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Effects of methyl jasmonate on quality properties and phytochemical compounds of kiwifruit (*Actinidia deliciosa* cv. 'Hayward') during cold storage and shelf life

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Abstract: The research aimed to assess the effects of methyl jasmonate (0.25, 0.5, and 1.0 mM MeJA) on weight loss and phytochemical compounds of kiwifruit (*Actinidia deliciosa* cv. 'Hayward') throughout the cold storage and shelf life. Kiwifruits were stored at 0 ± 0.5 °C and 90 ± 5% RH for 180 days, and at 20 ± 1.0 °C and 80 ± 5% RH for 5 days in shelf life conditions. During cold storage, weight loss was significantly lower ($P < 0.05$) in 0.25 and 1.0 mM MeJA treatments than those of control and 0.5 mM MeJA treatments. The highest flesh firmness was determined in MeJA-treated fruits. In the latest measurement period of cold storage and shelf life, the lowest respiration rate was obtained from 0.5 and 1.0 mM MeJA treatments. MeJA-treated fruits had significantly higher hue angle at the end of cold storage. Generally, in shelf life analysis, acidity of MeJA-treated fruits was significantly lower than that of control fruits. At the end of cold storage, the highest vitamin C, total flavonoids, and antioxidant activity (DPPH) were measured in 1.0 mM MeJA treatment, whereas the highest total phenolics were detected in 0.25 mM MeJA treatment. Present findings revealed that MeJA could be used as an effective postharvest tool to maintain flesh firmness and phytochemical compounds of kiwifruits.

Key words: *Actinidia deliciosa*, phenolics, respiration rate, weight loss, vitamin C

1. Introduction

Kiwifruit with a unique taste, flavor, and aroma is quite rich in dietary fiber, antioxidants, minerals, vitamin C, and phenolic compounds. It is mostly used in treatment of gastrointestinal disorders. Parallel to increasing consumptions, world kiwifruit production has also been continuously increasing every day (Huang, 2016; Ozturk et al., 2019a). Since the kiwifruits are not at sufficient ripeness for consumption at harvest time and are easily perishable, cold storage is an essential process in kiwifruit trade in order to prevent product buildup in markets and to regulate the supply chain. However, quality losses throughout cold storage and shelf life, especially flesh softening, cause significant economic losses for both the producers and traders. Therefore, recent researches mostly focused on ethylene-inhibiting practices, including aminoethoxyvinylglycine and 1-methylcyclopropene, salicylic acid, putrescine treatments, and modified atmosphere packaging (Zhang et al., 2003; Zhu et al., 2008; Li et al., 2017; Ozturk et al., 2019a). The number of studies conducted on methyl jasmonate (MeJA) is quite limited in kiwifruits. In a previous study (Li et al., 2017), rather than the effects of MeJA on fruit quality attributes and bioactive compounds, effects on lignification throughout 3 months of cold storage were investigated.

Jasmonic acid (JA) and its methyl ester, methyl jasmonate (MeJA), are linolenic acid-derived cyclopentanone-based compounds. It is well known that signaling molecules play an important role in regulating the reprogramming of gene expression in plant cells and in the biosynthesis of secondary metabolites such as anthocyanin, carotenoids, phenolic compounds, and ascorbic acid, which contribute to the antioxidant capacity of fruits and vegetables (Khan and Singh, 2007; Rohwer and Erwin, 2008; Mehrjerdi et al., 2013; Ozturk et al., 2013).

MeJA treatments were carried out on different fruit species (Kondo et al., 2001; Boonyaritthongchai and Supapvanich, 2017; Balbontin et al., 2018; Garcia-Pastor et al., 2020) through spraying and dipping at the pre and postharvest stages, and higher fruit flesh firmness values were reported for MeJA-treated fruits. On the basis of these studies, it is important to consider whether MeJA could be used as a postharvest tool to retard flesh softening throughout the cold storage and shelf life of kiwifruits. There are no detailed studies in literature about such effects of MeJA treatments on quality parameters of kiwifruits.

This study was conducted to investigate the effects of prestorage MeJA treatments applied at different doses on

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weight loss, flesh softening, and bioactive compounds of kiwifruits throughout the cold storage and shelf life.

2. Materials and methods

2.1. Plant materials

The fruits of the study were picked from 10 years-old Hayward (*Actinidia deliciosa*) kiwifruit trees grown in a kiwifruit orchard in Kabadüz town of Ordu province, Turkey. Kiwifruit trees were planted in 4 m × 3 m spacing and trained with "T" system. Orchard soils were loamy in texture with a water holding capacity of 48%, pH of 6.03 (slightly acidic), total salinity of 0.0159% (unsaline), lime ($CaCO_3$) content of 0.3607% (slightly limey) and organic matter content of 1.67% (low). All cultural practices (irrigation, fertilization etc.) were regularly performed in the orchard.

