Hainan Province, China. Sapodilla fruit (140 kg) was transported to the postharvest labora-

*Corresponding author; Phone: ++86 20 37 252 525; Fax: ++86 20 37 252 831; E-mail: Ymjiang@scib.ac.cn

tory at South University of Tropical Agriculture in open boxes within 25 min. Fruits were selected for similar colour, size, mass, good appearance and lack of defects. They were then randomly divided into lots of 45 fruits for various treatments.

1-MCP treatments

1-MCP was obtained from the Smart Fresh™, Rohm and Haas Co., Italy, with an active ingredient of 0.14 %. The fruits were placed in 20-litre glass jars, sealed and then exposed to 1-MCP for 24 h at 0 (control), 40 or 80 nL/L. 1-MCP concentration was calculated according to the manufacturer's instructions. After 1-MCP treatment, fruits were removed from the jars and kept at (20±1) °C and 80–90 % relative humidity (RH) for assessments. For each treatment, three replications were used. The fruits were sampled and analyzed for respiration, ethylene production rates, firmness, chlorophyll and ascorbic acid content, TSS, titratable acidity (TA), and polygalacturonase (PG) activity. The 1-MCP-treated fruit were sampled after 0, 3, 6, 9, 12, 15, 18, 21 and 24 days, and control fruit after 0, 3, 6, 9, 12 and 15 days of storage, because the control fruit was completely soft after 15 days of storage.

Respiration and ethylene production rates

Ten fruits were sealed for 2 h in a 2-litre glass container, and 1 mL of gas sample was withdrawn by a gas-tight hypodermic syringe and analyzed by a gas chromatograph (Shimadzu GC-9A, Kyoto, Japan). CO_2 was determined using a thermal conductivity detector (TCD) with a Poropak N column, whereas ethylene was determined with a flame ionization detector (FID) and an OV17 capillary column. Respiration rate was expressed as mass of CO_2 in mg/h/kg of fresh mass (FM), while ethylene production rate was expressed as nL/h/g FM.

Firmness

Firmness was determined on intact fruit using a penetrometer (Model L1000S Lloyd, UK) with a 13-mm probe. Six fruits per treatment were used and five points per fruit were selected to determine the firmness. Each firmness value was calculated from the average of five determinations.

Chlorophyll

Fruit peel tissue (0.5 g) was homogenized with acetone, and absorbance of the extract in a final volume of 5 mL was recorded at 663 nm by using a spectrophotometer (UV755B, Shanghai, China). The chlorophyll standard sample was obtained from Sigma Chemical Company. Chlorophyll concentration was determined by the method of Mir *et al.* (*15*) and expressed as mg/100 g FM.

Polygalacturonase (PG) activity

PG was extracted by the method of Pathak and Sanwal (*16*) with a slight modification. All extractions were performed at 4 °C. Pulp tissue (2 g) from six fruits was homogenized in 30 mL of 0.2 M acetic acid buffer (pH=6.0). The homogenate was filtered through four layers of cheesecloth and centrifuged for 20 min at 11 000 × *g* (Beckman, Allegra 64R). The supernatant was then collected as a crude enzyme extract. PG activity was assayed by the method of Tan *et al.* (*17*), using a reaction mixture of 0.2 mL of 0.2 M acetic acid buffer (pH=4.6) containing 3 mg of polygalacturonic acid and 0.4 mL of crude enzyme, with a final volume of 1.0 mL. After the mixture was incubated for 1 h at 37 °C, the reaction was stopped by the addition of 1 mL of dinitrosalicylic acid, then kept for 5 min in boiling water bath, and finally diluted with 8 mL of water. Absorbance at 540 nm was assayed by a spectrophotometer (UV755B, Shanghai, China) by measuring reducing sugars released from polygalacturonic acid. PG activity was expressed as μmol galacturonic acid (GA)/h/g FM.

TSS, TA and ascorbic acid contents

Pulp tissue (30 g) from six fruits was homogenized in a grinder and then centrifuged for 20 min at 14 000 × *g* (Beckman, Allegra 64R). The supernatant phase was collected for analyses of TSS, TA and ascorbic acid concentrations. TSS was determined by using a digital refractometer (Chengdu, China), and TA, expressed as percentage of citric acid, by titration with 0.1 M NaOH, while ascorbic acid was determined by 2,6-dichlorophenol indophenol titration.

Data handling

In all experiments, fruits were arranged in a completely randomized design. Data were subjected to analysis of variance (ANOVA). Least significant differences were calculated to compare data values at the 5 % significance level. Data were presented in figures as means ± standard errors.

