African Journal of Biotechnology Vol. 10(5), pp. 807-814, 31 January, 2011
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB10.1115
ISSN 1684–5315 © 2011 Academic Journals

Full Length Research Paper

Combined effects of 1-methyl cyclopropene (1-MCP) and modified atmosphere packaging (MAP) on different ripening stages of persimmon fruit during storage

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Accepted 20 December, 2010

The aim of this study is to evaluate the combined effects of 1-methyl cyclopropene (1-MCP) applications and modified atmosphere packaging (MAP) to improve the storability of two different harvest maturity stages of 'Harbiye' persimmon fruits during 90 days storage at 1°C. For this purpose, 1-MCP, an ethylene action blocker was applied before MAP storage. 'Harbiye' persimmon fruits were stored for 90 days at 1°C and 90% relative humidity (RH) under two different MAPs after being exposed to 2 µl l^{-1} 1-MCP for 12 h or not exposed to 2 µl l^{-1} 1-MCP for 12 h (control). 'Harbiye' fruit firmness, total soluble solids (TSS) content, pH, titratable acidity (TA), color (H^o) value and ethylene production changes were examined through the efficacy of 1-MCP and MAP treatment. 1-MCP-treated fruits delayed two different harvest maturity, persimmon fruits flesh firmness, and combination of 1-MCP with MAPA and MAPB reduced the ethylene production rate during storage. Treatment of 1-MCP improved storability of persimmon fruits more effectively than MAP storage. However, the results indicated that additional improvement in storage could be obtained by a combination of 1-MCP treatment followed by MAP storage. 1-MCP application maintained fruit firmness more effectively in less mature fruits more effectively than in fully mature fruits.

Key words: Ethylene, harvest, maturity, modified atmosphere, persimmon, 1- methylcyclopropene (1-MCP).

INTRODUCTION

Persimmon (*Diospyros kaki* L.) is an important fruit crop in Turkey. The nutritional assessment of the fruit revealed that it is a good source of ascorbic acid, minerals, fibers and carotenoides (Oz et al., 2004). East-Mediterranean region of Turkey has potential to produce high quality persimmon. It has been reported that persimmon grown in Eastern Mediterranean region of Turkey was free from fruit fly defects. The fruit has been specifically exported to the Middle East countries. Control of ripening is very important for development of persimmon industry in Turkey. The delicate nature of fruit, poor handling and inadequate transportation and storage make its market limited. Persimmon fruits are climacteric fruit whose ripening are regulated by ethylene. Therefore, inhibiting ethylene biosynthesis or action may play an important role in slowing the ripening process and enhancing the storage life of persimmon fruits (Luo, 2007). Ethylene has an undesirable effect on the quality of fresh persimmon fruits. 1- Methylcyclopropene (1-MCP) is a recently developed inhibitor of ethylene action (Sisler and Serek, 1997) and it is effective in delaying further ripening of many partially ripe climacteric fruits and extending storage life of persimmon fruits. Recently, re-search was conducted on the effects of 1-MCP on postharvest behavior of fruits and vegetables with the objective of reducing physiological disorders and quality losses in order to prolong their commercial life. It is important that the fruits treated with 1-MCP reached a good sensory quality at the commercial level (Akbudak et al., 2009). 1-MCP is more effective when fruits are harvested and it is applied immediately after harvest and then stored with modified atmosphere packaging (MAP)

Abbreviations: 1-MCP, 1- Methylcyclopropene; **MAP,** modified atmosphere packaging; **TSS,** total soluble solids, **TA,** titratable acidity; **H^O,** color value.

(Kim and Lee, 2005). MAP of fresh commodities is a successful technology for maintaining quality during storage and marketing (Park and Lee, 2008). Most persimmon fruits are stored and marketed using MAP to retard flesh softening and extend the storage life. On the other hand, in some cultivars, there are reports of injury developing which are related to MAP (Park and Lee, 2008) and that critical O_2 levels which induced MAP storage appear to be responsible for browning disorders in Fuyu persimmon fruits. Many studies have indicated effects of 1-MCP on persimmon fruit quality. However, combined effects of 1-MCP and MAP on early and late harvest maturity stage of 'Harbiye' persimmon fruits quality have not been shown.

The purpose of this study is to determine the combined effects of 1-MCP and MAP on changes in fruit softening, quality and ethylene production changes of two different harvest maturity stages of 'Harbiye' persimmon fruits during storage at 1°C.

