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Effect of 1-methylcyclopropene treatment on quality of 'Zebra' apricot harvested at different maturity stages

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ABSTRACT

This study focuses on the contribution of maturity stages and 1-methylcyclopropene (1-MCP) treatment to the quality of 'Zebra' apricot. Samples were harvested at mature-green, yellow and orange maturity stages. Fruit were treated with gaseous 1-MCP (24 h at 1 °C), followed by cold storage at 1 °C for 6 weeks. Non-destructive measurements were used to evaluate the quality changes of apricot during storage. The results showed that the maturity stages significantly affected the weight loss. The loss of weight increased rapidly for orange ripeness stage fruit, more than others during storage. Both maturity and 1-MCP affected the stiffness of apricot. The 1-MCP could delay the softening of fruit. The green and yellow maturity stages retained higher values in stiffness compared to orange. No significant difference in hue angle values was observed between 1-MCP treated and control fruit, however hue angle value decreased strongly in mature-

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green harvested fruit. The maturity stages and 1-MCP treatment had the effect on quality changes of apricot over storage. The maturity stage was an important factor contributing to the effectiveness of 1-MCP application as it was observed in slower softening after harvest.

KEYWORDS

storage, non-destructive, stiffness, acoustic firmness, *Prunus armeniaca* L., 'Zebra'

INTRODUCTION

Apricot (*Prunus armeniaca* L.) is a popular fruit because of its attractive orange color and nutritional value, however this produce has a short shelf-life (Rebeaud et al., 2023). Apricot loses its market acceptability rapidly after harvest. For the climacteric fruits, storage at low temperature may prolong their postharvest life but alone is unable to retain the quality during retail (Muftuoğlu et al., 2012). Moreover, the season of apricot is short, therefore the application of postharvest technology on this fruit is necessary to extend shelf life and maintain quality (Nguyen et al., 2016).

The maturity stage of apricot at harvest decides the customer perception (Rebeaud et al., 2023). Ripe apricot should be distributed to the retail market as soon as possible to avoid fruit losses. Apricot harvested at early maturity stage is good for long commercial distance, however, the sensory attributes of fruit do not meet the consumer expectation (Rebeaud et al., 2023). Thus, determining the harvest time is a challenge for producers (Rebeaud et al., 2023).

Recently, postharvest technologies have been applied widely to decrease the quality loss of fruit during storage (Pham et al., 2023). The 1-MCP treatment is an effective procedure for extending the shelf life of fruits and vegetables (Watkin, 2006). Application of 1-MCP and low storage temperature in enhancing the postharvest life and prolonging best quality period of fruit were reported including apple (Baranyai et al., 2020), apricot (Nguyen et al., 2016), melon (Nguyen et al., 2018), pear (Hitka et al., 2014; Nguyen et al., 2022), plum (Ha et al., 2023) and broccoli (Zsom et al., 2020).

The main goal of the presented work was to investigate the effect of gaseous 1-MCP treatment and different maturity stages of 'Zebra' apricot on quality parameters during 6 weeks of cold storage. Three maturity stages were evaluated including mature-green, yellow and light orange. Weight loss, color, stiffness was determined in each 2 weeks. More information about the impact and relationship between maturity and 1-MCP application on quality changes during storage will enhance the postharvest management and distribution of this cultivar.

MATERIALS AND METHODS

Materials

Apricots (*P. armeniaca* L. 'Zebra') have been harvested at three different maturity stages including mature-green, yellow and orange maturity stage directly by the farmer in the middle of July, Hungary. All fruit were transported to the university laboratory (Budapest, Hungary).

The gaseous 1-MCP with 0.14% concentration was used following the recommendations of the provider (AgroFresh, Philadelphia, PA, USA). The applied SmartFresh® system was provided by the company Rohm and Haas Polska Sp.z.o.o. (Warsaw, Poland).

After the 1-MCP treatment, all samples were cool stored in normal air with 1 °C and 90% relative humidity (RH) for 6 weeks.

1-MCP treatment

Apricots with uniform size, shape, and free from defects were selected for the experiment. The average diameter of fruit was 29 ± 4 mm. Each maturity stage had 2 groups (treated and control). Two hundred pieces of each maturity stage were selected. The total amount of 600 pieces of fruit were split into 6 groups randomly, resulting in 3 treated and 3 control (untreated) groups. In result, one group consisted of one hundred fruit. The 1-MCP treatment procedure followed Nguyen et al. (2016). Three groups were treated with gaseous 1-MCP of 650 ppb in an airtight storage cabinet at 1 °C for 24 h. Meanwhile, the three control (untreated) groups were stored at 1 °C.

Measurements

The measurement procedure followed Nguyen et al. (2019). Non-destructive measurements including stiffness and color were used to evaluate the changes of firmness and surface color of fruit. Weight loss and decay of samples were also investigated during 6 weeks of cold storage.

The weight loss of each fruit was measured on the basis of the initial and current values recorded on an electronic balance (Sartorius, Germany). Weight loss was expressed as relative value in percentage of the initial readings following Nguyen et al. (2020).