Results and Discussion

Respiration and ethylene production rates

As shown in Fig. 1A, respiration rate of sapodilla fruit expressed as mass of CO_2 in mg/h/kg decreased from 38.9 at harvest to 20.5 mg/h/kg of FM after 3 days, then increased progressively, with a peak level of 116 mg/h/kg of FM after 12 days of storage, and finally decreased rapidly, which suggested that sapodilla was a climacteric fruit. Fruit exposed to 1-MCP had a lower respiration rate than control fruit during storage. The inhibition of the respiration enhanced with the increase of the concentration of 1-MCP from 0 to 80 nL/L. 1-MCP treatments delayed the appearance of the respiration rate peak by 6 days. Compared to the respiration rate, similar effects in ethylene production rate by 1-MCP treatments were observed (Fig. 1B).

Firmness

Firmness of sapodilla fruit decreased rapidly during storage (Fig. 2). 1-MCP treatments delayed the decrease in the firmness. After 12 days of storage, fruit treated with 1-MCP at 40 or 80 nL/L exhibited a higher firmness value (31.5 or 37.8 N, respectively), which was significantly higher than that of control fruit (8.5 N).

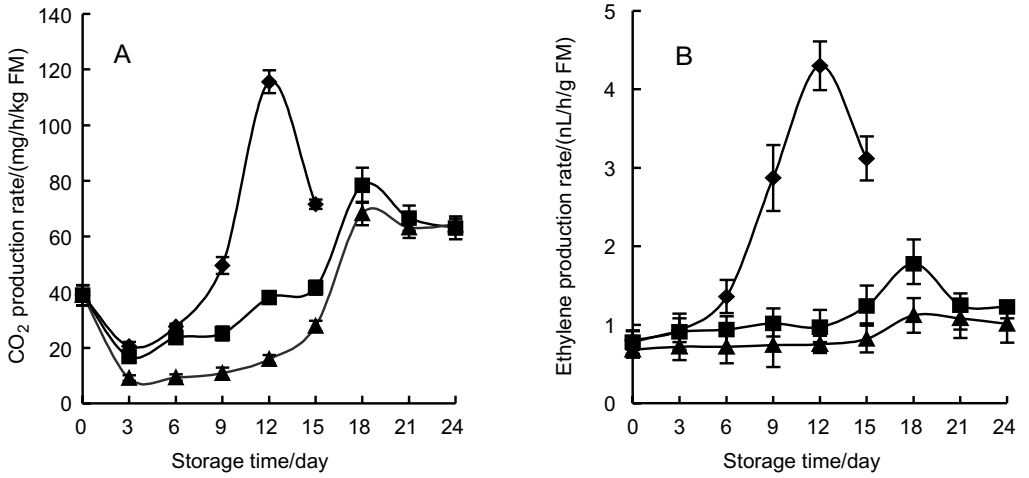

Fig. 1. Effect of treatment with 1-MCP on rates of respiration and ethylene production of sapodilla fruit. Fruits were exposed for 24 h to 1-MCP at 0 (◆), 40 (■) or 80 (▲) nL/L and then stored at 20 °C and 80–90 % RH. Each value is the mean of three replications, and vertical bars indicate the standard error

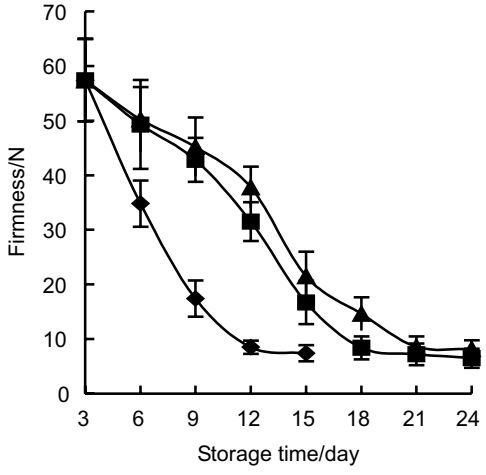

Fig. 2. Effect of treatment with 1-MCP on firmness of sapodilla fruit. Fruits were exposed for 24 h to 1-MCP at 0 (◆), 40 (■) or 80 (▲) nL/L and then stored at 20 °C and 80–90 % RH. Each value is the mean of three replications, and vertical bars indicate the standard error