MATERIALS AND METHODS

'Harbiye' persimmon is one of the pollination variant cultivar which becomes astringent when it is seedless. Persimmon fruits (*D. kaki* L cv. Harbiye) were harvested at two different maturity stages according to fruit skin color (two thirds of fruit surface was orange color and fully orange color). In the 2008 - 2009 season, 'Harbiye' persimmon fruits were obtained from an orchard in the district of Büyüksır (Kahramanmaraş), then transferred to laboratory of Kahramanmaraş Research Institute in 2 h, where fruits are free from visual defects, uniform weight and shape.

1-MCP treatments

Persimmon fruits were treated with 1-MCP the same day after harvest. 1-MCP (EthylBloc, Bio-Technologies for Horticulture, Walterboro, SC, 0.14% active ingredient) was weighed into test jars to obtain final gas concentrations of 2 µl l^{-1}. 1-MCP was dissolved in 100 ml of warm pure water (40°C) directly in the container. Test jars were shaken and placed in each container and an airtight lid was closed immediately. After 12 h at 20°C 1-MCP treatment, the plastic containers were vented. Control fruits were kept under the same conditions without 1-MCP treatment.

Fruit storage and sampling

Persimmon fruits were treated with 1-MCP (0 and 2 µl l^{-1} for 12 h at 20°C) before MAP stored. For MAP storage, persimmon fruits treated and untreated with 1-MCP were filled in two different polyethylene bulk liner, called MAP A (30 µ /p-plus antimist) (sealed for CA, unsealed for normal atmosphere) or MAP B (32 µ /p-plus antimist). MAP B (30EF120) is more permeable to O_2 and CO_2 gases than the MAP A (30EF60). Polyethylene bulk liner bag size was 700 × 700 pack wıth weight of 5 kg. MAP A, MAP B and unwrapped were combined with concentrations of 2 µl l^{-1} 1-MCP. 'Harbiye' persimmon fruits were stored at 1°C storage room and ventilated with 90% relative humidity cold air during 3 months storage. Fruit flesh firmness, total soluble solids (TSS), pH, titratable acidity (TA), color value (H^O) and ethylene production changes were examined to determine the combined effects of 1-MCP and MAPA and MAPB applications. Fruits were peeled on two opposite sides in the equatorial region where firmness was measured as resistance of flesh to puncture using an Effegi-type firmness tester with an 8 mm tip. Results were expressed as N. The TSS content of juice was measured with a hand refractometer (Atago Inc.). The results were expressed as percentage (%) at 20°C. TA was titrated with 0.1 M NaOH to pH 8.1, and the results were expressed as percentage of malic acid (Cemeroglu, 1992). The pH values were determined for the persimmon fruit juice and measured using a CG 710 pH meter. For ethylene determination, four pairs of fruits from each treatment were enclosed in about 4 L airtight jar for 24 h at 20°C, and then ethylene production rates were measured using ICA56 ethylene tester. Ethylene production was given as μlC_2H_4/kg.h (Oz and Ergun, 2009). Skin color of persimmon fruit was measured by two readings on the two different symmetrical faces of the fruit in each replicate, using a Hunterlab (Colorflex) and colorimeter calibrated with a white and black standard tile. Results were expressed as skin color as described by Hue angle (H^O), from arc-tan b*/a* value. The experiments were conducted in a completely randomized design with ten replicates. The results were analyzed by general linear model (GLM) multivariate procedures using analysis of variance by one or more factor variables. Means were compared by the least significant difference tested at significance levels of $P < 0.05$.

RESULTS AND DISCUSSION

Fruit firmness

Firmness of the fruit is one of the most common physical parameters used to assess the progress of ripening. Fruit firmness is regarded as a decisive factor determining the degree of fruit ripening. Results showed that there was a significant difference between MAP and 1-MCP treatment and interaction between treatments on firmness of persimmon fruit during storage. At harvest, maturity stage I had a firmness value of 55.8 N showing two third of fruit surface orange color while maturity stage II had a firmness value of 53.5 N with a full-orange external coloration. As shown in Figure 1, 1-MCP + unpacked treatment retarded the loss of first harvest fruit firmness much more than unpacked + control, MAPA + control and MAPB + control and combination of MAPA + 1-MCP and MAPB + 1-MCP storage for first harvest fruits. Fruit stored in MAP without 1-MCP treatment, in their first harvest showed softened fruit firmness much more rapidly than fruit kept in unpacked + 1-MCP, combination of MAP with 1-MCP treatment and unpacked + control. This may be due to the degradation of biochemical constituents of the un-ripened fruits during storage. However, second harvest maturity fruit improvement in storage could be obtained by combination of 1-MCP treatment with MAPA and 1-MCP + MAPB, unwrapped + 1-MCP, respectively. This delay of softening probably resulted from the retardation of senescence processes due to inhibition of the ripening rate. Similar results were obtained by Kim and Lee (2005). Fruit firmness value was found to be significantly different from 1-MCP and/or MAP storage harvest maturity and interaction between factors. There was generally very little difference in persimmon fruit firmness of two types of MAP during