The firmness of apricots was determined utilizing the induced sonic vibration (Chen and De Baerdemaeker, 1993). The acoustic firmness parameter, named Stiffness (S), was expressed in the unit of $g^{2/3}\,s^{-2}$. The mass and frequency are measured simultaneously, from which this parameter is computed. Measurements were performed at 2 points on the equatorial area with a specific instrument of acoustic firmness (type AFS DTF V0.0.0.105, AWETA, Nootdorp, The Netherlands).

The surface color of apricot was recorded with a portable device (type CR-400, Minolta Corporation, Osaka, Japan). Standard CIELAB color space parameters L^*, a^* and b^* were measured at 2 points on the equatorial area of each fruit.

Sensory evaluation was performed in terms of visual inspection looking for mold growth on the surface. The parameter decay was defined as proportion of fruit with mold infection in the whole group.

Statistical analysis

Collected data were processed and visualized with the software Microsoft® Excel® (version 16.45). Statistical evaluation using analysis of variance (ANOVA) was performed with SPSS version 11.0.1 (SPSS Inc, USA). The threshold of significant differences was adjusted to $P < 0.05$. The results are presented on charts with mean and standard deviation.

RESULTS AND DISCUSSION

Weight loss

The results showed that significant weight loss occurred during 6 weeks of cold storage in all sample groups (Fig. 1). However, the rate of weight loss depended on the maturity of samples. There was no significant difference between mature green and yellow stage in this parameter. The orange apricot had the highest value in weight loss over the storage period regardless of treated or untreated fruit. The result of this work indicated that after 4 weeks of cold storage, around 5.5% of weight loss was recorded for green and yellow maturity stage. Another study also reported that 5.0% loss in weight was observed for 'Cluthagold' apricot after 3 weeks cold storage at 0 °C (Stanley et al., 2013).

1-MCP treatment had no effect on the weight loss. At the beginning until two weeks of the experiment, the difference in weight loss among groups was small, later on the significant difference between orange stage and others was observed.

Stiffness

Firmness is a critical quality measure indicating the degree of ripening of fruit during storage (Baranyai et al., 2020). This parameter shows the changes in the texture of fruit over storage. As shown in Fig. 2, the result of firmness for different groups during 6 weeks at 1 °C. The firmness declined with increasing storage time for all groups, however, the rate of decreasing was different. The untreated groups had a decline in firmness more rapidly than 1-MCP treated samples at the same period. No significant difference between control and treated fruit was observed for orange maturity stage. In contrast, for the green and yellow maturity stages, significant difference was found between treated and control (untreated) apricots. This work showed that 1-MCP treatment can delay the ripening of 'Zebra' apricot at green and yellow maturity stages. Maturity at harvest affected the texture of 'CluthaGold' and 'Larclyd' apricot

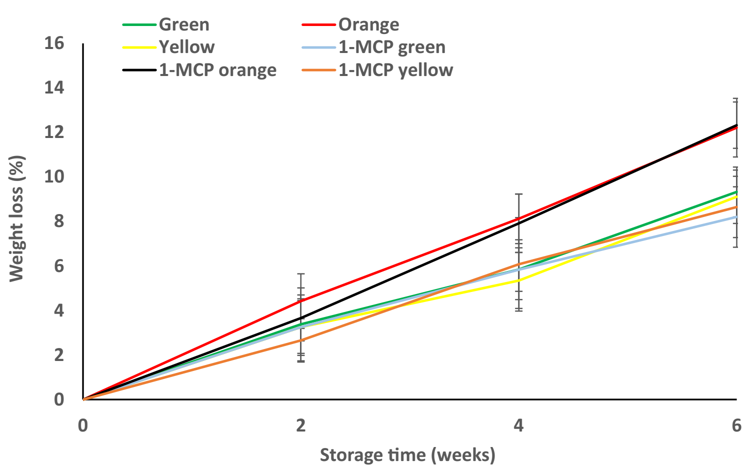

Fig. 1. Effect of 1-MCP and maturity stages on weight loss of apricot during storage

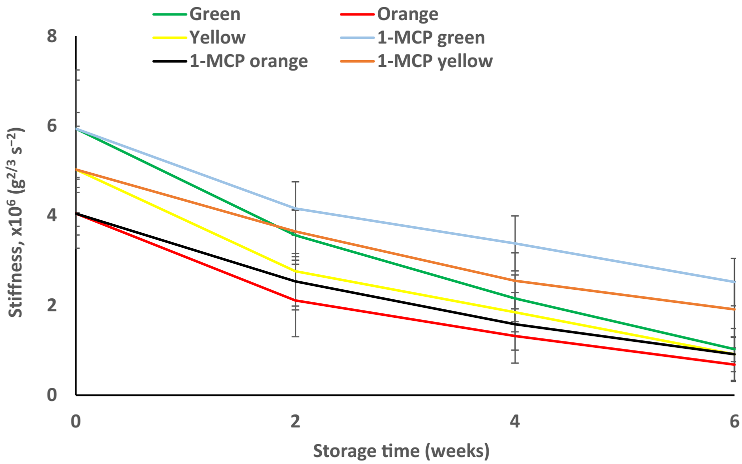

Fig. 2. Effect of 1-MCP treatment and maturity on apricot stiffness during storage

