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Evaluation of the Potency of Aqueous 1-Methylcyclopropene (1-MCP) Application in Carrots

Muharrem Ergun[1*] and Awat Ali Hussein[1]

[1]Department of Horticulture, Bingol University, Bingol, Turkey.

Authors' contributions

This manuscript is produced from MSc thesis of author AAH under supervision of author ME. Author ME designed the study, performed the statistical analyses and wrote the initial draft of the manuscript. Author AAH carried out the research. Both authors read and approved the final manuscript.

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ABSTRACT

The study aimed to evaluate the efficacy of aqueous 1-methylcyclopropene (1-MCP) on postharvest quality of carrots and to compare with/to gaseous 1-MCP and modified atmosphere packaging (MAP) treatments. Carrots initially washed with tap water were distributed into 4 batches the first of which was subject to aqueous 1-MCP application, the second to the gaseous 1-MCP application, the third to MAP and the fourth left non-treated as a control. Carrots were placed in clamshell polyethene terephthalate (PET) boxes except MAP-treated ones and stored 23 ± 1°C for 10 days. During the 10-day period, carrots were evaluated by tracking weight loss, firmness, color, headspace gas composition, total soluble solids, pH, titratable acidity, carotenoid content and decays. The results showed that gaseous 1-MCP application may have the potential for delaying postharvest quality losses by restricting decay ratios for carrots held at room temperature. Aqueous 1-MCP and MAP applications were however found to be inefficient suppressing or delaying postharvest quality losses.

Keywords: Postharvest quality loss; modified atmosphere packaging; carrot firmness; carrot decay.

**Corresponding author: E-mail: muharrem.ergun@yahoo.com;*

1. INTRODUCTION

A member of Umbelliferae family, carrot (*Daucus carota* L.) is cultivated for its fleshy roots used like a vegetable. The roots are mostly consumed fresh but can be treated into frozen, dried, canned and fermented products which can be used in cakes, puddings, jams, preserves, fruit juices and even baby foods especially due to their unique color and taste [1,2]. Carrot is wealthy with a precursor of vitamin A and carotene [3] whose dietary shortages can lead to premature childhood mortality and blindness [4,5]. The root also includes appreciable amounts of protein, sugar, thiamine, fiber, riboflavin, carbohydrate, potassium and sodium [6]. Carrots are usually orange in color but yellow, red, white, black and purple cultivars do exist as well. China, Uzbekistan and USA are the chief carrot producing countries. The production quantity of carrot in Turkey was 554,736 tons and cultivated in 101.080 ha area [7].

Carrots are harvested when they reach a diameter of 20 mm and more, still young and tender. After harvest, roots should be immediately stored at low temperatures (0°C) and high relative humidity media (93-98%) to decrease postharvest quality losses [8]. Deterioration due to water loss and microbial spoilage are the most common postharvest losses in carrots followed by loss of sweetness and carotenoids, and formation of bitterness and oxidized flavor [8].

Although carrot is one of the most commonly consumed vegetables, marketing of carrot is limited due to its short shelf life [9]. Both during storage and transportation, carrots subject to some inevitable changes which decrease their quality and causes postharvest losses [10]. During storage, in addition to water loss and microbiological spoilage, some biochemical changes happen; polysaccharides are transformed in simple sugars, and sucrose in decreasing sugars which leads to the emission of structural breakdown, color change, off flavors and textural changes [11,12].

Postharvest quality losses in some vegetables may be lessened by several postharvest applications such as 1-methylcycloprone (1-MCP) and modified atmosphere packaging (MAP). 1-MCP, an ethylene action inhibitor, has been extensively used in postharvest studies to prolong the postharvest shelf life of a broad range of horticultural products, including flowers, climacteric and non-climacteric fruits, and vegetables [13,14]. The inhibitor is a gaseous cyclic olefin that apparently binds irreversibly to the cellular ethylene receptors inhibiting the action of ethylene [15]. Few studies exist about use of 1-MCP on carrots. 1-MCP effectively decreased bitterness in carrots [16-18]; suppressed loss of sucrose, respiration rates, and increase in fructose and glucose [19].

