1-MCP application to prolong avocado shelflife

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Abstract

1-MCP inhibits the activity of ethylene by blocking ethylene perception. For climacteric fruits like avocado, 1-MCP application is expected to delay the climacteric process, so as to extend shelf-life. In this study, 1-MCP application was made in two forms, gases with concentrations of 0, 0.2 and 0.4 µL L^{-1}, and a solution with a concentration of 0, 0.3, and 0.6 µL L^{-1}. The results showed that 1-MCP application in the form of gas or solution could extend avocado shelflife up to 2-2.5 times longer than control. Fruit could be stored for up to 16 days after treatment. 1-MCP treatment did not prevent the occurrence of fruit ripening, but delayed it. Exposure treatment with 1-MCP gas and the immersion solution of 1-MCP did not significantly change respiration rate, weight loss and color of the fruit flesh. As the technique of immersion in 1-MCP solution was easier to do, then this technique is recommended.

Keywords: 1-methylcyclopropene, ethylene, α-cyclodextrin, 1-MCP solution, climacteric

INTRODUCTION

Avocado (*Persea americana* Mill.) is a commercial fruit with high economic potential. This fruit also has a high nutrient content of unsaturated fats and is good for health (Ascherio and Willett, 1997). But the fruit shelf life is quite short. Avocado fruit have a high respiration and ethylene production rate. There are several methods to prolong the shelf life of avocado fruit, including the use of $CaCl_2$, polyamine, $KMnO_4$ as an ethylene absorbent, or coating with wax (Wills, 1981; Rahman, 2007). In addition there are also other methods to extend the shelf life of the fruit, by using controlled atmosphere storage (CAS) and cold storage (Kader and Arpaia, 2000). A recent effective technique to increase the shelf life of fruit is the use of 1-methylcyclopropene (1-MCP).

According to Sisler and Serek (1997), 1-MCP is a cyclopropene derivative volatile compounds that has the ability to block ethylene receptors that send signals to ripening fruit. 1-MCP's ability to bind to the receptor is 10 times greater than ethylene. 1-MCP is active at low concentrations (an average of 0.1-1 µL L^{-1}) and is non-toxic (Watkins, 2006). Various studies suggest that 1-MCP gas has the effect of blocking the action of ethylene from various fruits, such as banana, strawberry, pear, pineapple, papaya, tomato, kiwi, melon, and apple (Mahajan et al., 2014; Mohapatra et al., 2013). 1-MCP compounds could potentially be used as an inhibitor of ethylene in ripening avocado (Whiley et al., 2002). 1-MCP affects ethylene biosynthesis in some fruits or vegetables (Blankenship and Dole, 2003). From several studies it is known that 1-MCP as an ethylene inhibitor is more effective than some other compounds such as silver thiosulfate (STS) and diazocyclopentadiene (DaCP) (Serek et al., 1994), aminoethoxyvinylglycine (AVG), and 2,5-norbornadiene (2,5-NBD).

Effect of 1-MCP is a function of dose, storage temperature and physiological growth stage of the product when applied. If fruits or vegetables are stored at low temperatures generally 1-MCP response to ethylene will be longer than at room temperature (although the period of 1-MCP treatment is usually at room temperature (20-25°C, Jiang et al. 2002). Mir et al. (2001) compared the use on apples at 2 and 20°C, indicating that 20°C is the more effective temperature for 1-MCP application. Through various studies, Blankenship and Dole (2003) also concluded that 1-MCP is more effective if applied at a temperature of 20-25°C.

The 1-MCP effects on all the parameters related to banana ripening were enhanced by low temperature storage and reduced by high temperature storage (Jiang et al., 2004). Storage or ripening duration at room temperature to give a response to ethylene is generally

7-14 days. Jiang et al. (2002) reported that 1-MCP is not effective at extending *Coriander sativum* storage at a temperature of 5-10°C.