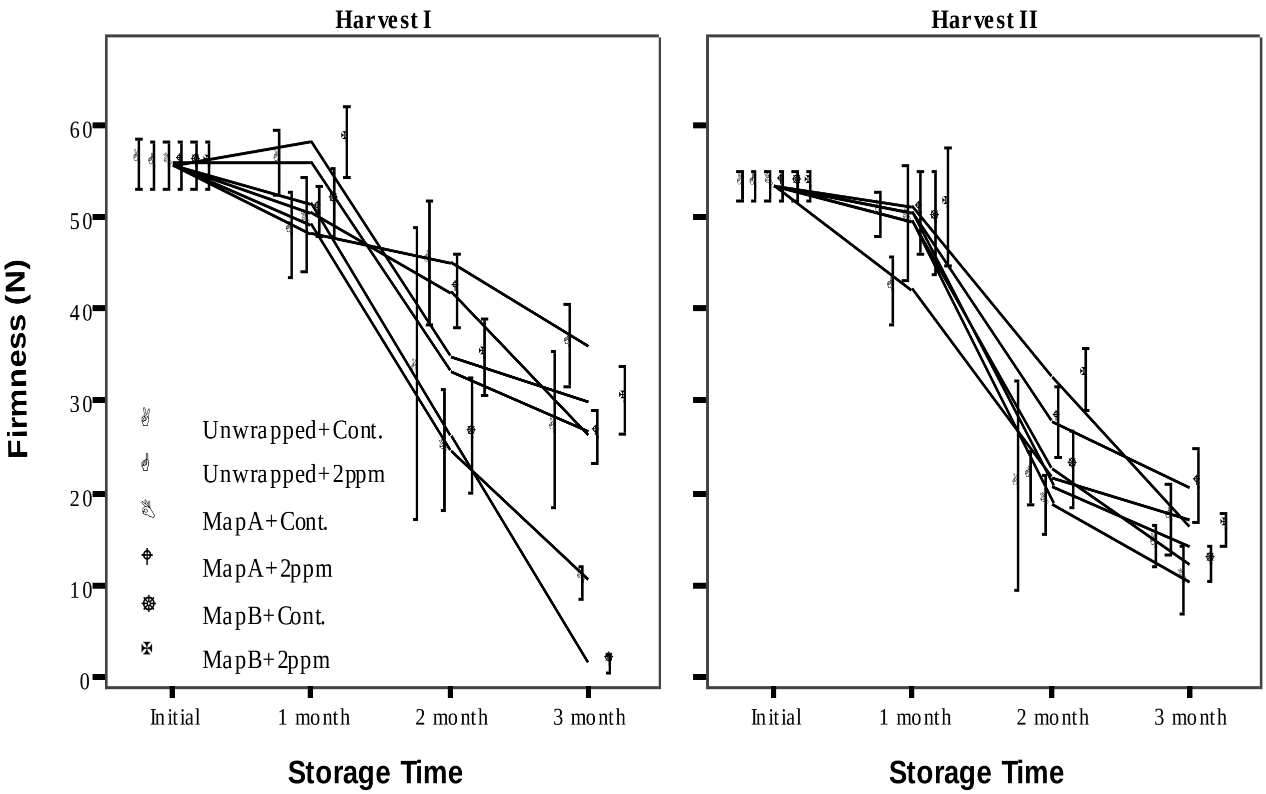

Figure 1. Combined effects of 1-MCP and MAP on two different ripening stages of persimmon fruit flesh firmness (N) during storage. The mean difference is significant at the 5% level. Error bars indicate the standard error.

storage. 1-MCP treatment was more effective on fruit firmness of first harvest persimmon fruit than MAP storage. However, combi-nation of 1-MCP with MAP storage has an important effect on fruit firmness of second maturity stage during storage. These results are similar to those of the study conducted by Cia et al. (2006). The lowest and the highest firmness values at the end of the storage were obtained from MAPB + control, MAPA + control, un-packed + control, MAPA + 1-MCP, MAPB + 1-MCP and unpacked + 1-MCP, respectively. The high degree of firmness at harvest time plays a crucial role in whether the quality can be maintained during the post harvest period or not (Salvador et al., 2007; Tian and Xu, 1991). Late harvesting had reduced fruit flesh firmness than early harvesting during storage.