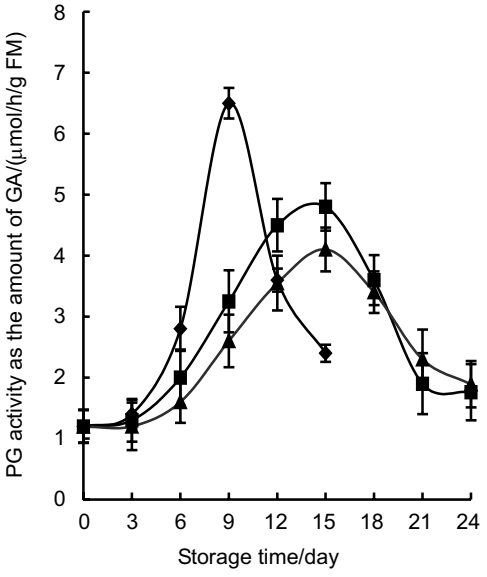

Fig. 3. Effect of treatment with 1-MCP on PG activity of sapodilla fruit. Fruits were exposed for 24 h to 1-MCP at 0 (◆), 40 (■) or 80 (▲) nL/L and then stored at 20 °C and 80–90 % RH. Each value is the mean of three replications, and vertical bars indicate the standard error

PG activity

Delay in fruit softening by 1-MCP treatment was attributed to the inhibition of hydrolysis enzymes, such as PG (*18*), cellulose and pectin methylesterase (*12*). In this study, sapodilla fruit had a very low PG activity at harvest, but the enzyme activity increased later and then reached a peak before climacteric respiration rate appeared (Figs. 1 and 3). 1-MCP treatment significantly inhibited the PG activity of sapodilla fruit within 9 days of storage, and there was a 6-day delay in the peak of the PG activity when 40 or 80 nL/L 1-MCP was applied to the fruit (Fig. 3).

Chlorophyll content

Chlorophyll content of sapodilla fruit decreased as storage time progressed (Fig. 4). 1-MCP treatment delayed significantly chlorophyll degradation. Feng *et al.* (*18*) and Jiang *et al.* (*19*) reported that exposure of avocado and banana fruits to 1-MCP inhibited chlorophyll degradation and delayed skin colour change, which was attributed to the inhibition of ethylene-induced effects.

Ascorbic acid content

Ascorbic acid content in sapodilla fruit declined gradually during storage. Fruit exposed to 1-MCP had higher ascorbic acid content (Fig. 5). Similar results were reported for pineapples (*20*).

TSS concentration

TSS concentration in sapodilla fruit increased a little and decreased during storage (Fig. 6). Compared to con-

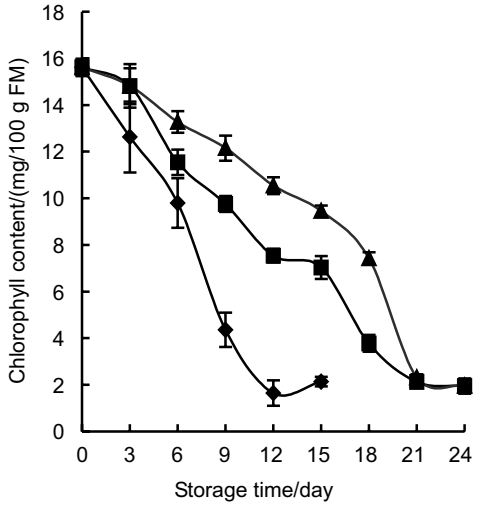

Fig. 4. Effect of treatment with 1-MCP on chlorophyll content of sapodilla fruit. Fruits were exposed for 24 h to 1-MCP at 0 (◆), 40 (■) or 80 (▲) nL/L and then stored at 20 °C and 80–90 % RH. Each value is the mean of three replications, and vertical bars indicate the standard error

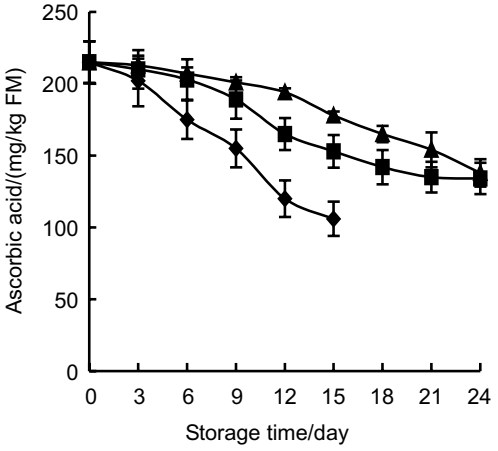

Fig. 5. Effect of treatment with 1-MCP on ascorbic acid content of sapodilla fruit. Fruits were exposed for 24 h to 1-MCP at 0 (◆), 40 (■) or 80 (▲) nL/L and then stored at 20 °C and 80–90 % RH. Each value is the mean of three replications, and vertical bars indicate the standard error

trol fruit, 1-MCP-treated fruits had a higher TSS concentration. Biale (*21*) reported that increase in TSS during fruit ripening was attributed to the increased activity of enzymes responsible for the hydrolysis of starch to soluble sugars. Similar findings were observed in fruits of papaya (*9*) and apples (*22*).