MAP is a very successful postharvest technology for increasing the shelf life of fresh horticultural crops. The technology replaces the atmospheric air inside a package with a protective gas mix which helps ensure that the product will stay fresh for as long as possible [20,21]. MAP can be explicated as a dynamic system with two gas fluxes, the gas exchange through the packaging film and the respiration rate of the fresh product [22]. Previous studied indicated that carrots benefit from MAP applications such as by decreasing biochemical and biological activities [23], protecting microbial spoilage [24], and suppressing postharvest quality losses [25-27].

To our knowledge very few reports associated with the technique of using both 1-MCP and MAP together in fresh horticultural crops. This study attempts to explore the influence of aqueous 1-MCP on postharvest quality of carrots held in the room temperature and to compare with/to gaseous 1-MCP and modified atmosphere packaging (MAP) exercise.

2. MATERIALS AND METHODS

Carrots (*Daucutus carota* L. cv. 'Nantes') were obtained from a farmer in Kırıkhan, Hatay. The carrots were sorted for uniformity of size and color; roots with physical damage or infections were not used. The defect-free roots were washed with tap water to remove any dirt and surface-dried in a slow air draft. The carrots were distributed randomly into four lots. The first one was allotted for the control, the second one for MAP, the third one for aqueous 1-MCP and the fourth one for gaseous 1-MCP applications. Approximately 80 kg carrots were used in the study; 75 carrot roots were employed for each treatment. For the control, a 2-L rigid PET box (8 x 12.5 x 20 cm^3) was used.

For the MAP application, a LPDE-type packaging material with a thickness of 45 µm was used. The company was not released the water vapor transmission rate of the film. MAP bags were cut into 6 same sized bags. Loose ends of the bags

were hot-sealed by a hot sealer and only one side of the bag was left unsealed. Three carrot roots were placed into the bags and the loose end and the unsealed end was loosely enclosed by a rubber band.

Aqueous 1-MCP was prepared from Sensy Fresh powder (active ingredient 3.3% 1-MCP; Agrobest). The required amount of the powder was dissolved in the 20-L distilled water to obtain 1000 μ L^{-1} concentration. The solution was stirred with a plastic spatula for 1 min and waited for 9 more min. Carrot roots were immersed into the solution in a 50-L plastic bucket and waited for 30 min. The carrots were then dried with a paper towel and placed into the PET boxes.

Gaseous 1-MCP was prepared from the same powder used for the aqueous 1-MCP application. According to the company instruction, 0.042 g powder releases 625 ppb in a m^3. Desired amount of powder dissolved in a glass vial to obtain 1 ppm (1000 μg L^{-1}) 1-MCP gas. Carrots were placed in a 50-L plastic cap along with the vial containing the solution, and then the lid sealed with a duct tape and waited for 12 h. The lid was opened the vial was replaced containing fresh solution and treated 12 more h. A total of 24 h gaseous 1-MCP application was applied to the carrots. Then the carrots were placed into the PET boxes.

Five boxes or bags from each treatment were weighed starting from day zero for every other day to calculate the weight loss percentage. A total of five carrots from five different bags or container were randomly selected for firmness, color, total soluble solids (TSS), pH and titratable acidity (TA) measurement. For firmness, TA-XT Plus Texture Analyzer was used (Stable Micro System Ltd., Surrey, UK). A probe with 2-mm diameter was inserted into carrot at the equatorial area at a speed of 0.83 mm s^{-1} with a depth of 10 mm, then the reading was recorded as N (newton) at the depth of 0.2 or 0.5 mm.

Lovibond (RT 300; Amesbury, Germany) reflectance colorimeter was used to quantify peel, cortex and endodermis color. The values L*, a* and b* were recorded from the carrots. At the equatorial area, peel color was read, then the carrot was sliced to read cortex and endodermis values.

A total of 5 carrots were used for TSS, pH and TA measurements. Carrot juice was obtained from a fruit juicer (Premier, PR-603, Hong Kong). From the juice, TSS was measured using a digital refractometer (Krüss, Germany) and pH, a pH meter (Hanna, HI 2211, Woonsocket, RI, USA). For TA (%) 6 g juice was titrated with 0.1 M NaOH until the pH reaches 8.2 using automatic titrator (Automatic Potentiometric Titrator, AT-510; KEM Kyoto Elect., Tokyo, Japan).