Soluble solids content

As shown in Figure 2, the TSS was increased significantly during storage after the first month of the first harvest (from 19 to 21%), but increased slowly in the second harvest for those fruits treated with MAPA + control and MAPB + 2ppm 1-MCP. When compared to the effects of 1-MCP and MAP on TSS of two different maturity stages, the TSS content of second maturity stage was more variable than the first one with ripening end of storage. Previously, Turk (1993) has reported decrease in TSS of fruits during storage, while Mohla et al. (2000) reported on increase in TSS for storage intervals. This increase in TSS may be attributed to the treatment, packaging and maturity stage of the fruits at harvest. TSS content was significantly different from harvest maturity and interaction between factors. When the TSS of fruits was examined at the level of treatments and storage period, the differences noted were determined to be statistically insignificant. 1-MCP treatments were found to be ineffective on the changes in TSS (Figure 2).

pH

The effects of 1-MCP and two different packaging materials on pH changes of different harvest maturity of persimmon fruits during storage are shown in Figure 3. The pH values of treatments were increased from initial 5.7 to 6.7 during storage. Maximum increase was observed for fruits packaged in MAPB + control, while minimum for those packaged in MAPB + 1-MCP (0.44). Differences between treatments were found to be insignificant. 1-MCP treatments were determined to be ineffective on the changes in pH. These results are similar to those of Koyuncu et al. (2005).

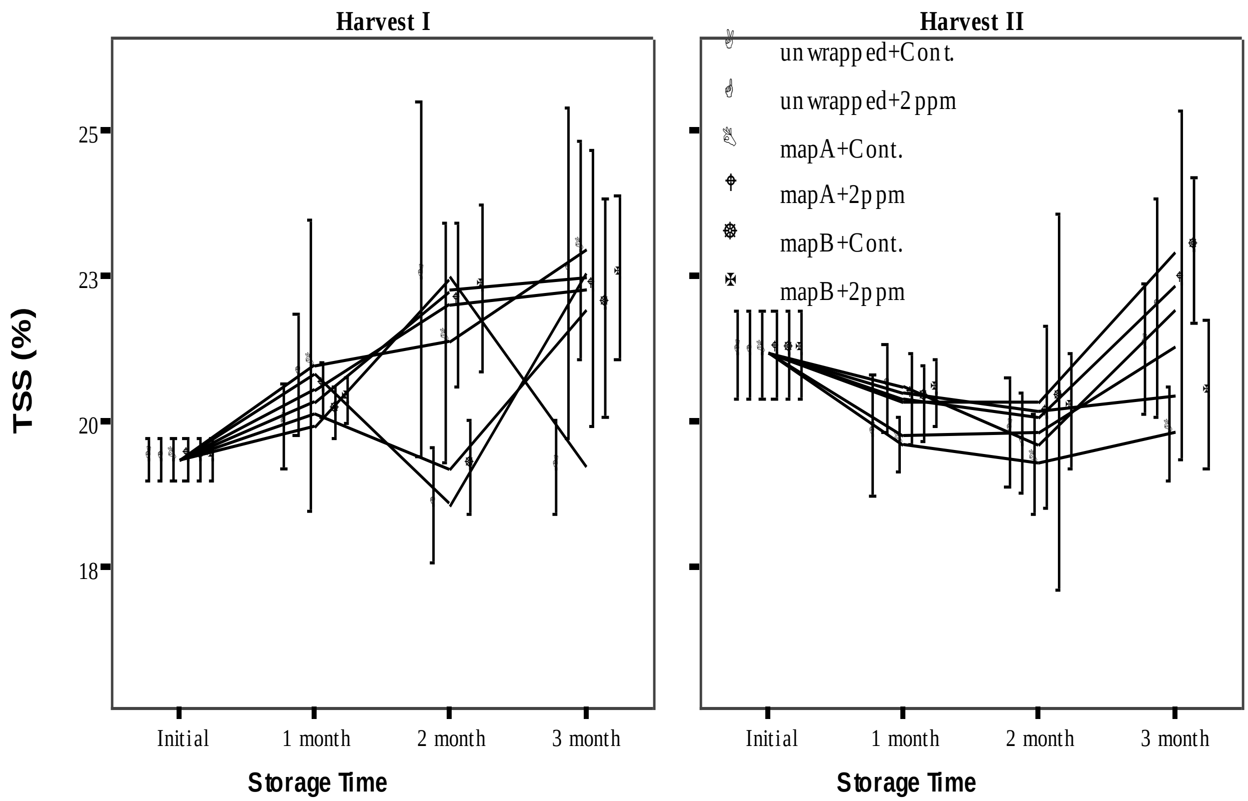

Figure 2. Combined effects of 1-MCP and MAP on two different ripening stages of persimmon fruit soluble solids (%) during storage. The mean difference is significant at the 5% level. Error bars indicate the standard error.