during storage (Stanley et al., 2013). Those authors found that more mature fruit softened quickly after 3 weeks of cold storage for 'Larclyd' apricot (Stanley et al., 2013). The result of this work agrees with Özkaya et al. (2016), who found that 1-MCP treatment enhances the storage time of nectarine, slowing down postharvest ripening and softening. Furthermore, Nguyen et al. (2022) observed that 1-MCP significantly inhibits the decrease of pear firmness. Ha et al. (2023) concluded that 1-MCP reduces the firmness loss of plum fruit as well.

Fruit color

Surface color is also an important indicator for determining the ripening of fruit (Nguyen et al., 2020, 2021). The effects of the applied 1-MCP treatment and different maturity stages on hue angle value of apricot during storage is presented in Fig. 3.

Hue angle value showed a downward trend for all groups during storage. The hue angle value for the green maturity stage declined sharply at the beginning of storage, probably because the surface color of fruit turned from green to yellow. While the surface color of the other maturities changed less, thus the hue angle value of that had small changes. After 4 weeks of storage, the hue angle value remained stable for all groups. The result also showed that 1-MCP had no effect on color change for all maturities. At harvest, the hue angle value of green maturity group had higher value than those of the yellow and orange maturity stages. Also, after 6 weeks of cold storage, hue angle value was higher on green maturity than yellow and orange maturity stage. This result is similar to those of Infante et al. (2008), who observed similar changes for 'Palsteyn' apricot after 6 weeks of cold storage at 0 °C.

Decay

The microbial infection is the main cause of postharvest loss for stone fruit (Fan et al., 2018). The early symptoms of fungal infection were recognized on the 2nd week of storage in the group of orange maturity stage (Table 1). 1-MCP treatment had no effect on decay for all groups. The

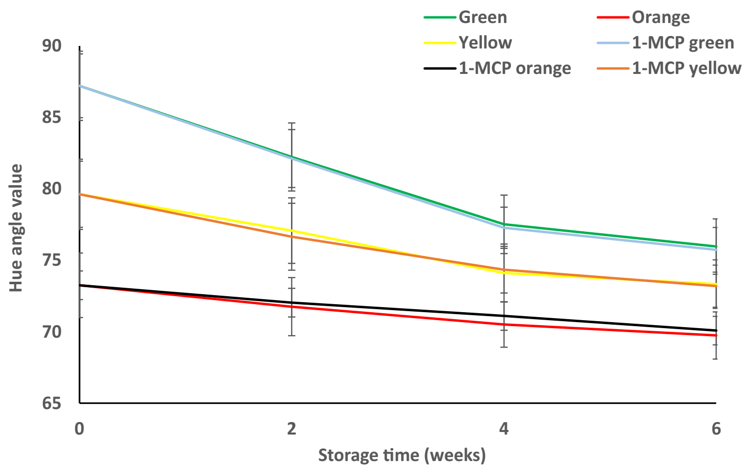

Fig. 3. Effect of 1-MCP and maturity stages on hue angle value of apricot during storage

Table 1. The proportion of decay of apricot in cold storage

Groups	Decay (%)		
	2 weeks	4 weeks	6 weeks
Green	0	2	4
Yellow	0	2	4
Orange	3	6	8
1-MCP green	0	2	5
1-MCP yellow	0	2	4
1-MCP orange	4	5	9

reason behind rapid decay of orange fruit might be their advanced ripening, resulting higher sensitivity to microbial infection. The susceptibility of fruit depended on the maturity stage and the storage time. The collected data are similar to those reported by Fan et al. (2018). They also found that low maturity 'Shushanggan' apricot had less decay than that of medium maturity. This could be explained that tissue membrane permeability of apricots increased with the advanced maturity stage.

Decay was observed to increase monotonously in time for all groups. During the experiment, no chilling injury was found for any maturity stage with cold storage at 1 °C. According to these results, 1-MCP treatment did not affect the decay of 'Zebra' apricot.

CONCLUSION

The result of this study shows that different maturity stages of apricot had different behavior during storage. Similar effect of maturity has been observed for fruits, but physiological response and sensitivity can be cultivar specific. 1-MCP treatment retained texture of 'Zebra' apricot at green and yellow maturity stages. The firmness difference between treated and control fruit had relationship with maturity stages. This suggests early application of 1-MCP treatment, before ripening induced enzymatic changes can develop. The proper postharvest technology is a key to control the ripening of the product. Application of 1-MCP and low temperature storage can be a successful combined technique on climacteric produces in early and middle ripeness stages to extend shelf life in the supply chain.

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