Five boxes or bags from each treatment were used to obtain headspace gas composition. The measurement was done by a gas analyzer (Systech Inst., Gaspace Advance, GS3/L; Johnsburg, IL, USA).

Five carrots from each treatment were used for carotenoid extraction. After mixing 1 mL carrot juice with 9 mL acetone, the solution was vortexed, and then kept at the dark at 4°C for at least 4 h. The sample was later centrifuged at a speed of 2,000 rpm for 10 min. The supernatant was separated form and read at a spectrophotometry at 443, 475 and 492 nm for α -carotene; 443 and 492 nm for β-carotene; and 475 nm for total carotenoids.

During the experiment, total decayed carrots were counted and ratio was calculated over total carrot counted at the beginning of the experiment.

There were 4 treatments with 5 replications, and each replication seeded with 3 sub replications when needed. A randomized complete block design (RCBD) was set up for the experiment. Weight loss, firmness, color, TSS, pH, TA, package gas composition was measured bi-daily; carotenoid extraction was done at day 0, 6 and 10.

Data analysis was done by an analysis of variance, with mean separation of DUNCAN at 0.05 level, using SAS statistical software (Version 8.1, SAS Inst., Cary, NC, USA). Data are presented as the mean ± standard error of the mean.

3. RESULTS AND DISCUSSION

[(Detailed Weight loss was diminutively increased during the course of the storage (Fig. 1). Weight loss of control reached 2.20%, of MAP 21.84%, of A-1-MCP 2.03% and of G-1-MCP 1.68% at the end of storage. Control, A-1-MCP and G-1-MCP did not show a significant difference when compared to each

other, however, the weight loss was significantly higher in carrots subject to MAP application. MAP was designed to allow a limited gas exchange including water vapor. Therefore, carrot saved in MAP lost more water than those stored in clamshells.

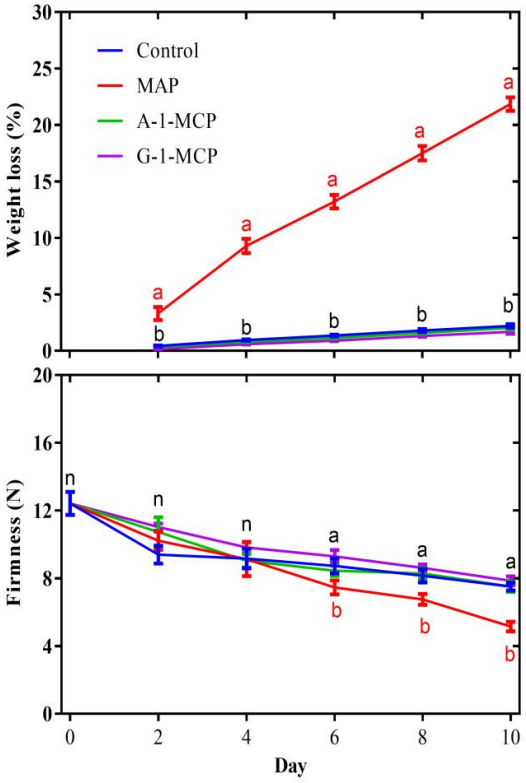

Fig. 1. Changes in weight loss (%) and firmness of carrots stored at 23 ± 1 °C. Control: no treatment; MAP: modified atmosphere packaging; A-1-MCP: aqueous 1-MCP treatment; G-1-MCP: gaseous 1-MCP treatment

Vertical bars represent standard errors of means
Means followed by the same letters on the same day are not significantly different by DUNCAN test P < 0.05
n: nonsignificant

Carrot firmness gradually reduced during storage in all treatments (Fig. 1). Carrots saved in MAP, however, had significantly deeper firmness loss after 6 days. The film of the MAP was designed for carrots to allow water vapor exchange, which resulted higher water loss compared to other treatments. Water loss eventually cause carrot tissue to become soft. Carrots stored in clamshells irrespective of the 1-MCP application had almost same degree of firmness loss during the storage, indicating that firmness loss in carrots are rather a physical process while biochemical processes contribution is lesser [28]. Treatment with 1-MCP having no effect on carrot weight loss or firmness was also observed by Fan and Mattheis [16].