TA concentration

Recent research showed that 1-MCP treatments prevented ethylene-induced acidity loss in carrots (*23*) and delayed or inhibited TA loss in tomatoes (*24*) and plums (*11*). However, Dong *et al.* (*11*) and Porat *et al.* (*6*) found that application of 1-MCP did not affect the content of TA in apricot and Shamouti orange. Thus, the effects of 1-MCP on TA may rely on fruit cultivars and storage conditions. In this investigation, 1-MCP treatment de-

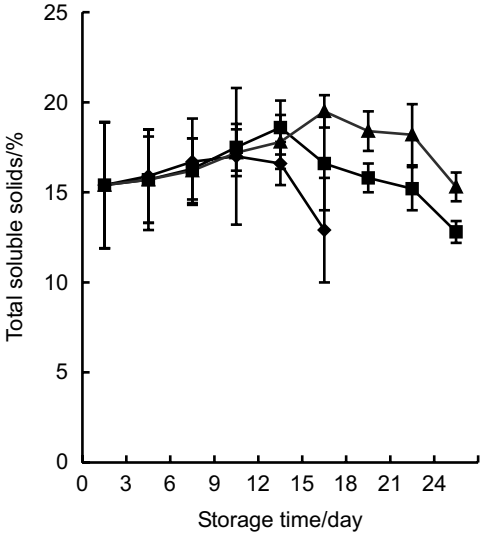

Fig. 6. Effect of treatment with 1-MCP on TSS content of sapodilla fruit. Fruits were exposed for 24 h to 1-MCP at 0 (◆), 40 (■) or 80 (▲) nL/L and then stored at 20 °C and 80–90 % RH. Each value is the mean of three replications, and vertical bars indicate the standard error

layed TA loss of sapodilla fruit during storage, but there was no significant difference at the 5 % level between 40 and 80 nL/L when the fruit was treated with 1-MCP and then stored for the first 12 days at 20 °C (Fig. 7).

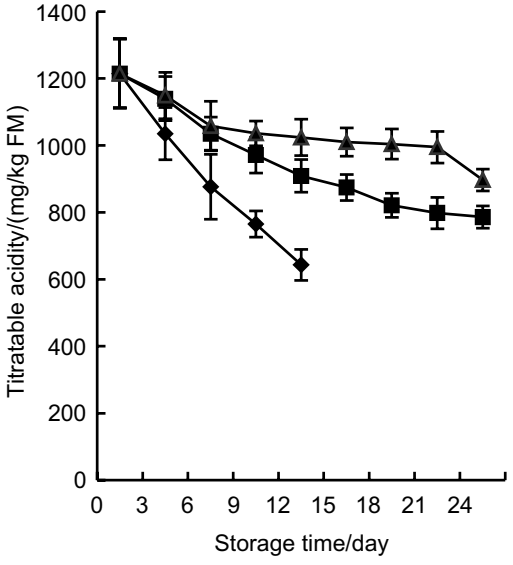

Fig. 7. Effect of treatment with 1-MCP on titratable acidity of sapodilla fruit. Fruits were exposed for 24 h to 1-MCP at 0 (◆), 40 (■) or 80 (▲) nL/L and then stored at 20 °C and 80–90 % RH. Each value is the mean of three replications, and vertical bars indicate the standard error

Conclusion

Exposure of sapodilla fruit to 1-MCP at 40 or 80 nL/L for 24 h at 20 °C inhibited markedly the rates of respiration and ethylene production, and ethylene-induced ripening such as softening and chlorophyll degradation.

1-MCP treatments delayed the appearance of the PG activity peak by 6 days. Fruit exposed to 1-MCP exhibited higher concentrations of TSS, TA and ascorbic acid by the end of storage. This investigation indicated that 1-MCP is a potent ethylene action inhibitor and the application of the 1-MCP is a feasible technology for ripening inhibition and quality maintenance of harvested sapodilla fruit related to expanded marketability.

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