In the study conducted, Jiang et al. (2004) note that the contact time with 1-MCP to inhibit banana ripening correlated with the concentration of 1-MCP used. Contact of 1-MCP for 1 h at 20°C was required for a concentration of 1000 nL L^{-1}, while at the same temperature, a contact time of 12 h was required for 50 nL L^{-1}.

There are a couple of 1-MCP application techniques. The most common commercial formulation of 1-MCP is an α-cyclodextrin powder. This substance will release 1-MCP gas if mixed with water (Blankenship and Dole, 2003). 1-MCP application is generally done by exposure of fruit to 1-MCP gas. However, exposure to the gas is less practical and somewhat complicated for farmers because it requires a gas-tight space. This study was conducted by dipping avocado in a solution of 1-MCP for 5 min immediately after α-cyclodextrin powder was dissolved in water. The technique is relatively easy, and it is expected that 1-MCP is still in solution and can affect the avocado fruit dipped in it. This study aims to obtain an application technique and the appropriate concentration of 1-MCP able to extend the shelf life of avocado as well as studying the effects and physicochemical changes that occur during storage of avocado treated with 1-MCP.

MATERIALS AND METHODS

This research was conducted at the Laboratory of Post-Harvest, Department of Agronomy and Horticulture, Bogor Agricultural University in April to May 2011. Avocados used in this study were Miki varieties obtained from growers in Depok, West Java. Uniform Avocado fruit with optimal maturity, approximately 100 days after flower anthesis, a relatively large size (weight 400-600 g), and dark green and somewhat shiny were used.

The experimental design used was a completely randomized design (CRD) with six treatments and three replications level for each treatment, so that there are 18 experimental units. Each experimental unit consisted of nine fruits, so the test used 162 avocados. The treatment consisted of: (a) 1-MCP gas exposure at concentrations of 0, 0.2 or 0.4 μL L^{-1}, and (b) immersion in a solution of 1-MCP at concentrations of 0, 0.3 or 0.6 μL L^{-1}.

For 1-MCP application in the form of gas, the volume of the box container used was 70 L and the volume of avocados fruit used was an average of 10 L. To obtain 1-MCP gas at a concentration of 0.4 μL L^{-1}, 1.72 g of α-cyclodextrin powder is needed. α-cyclodextrin powder was put into a small glass beaker and then 3-7 mL of water (ratio 4:1 to weight of 1-MCP) was added to dissolve α-cyclodextrin and release 1-MCP gas. At the top of the glass cups were placed a small fan to help 1-MCP gas spread to all parts of the box. When the α-cyclodextrin was contacted with water, the box was immediately sealed with the help of an adhesive and then stored at room temperature (24-30°C) for 24 h. After 1-MCP application, avocados were aerated by opening the box lid. For immersion treatment of avocados in 1-MCP solution, initially as much as 10 L of water was put into a large plastic jar. Then powder of α-cyclodextrin weighed according to the concentration of the test was applied to the avocado. To obtain a solution of 0.6 ppm 1-MCP, 0.43 g of α-cyclodextrin powder was required. α-cyclodextrin powder was dissolved in water, avocados were added and immediately after the fruit were immersed, jars were sealed. Avocado fruit soaked in a solution of 1-MCP for 5 min; the control fruits were soaked in water. Avocado were stored at room temperature (24-30°C) and observed every second day for 16 days. The parameters measured were: (a) the rate of respiration by CO_2 production using Cosmotector; (b) weight loss; (c) TSS was measured by refractometer of the juice squeezed from the center of the fruit pulp; (d) fruit hardness using a penetrometer in three places, namely stem end, middle, and blossom end of the fruit. The penetrometer used was Stanhope-Seta with plunger weight of 102 g and additional weight of 50 g. The measurement time was 5 s. Avocado fruit was measured without peeling the skin. Fruit hardness was measured by the depth of the needle penetrating fruit flesh. Parametric data were tested by analysis of variance, if it showed significant effect then it was followed by Duncan's Multiple Range Test at the 5% level. Non-parametric data were tested using Kruskal-Wallis rank test and if it showed a significant effect then Dunn's test was performed at 5% level.