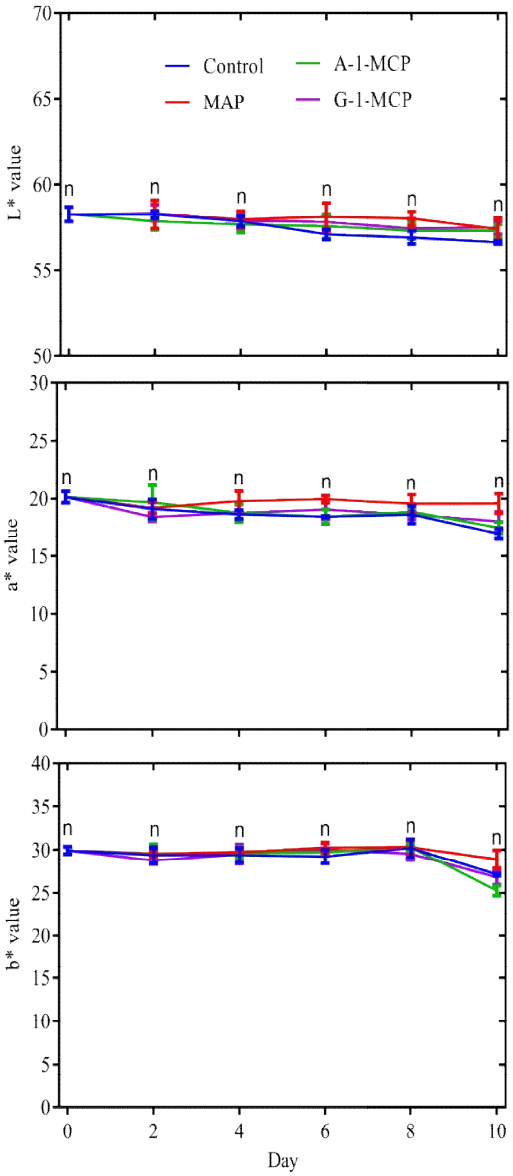

Fig. 2. Changes in peel color (L*, a* b*) of carrots stored at 23 ± 1 °C

Treatment abbreviations and figure legends are the same as in Fig. 1

Carrot peel color assessed by lightness (L*), redness (a*) and yellowness (b*) showed no statistical changes in the course of the storage irrespective of treatments, thus, no variation among the applications were

recorded (Fig. 2). Similar to our findings, Song et al. [17] recorded that 1-MCP had no effect on carrot root peel color. Cortex and endodermis color values were almost superimposed except for lightness (Fig. 3).

Endodermis seemed to be brighter than cortex while redness and yellowness almost identical in both tissues. Yellowness in both tissues decreased after day 8, which might be due to the decrease in total carotenoid content. Similar to the peel color, 1-MCP had no effect on cortex or endodermis color values.

Evolution of headspace gas concentration during the storage of carrots is seen in Fig. 4. Nitrogen percentage was stable for all treatments during storage while CO_2 and O_2 amounts showed some degree of changes. Carrots saved in MAP had lower oxygen and higher carbon dioxide ratio until day 8 then reached the equilibrium. The film of MAP allowed some degree of gas exchange unlike clamshells, which were the cause lower oxygen concentrations and higher CO_2 concentrations in carrots stored in MAP until day 8.

TSS, pH and TA values and their evaluation over the course of storage are shown in Fig. 5.