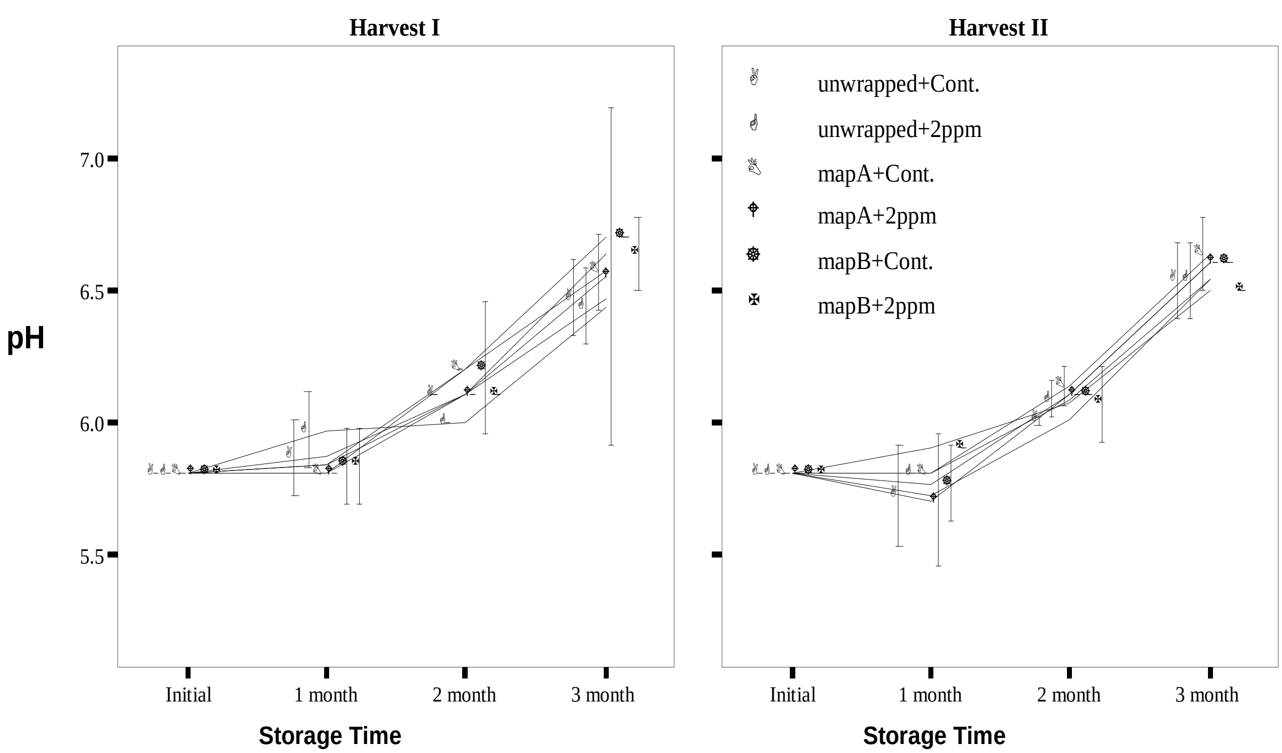

Figure 3. Combined effects of 1-MCP and MAP on two different ripening stages of persimmon fruit soluble solids (%) during storage. The mean difference is significant at the 5% level. Error bars indicate the standard error.