RESULTS AND DISCUSSION

Shelf-life

The parameters used to calculate the shelf-life were to observe the physical changes of the fruit. Application of 1-MCP prolonged the shelf-life of avocado fruit significantly (Table 1). For avocado fruit that were not treated with 1-MCP (concentration of 0 ppm), the shelf-life was only about six days after treatment (DAT). In contrast, application of 1-MCP with different concentrations increased the shelf-life. A 1-MCP treatment was demonstrated to prolong the shelf life of avocado fruit 2-2.5-fold. Treatment of 1-MCP gas at 0.2 µL L^{-1} is the best treatment that was able to achieve a shelf life of up to 16 DAT. However, when viewed from the effectiveness and convenience factors, techniques on 1-MCP application by immersion in a solution with a concentration of 0.3 ppm was better, because even though the shelf-life was somewhat shorter than the gas exposure treatment of 0.2 ppm, this technique was relatively easy to be adopted even by small farmers, the application time was not long, as well as support tools are simple to use and easy to find.

Table 1. Shelf-life (days after treatments) of avocado fruits after 1-MCP treatments at 24-30°C. Three replicate batches of 9 fruit $treatment^{-1}$.

1-MCP		Days after treatment
Gas	0.4 ppm	12 c
	0.2 ppm	16 a
	0 ppm	6 e
Solution	0.6 ppm	10 d
	0.3 ppm	14 b
	0 ppm	6 e

Respiration rate

Avocado fruit respiration followed a climacteric pattern, increasing to a certain extent and then reducing. The most visible effect from application of 1-MCP was shifting the peak respiration rate to the right. This indicates that the respiration rate of avocado fruit when not given 1-MCP (concentration of 0 ppm) was faster than those treated with 1-MCP in the initial DAT. In avocado fruit that was not given 1-MCP, the respiration peak occurred at eight days after treatment (DAT). In the fruit treated with 1-MCP gas concentrations 0.4 µL L^{-1}, respiration peak occurred in 14 DAT with the respiration rate of 204.71 mL kg^{-1} h^{-1} and for a concentration of 0.2 ppm respiration peak occurred in 16 DAT with the respiration rate of 214.41 mL kg^{-1} h^{-1}. When avocado fruit was soaked in a solution of 1-MCP concentration of 0.6 ppm, respiration peak occurred in 12 DAT with the respiration rate of 195.60 mL kg^{-1} h^{-1} and for a concentration of 0.3 ppm respiration peak occurred in 16 DAT with the respiration rate of 213.03 mL kg^{-1} h^{-1} (Figure 1). Treatment of 1-MCP gas at 0.2 µL L^{-1} and immersion in a solution at of 0.3 µL L^{-1} were the best treatments because they inhibited the respiration rate for the longest period.

Respiration rate is a good index to determine the shelf life of fruit. High respiration rate is usually associated with a short shelf-life. Pantastico (1989) states that the rate of respiration is considered as a measure of metabolic rate. Inhibition of respiration rate is followed by a longer shelf-life.

Effect of 1-MCP is an ethylene receptor block, so that ethylene is not able to transmit a signal to accelerate ripening, respiration rate consequently slowed and the result was delayed senescence. Ethylene production increased along with the increase in fruit metabolism. This resulted in 1-MCP is no longer able to block ethylene receptors. At that moment the fruit respiration rate began to increase. This indicates that 1-MCP did not affect the ripeness of the fruit, but only delayed fruit maturity. Research on other commodities shows that in general 1-MCP also slows the rate of respiration. Respiration of bananas, apples, strawberries, and tomatoes can be inhibited by 1-MCP so that the shelf life can be extended (Blankenship and Dole, 2003).