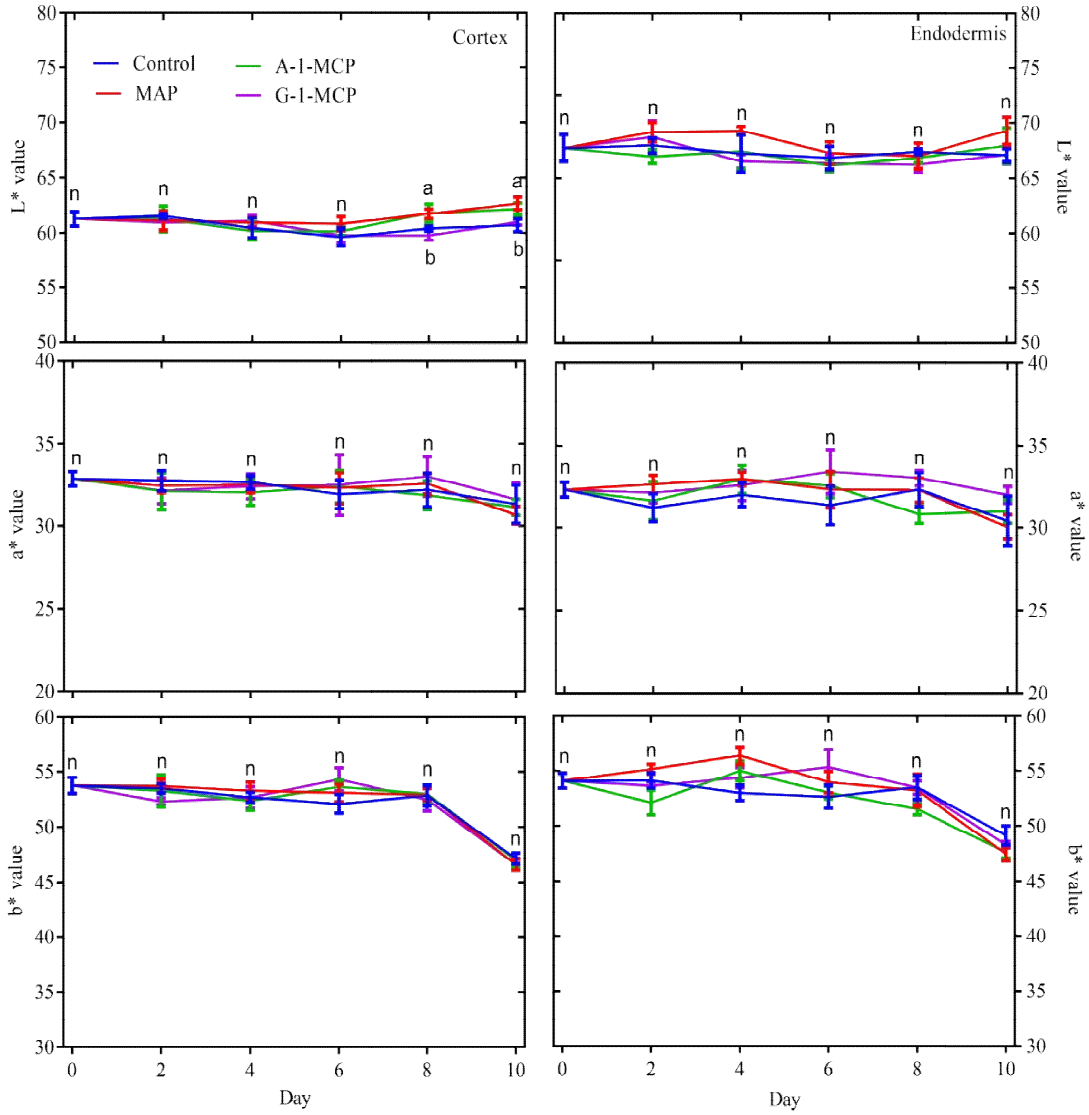

Fig. 3. Changes in cortex and endodermis color (L*, a* b*) of carrots stored at 23 ± 1°C
Treatment abbreviations and figure legends are the same as in Fig. 1

Neither TSS, nor pH nor TA expressed a significant change or variations among treatments during the period of storage. TSS was around 9.5 -10%, pH 6.0 – 6.2 and TA 0.9- 1.0% for all treatments. Ineffectiveness of 1-MCP on TSS and TA in carrots was also recorded by Fan and Matheis [16].