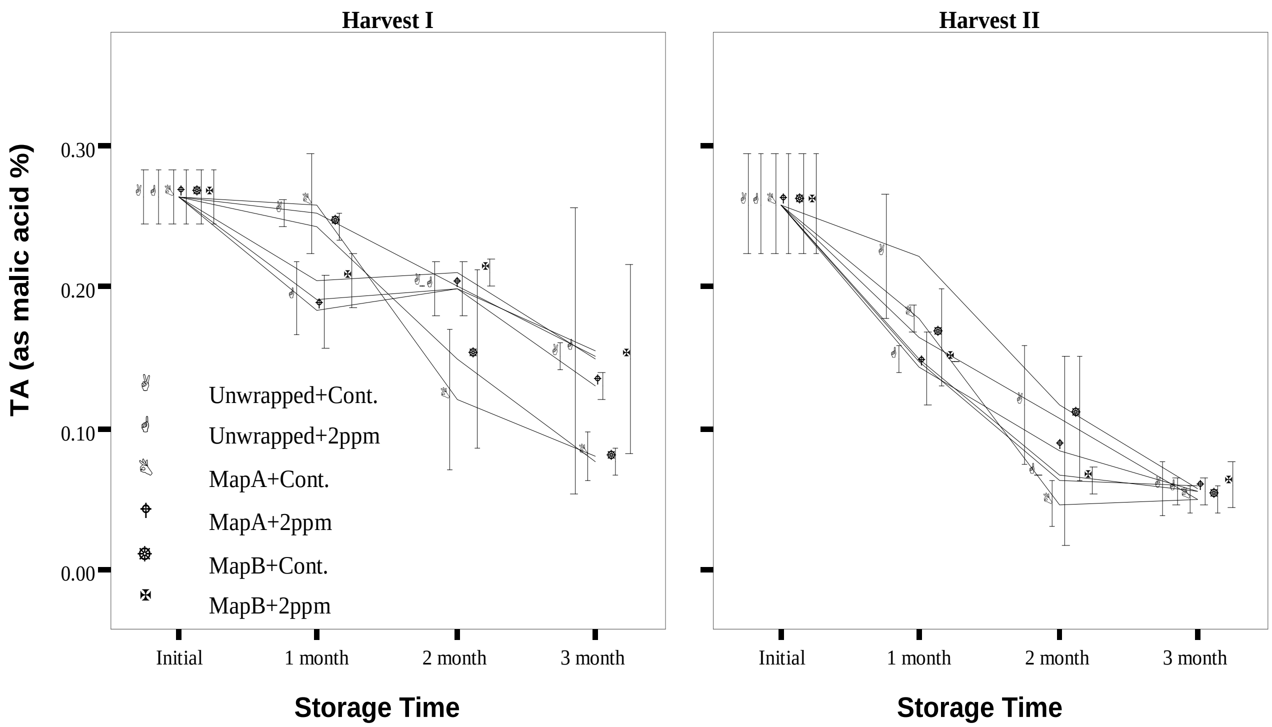

Figure 4. Combined effects of 1-MCP and MAP on two different ripening stages of persimmon fruit soluble solids (%) during storage. The mean difference is significant at the 5% level. Error bars indicate the standard error.

Titretable acidity

Fruit acidity was assessed as malic acid and fruit acidity decreased especially in combination of 1-MCP treatment with MAP materials during first month of storage, but 1-MCP treatment with MAP kept the fruit acidity more than unwrapped + MAP at the rest of the storage. However, TA decreased more quickly in second harvest for all treatments, while TA of unwrapped + control decreased slightly during the first and second months (Figure 4); statistical test showed that result of TA was significantly different from harvest date, 1-MCP treatment, different MAP materials and interaction between factors. 1-MCP treated fruit effectively reduced loss of TA after 30 days storing at 1°C (Figure 4). Fruits treated with 1-MCP (2 µl L^{-1}) showed higher fruit TA after 30 days storage at 1°C when compared with control; the differences were highly significant ($P < 0.05$). In our study, reductions were observed in TA values for the second harvest during storage (Figure 4). Acidity of the second harvest during storage was decreased more than that of the first harvest. The reduced TA was correlated with the physiological processes (such as respiration) of acids. This is another important factor with regard to the treatments, especially in terms of slowing the loss of fruit quality. With these methods, changes in fruit quality during storage could be kept within certain limits, since sugar accumulation was stable and loss of TA was retarded in the fruit stored using a combination of 1-MCP + MAP. In previous studies, results of the effects of 1-MCP on acid retention were ambiguous. Similarly, in the present study, the treatments with 1-MCP + MAP maintained the TA values of persimmon at higher levels than control + MAP, especially in the first harvest.

Fruit color changes

Fruit color and Hue values were determined during storage, and results are shown in Figure 5. Hue value of both maturity stages showed very slight difference between the two different maturity stages at harvest. Hue was decreased rapidly for both maturity stages with ripening during the first month of storage. However, Hue value of the first harvest of fruit was increased at the second month. Maturity stage I and II showed close mean values at the rest of storage. Harvest time had important effect on color value. H^o value was found to be significantly different in harvest maturity stages and interaction between factors.

Ethylene production

In general, ethylene production of both maturity stages were low at harvest time and the first month of storage (Figure 6). Thereafter, ethylene production increased from values of 0.03 to 0.28 in maturity stage I at the