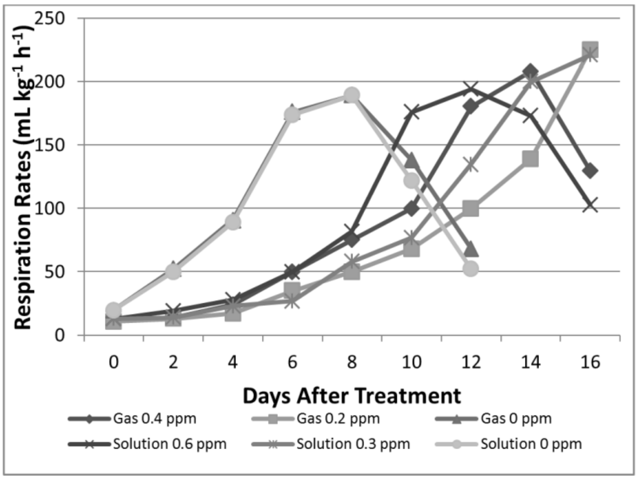

Figure 1. Respiration rates (mL CO_2 kg^{-1} h^{-1}) of avocado fruit after 1-MCP treatment.

Fruit softness

Avocado softness increased during storage indicated by the decreasing resistance of the peel and flesh of fruit to penetrometer needle. Figure 2 shows that up to 2 DAT fruit softness values in all treatments had not undergone significant changes relative to control.

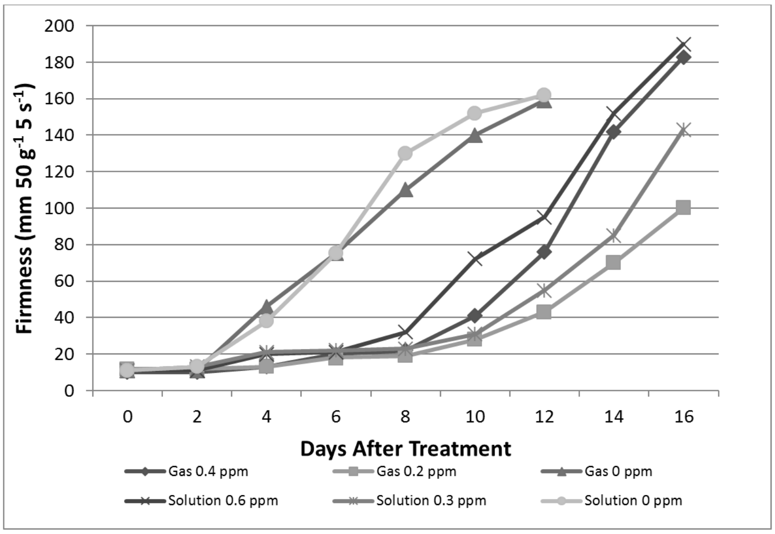

Figure 2. Firmness (mm 50 g^{-1} 5 s^{-1}) of avocado fruit after 1-MCP treatment.

After 2 DAT, the softness of 1-MCP untreated fruit avocado began to increase in the value of softness, and the fruit rot on DAT 12. Application of 1-MCP caused a significant delay in avocado softening. Avocado fruit treated with 0.2 ppm 1-MCP gas has a softness value smaller than the other treatments. This indicates that the treatment was the best treatment to delay softening in avocado. Delaying softening the skin and flesh of the fruit is also one of the indicators for extending the shelf life of avocado fruit.

In 1-MCP untreated (0 ppm) fruit, fruit softness value at the end of the observation (DAT 12) was 75.57 mm 50 g^{-1} 5 s^{-1} (gas) and 97.70 mm 50 g^{-1} 5 s^{-1} (immersion). Decreasing the softness occurred because fruit begins to soften at 4 DAT and ripen perfectly at 6 DAT. In avocado fruit treated with 1-MCP, the fruit can still be observed up to 16 DAT. In the treatment of immersion in a solution of 0.6 ppm 1-MCP, fruit softness decreased significantly at 8 DAT, followed by exposure of 0.4 ppm 1-MCP at 10 DAT, as well as a solution of 0.3 ppm 1-MCP and gas exposure of 0.2 ppm 1-MCP at 12 DAT.