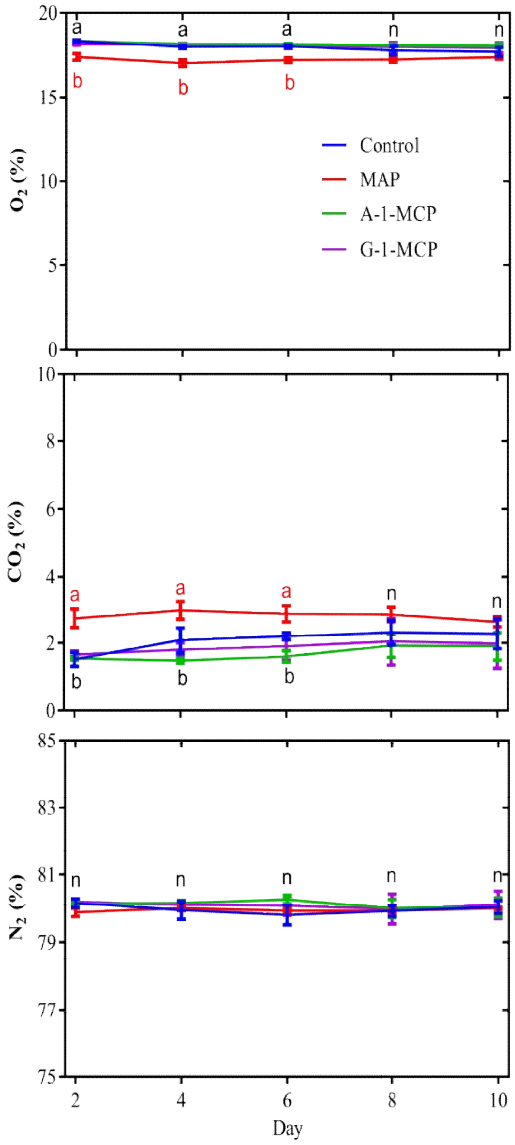

Fig. 4. Changes in headspace gas composition of packages stored with carrots at 23 ± 1°C

Treatment abbreviations and figure legends are the same as in Fig. 1

Alfa-, beta and total carotenoid amounts slightly declined in all treatments during the storage period as seen in Fig. 6. However, no differences were registered among treatments. Alfa-carotene value was around 5 to 6, beta-carotene 4 to 5 and total carotene 10 to 12 mg g fw^{-1} for all treatments.

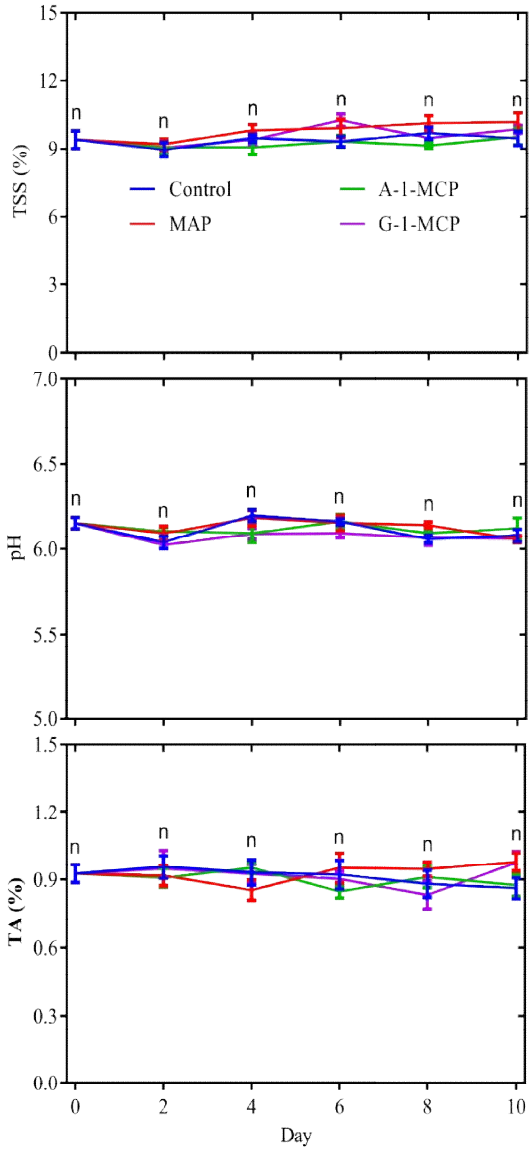

Fig. 5. Changes in total soluble solids, pH and titratable acidity contents carrots at 23 ± 1°C

Treatment abbreviations and figure legends are the same as in Fig. 1

Carrots had decays at the end of the storage irrespective of treatments (Fig. 7). The decayed fruit ratio ranged from 29 (control), 25 (A-1-MCP), 20 (MAP) to 16 (G-1-MCP) %. Control fruit had the highest decay ratio followed by A-1-MCP, MAP and G-1-MCP respectively.