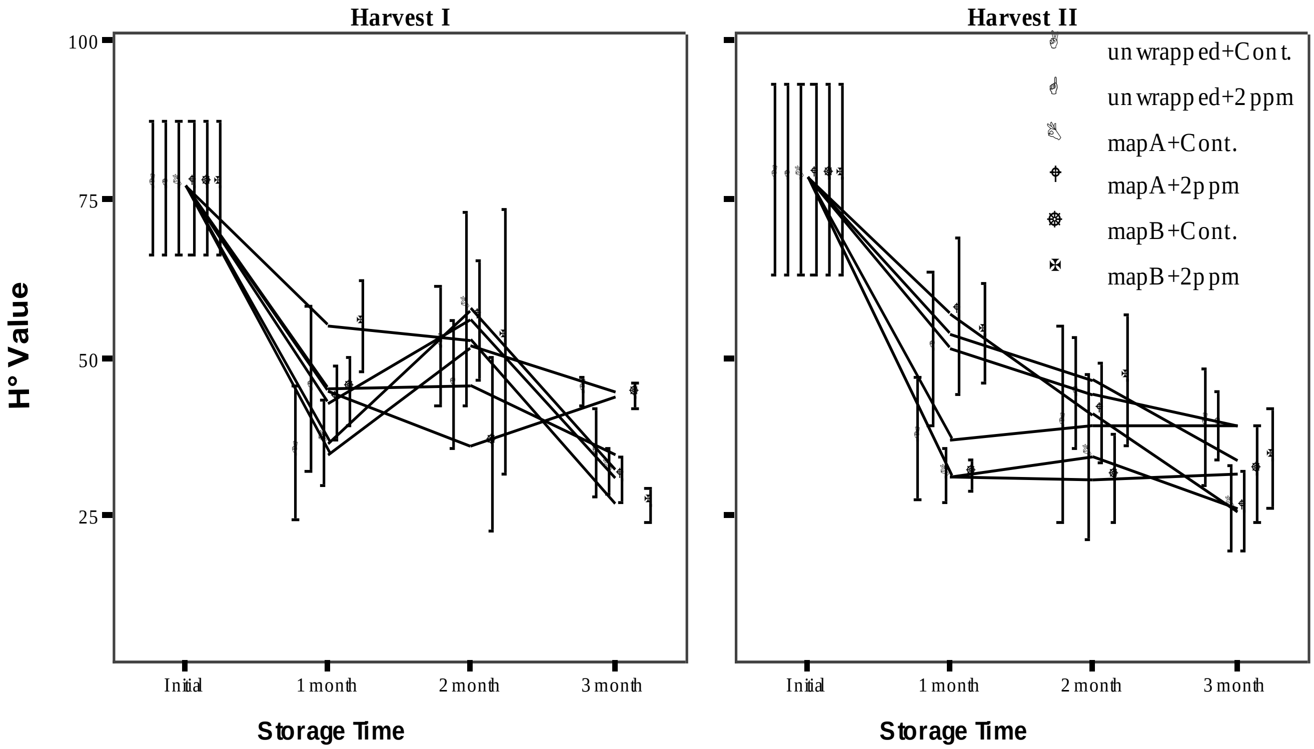

Figure 5. Combined effects of 1-MCP and MAP on two different ripening stages of persimmon fruit color value changes during storage. The mean difference is significant at the 5% level. Error bars indicate the standard error.