Softening occurs at the climacteric stage of ripening due to the breakdown and dissolution of cell wall pectin. This change is caused by increased activity of enzymes that hydrolyze cell wall components (protopectin, cellulose, and hemicellulose) associated with the signaling molecule maturity. These enzymes are pectin methyl esterase (PME), polygalacturonase (PG), pectate lyase (PL), and cellulase. Softening of the peel and flesh of an avocado is associated with the process of ethylene production due to fruit respiration. Ethylene can stimulate the activity of the enzymes while 1-MCP is thought to suppress the effect of ethylene with delayed activity of these enzymes (Jiang et al., 2002) and stimulate the production of IAA (indole acetic acid) which can inhibit hydrolysis by the enzymes (Luo, 2007).

Total soluble solid

Figure 3 shows the change in total soluble solid of avocados during storage. Total soluble solid (TSS) of 1-MCP untreated (concentration of 0 ppm) fruit increased faster than treated, indicating that the fruit matures faster. Avocado of all treatments reached peak values of TSS approximately 12 °Brix. This suggests that application of 1-MCP does not reduce the levels of avocado sweetness. The role of 1-MCP in this case was to only delay the ripening of fruit without reducing the sweetness of the fruit when the fruit is ripe. Application of 1-MCP significantly delayed the increase of TSS value on DAT 2-16. Increasing in the value of TSS of avocado fruit treated with 0.2 ppm 1-MCP gas and immersion in 0.3 ppm 1-MCP solution was slower than the other treatments (Figure 3). In pineapple, papaya and apples, the total soluble solid is higher after 1-MCP treatment. However, in strawberry, orange, peach, mango, and some types of apples will be lower (Blankenship and Dole, 2003).

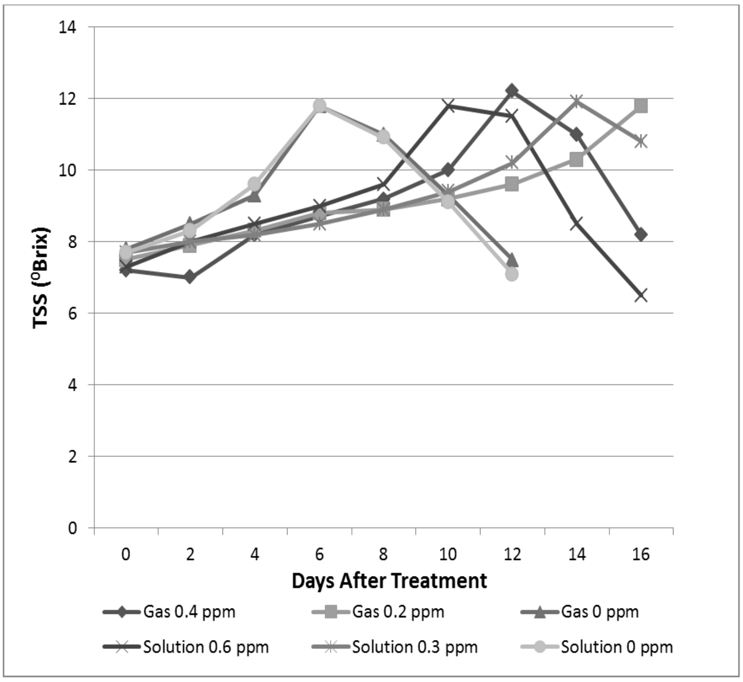

Figure 3. TSS (°Brix) of avocado fruit after 1-MCP treatment.

CONCLUSIONS

1. 1-MCP application in the form of gas or solution could prolong avocado shelf-life up to 2-2.5 times longer than control. Fruit can be stored for up to 16 days after treatment at 24-30°C.
2. 1-MCP treatment did not prevent the occurrence of fruit ripening, but delayed it.

3. Exposure treatment with 1-MCP gas and the immersion solution of 1-MCP was not significantly different in respiration rate, weight loss and color of the fruit flesh.
4. As the technique of immersion in 1-MCP solution was easier to do, then this technique is recommended.

ACKNOWLEDGEMENTS

Thanks to Center for Tropical Horticulture Studies, and Department of Agronomy and Horticulture-Bogor Agricultural University for support and facilities.

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