Especially gaseous application of 1-MCP was very effective in terms of suppressing decay compared to other treatments. Gaseous 1-MCP acts on the ethylene action pathway and delays senescence or ripening especially in climacteric fruits by suppressing firmness losses which might trigger decay development [14]. MAP or A-1-MCP application did not recorded an effective result as much as G-1-MCP did. This might be resulted from that MAP provided a good environment for microorganisms to flourish in the package or 1-MCP in water penetrated only very little into carrot tissues.

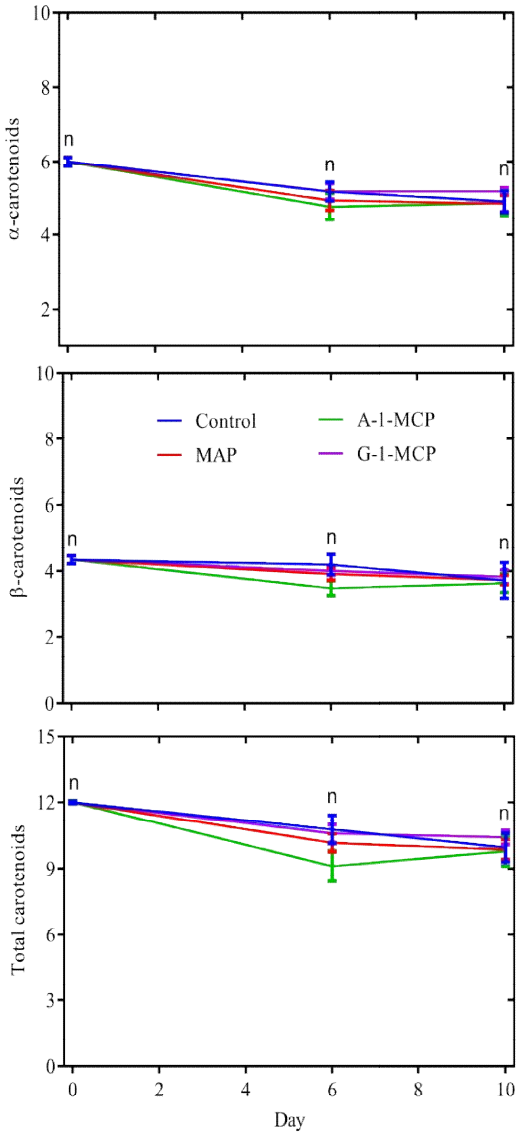

Fig. 6. Changes in carotenoid contents of carrots at 23 ± 1°C

Treatment abbreviations and figure legends are the same as in Fig. 1

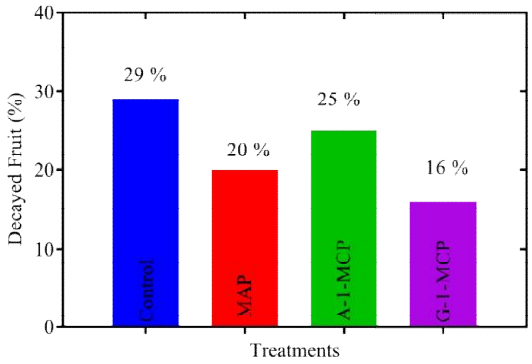

Fig. 7. Decayed root ratio of carrots at the end of storage period stored at 23 ± 1°C

Treatment abbreviations and figure legends are the same as in Fig. 1

4. CONCLUSION

Carrot is one of the important horticultural crops that have short shelf lives after harvesting or cold storages. This short shelf life results from mainly color changes, weight loss, firmness loss, decay, and developing bitterness. Thus, the purpose of this research was to minimize or prevent the changes or losses by the aqueous 1-MCP application at the room temperature. Aqueous 1-MCP was however found to be ineffective at minimizing or preventing the changes or losses. The gaseous 1-MCP application, however, has a potential to extend shelf life of carrot especially by suppressing decay ratios.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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