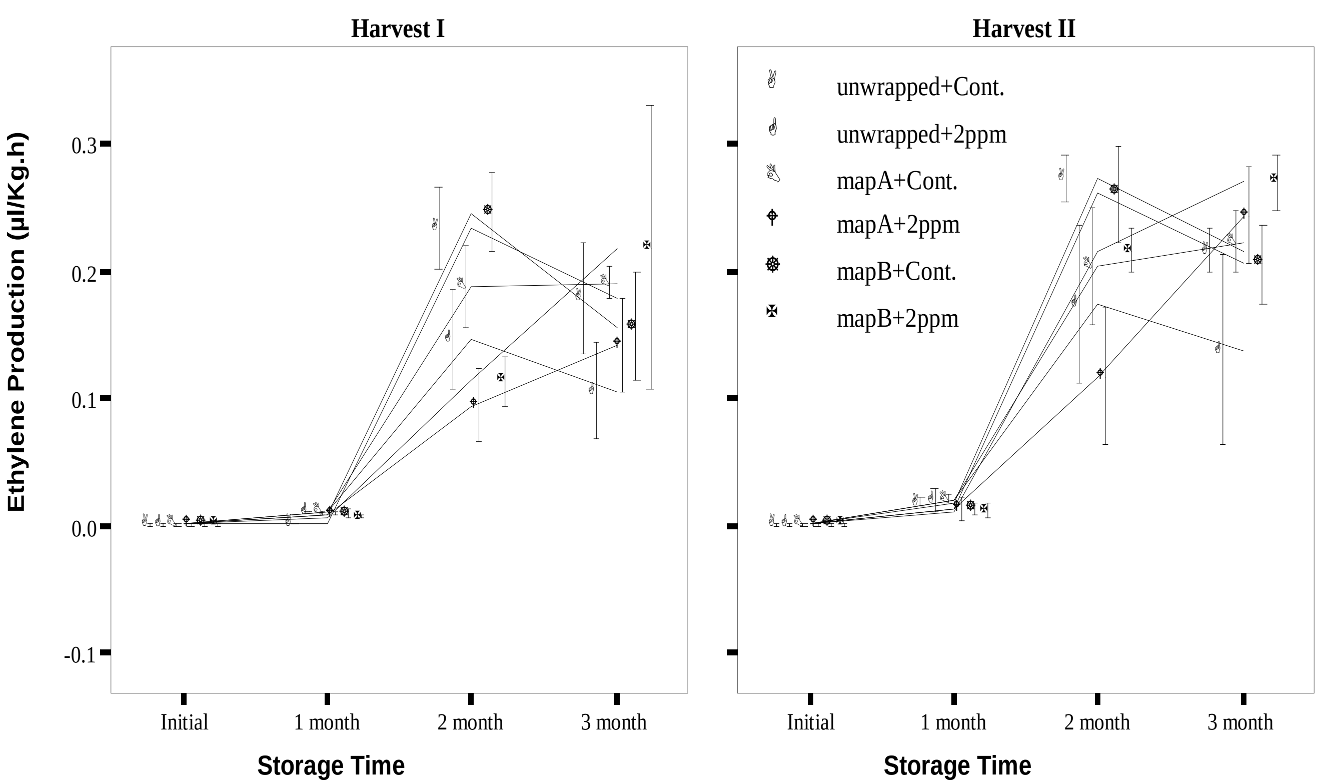

Figure 6. Combined effects of 1-MCP and MAP on two different ripening stages of persimmon fruit ethylene production during storage. The mean difference is significant at the 5% level. Error bars indicate the standard error.

second month of storage. But, this increase was higher in maturity stage II with 0.28 µl/kg.h during storage. This change in ethylene production reflects the typical climacteric behavior of this variety (Oz and Ergun, 2009). The combined effects of MAPA + 1-MCP, MAPB + 1-MCP, unwrapped + 1-MCP on ethylene production of first harvest maturity fruit were especially notable during the second month (Figure 6). Ethylene production rate of persimmon fruit at the second harvest periods showed similar trend in first harvest period during storage. However, production rate was suppressed at first harvest storage compared to the second harvest period during storage. In addition, both the first and second harvest maturity of fruit and improvement in storage could be obtained by combination of 1-MCP treatment with MAPA, 1-MCP + MAPB and unwrapped + 1-MCP, respectively, at the second month of storage. On the other hand, the unwrapped + control, MAPB + control and MAPA + control showed the highest ethylene production at the second month of storage for first harvest maturity of fruit, respectively. Thereafter, ethylene production of persimmon fruit decreased at the last month of storage. However, ethylene production of 1-MCP treatment with MAPA and 1-MCP + MAPB did not show typical climacteric behavior for ethylene production during the last month. Ethylene production rate of 1-MCP + MAPA and 1-MCP + MAPB treated fruit started to increase at the second month till end of storage.

Ethylene production of 'Harbiye' persimmon fruit was very low and production was not greater than 0.28 µl/kg.h. Ethylene production was found to be significantly different in treatment of 1-MCP, MAP and interaction between factors during storage. Harvest maturity stage influenced the final eating quality of persimmon fruit for long period.

Conclusion

External color of the fruit influenced the firmness of fruit in stage I and II, during shelf life. TSS content increased. Generally, persimmon fruits produce small amount of ethylene (Kader, 1992), but they are very sensitive to ethylene action. Results showed that early harvested fruits were firmer and ethylene production was slightly lower than those of late harvest. Harvest time at maturity stage cannot delay the ethylene climacteric, but the first harvest fruits reduced the ethylene production rate during storage. Thus, persimmon fruits harvest maturity is a very important factor on fruit quality and ethylene production rate during storage. This study indicates that 'Harbiye' persimmon fruits can be harvested at first stage (two thirds of fruit surface is orange color). The color Hue value of both maturity stages was negatively correlated with ripening. The results obtained in this study indicated that fruits harvested at the first harvest time were also firmer at the end of storage than the second harvest. 1-MCP + MAP storage inhibited ethylene production, changed fruit firmness and increased TSS content. In more detail, quality changes of fruits harvested at the first and second stages were closed to each other. However, at the end of storage, 1-MCP treatment gave the best results while considering ethylene biosynthesis and other quality parameters. Therefore, combination of MAP and 1-MCP treatment reduced ethylene production at the second month, but 1-MCP treatment with MAP has better effect on fruits at the first harvest than second harvest. Applications of 1-MCP + MAP can extend the post harvest life and quality chances of 'Harbiye' persimmon fruits.

ACKNOWLEDGEMENTS

The author is grateful to Amcor Flexibles Packaging Company (Ledbury Herefordshire, UK) for donating the packaging materials, which are the sources of 1-MCP for AgroFresh Inc./Rohm and Haas Company for the sources of fruit materials for Cingöz Tarım.

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