2.2. Experimental design and treatments

Fruits were hand-harvested at 6.5% SSC on November 7, 2018. Then, they were placed into 5 kg plastic boxes (39 × 29 × 21 cm, Plastas, Turkey) and transferred to the Postharvest Physiology Laboratory of Horticulture Department at Ordu University Agricultural Faculty with frigorific trucks at 10 °C temperature and 85% relative humidity (RH) within 30 min after harvest. Damaged, defected, wounded, and twin fruits were discarded in the laboratory. Homogeneous fruits in terms of shape and weight (100–120 g) were used in the experiments.

Initially, 60 fruits were selected for measurements and analyses at harvest. Fruits were separated into 3 groups with 20 fruits in each. Each group represented a replicate. Shelf life measurements and analyses were performed instantly on half of the fruits in each replicate and after 5 days (d) storage at 20 ± 1 °C and 85 ± 5% RH on the other half of the fruits.

Four different postharvest treatments; control, 0.25 mM, 0.5 mM, and 1.0 mM MeJA (Sigma-Aldrich, Germany) were practiced. Therefore, fruits were randomly separated into 4 groups. The 1st group of fruits (control) was immersed only in distilled water. The 2nd group of fruits was immersed in 0.25 mM, the 3rd group of fruits in 0.5 mM, and the 4th group of fruits in 1.0 mM MeJA solutions. In all solutions, Triton X-100 (0.077% (vv^{-1}), Sigma-Aldrich) was used as a dissolvent. Fruits were kept in a 18 °C solution for 1 min and dried at 20 ± 1 °C and 85% RH for 1 h.

Then, each group of fruits was randomly placed into 18 plastic boxes (39 × 29 × 21 cm, Plastas, Turkey) with 20 fruits in each in modified atmosphere packaging (MAP) (passive) (Xtend, Stepac, Israel). The O_2 and CO_2 concentrations were measured with a gas analyzer (Abiss, Legend, France) in the same MAP for each treatment during the storage. The O_2 concentrations varied from 20.7 to 6.80% in the control, from 20.9 to 8.80% in 0.25 mM, from 20.8 to 13.7% in 0.5 mM, and from 20.9 to 12.9% in 1.0 mM MeJA treatments. The CO_2 concentrations varied from 0.7 to 11.4% in the control, from 1.2 to 10.5% in 0.25 mM, from 0.60 to 7.90% in 0.5 mM, and from 1.1 to 8.60% in 1.0 mM MeJA treatments during the storage.

Fruits were subjected to precooling at 4 ± 0.5 °C and 90 ± 5% RH for 24 h, and then MAP was closed with plastic clips. After that, fruits were stored at 0 ± 0.5 °C and 90 ± 5% RH for 180 days. Measurements and analyses were performed at 30, 60, 90, 120, 150, and 180 days of cold storage. The same fruits were kept at 20 ± 1 °C and 80 ± 5% RH for 5 days for shelf life measurements and analyses. In each measurement period, 3 boxes were taken for each treatment. Each box represented a replicate. Of 20 fruits in each box, half were used for cold storage and the other half were used for shelf life measurements.

2.3. Methods

2.3.1. Weight loss

Initial fruit weight (Wi) was determined at the beginning of the enclosure by a digital scale with a precision of 0.01 g (Radwag, Poland). Then, at 30, 60, 90, 120, 150 and 180 days of storage, the final fruit weight (W_f) was determined. Equation (1) was used to get weight loss (WL) as a percentage of the initial fruit weight.

$$WL = \frac{Wi - Wf}{Wi} \times 100 \quad \text{(Eq.1)}$$

2.3.2. Respiration rate and firmness

To measure respiration rates, 2 L airtight chambers were fitted with a rubber septum and 4 fruits were sealed in each chamber at 20 ± 1 °C temperature and 80% RH for 1 h. The chambers were then connected to a gas sensor (Vernier, Oregon, USA) and the amount of CO_2 produced by the fruits was considered as the respiration rate. Results were presented in nmol CO_2 kg^{-1} s^{-1}.

To determine the fruit firmness (10 fruits in each replication), the peel of kiwifruit was removed from 3 equilateral sections with a stainless peeler and a hand penetrometer (FT–327, McCormick Fruit Tech. USA) with a 11.1 mm probe was used. The results were presented in Newtons (N) (Ozturk et al., 2019a).

2.3.3. Color characteristics

The L*, chroma, and hue angles were measured by a colorimeter (Konica-Minolta, CR-400, Japan). The CIE (Commission Internationale de l'Eclairage system) was used in color measurements. L*, chroma, and hue angle values were measured from the flesh of 10 fruits. Then, the X, Y, and Z values were converted into L*, a*, and b* coordinates using the equations corresponding to illuminant D65 and standard observer of 10°. The equations of $C^* = (a^{*2} + b^{*2})^{1/2}$ for chroma and $h^\circ = \tan^{-1} b^*/a^*$ for hue angle were used (McGuire, 1992).

2.3.4. Soluble solids content, titratable acidity, and vitamin C

Five fruits taken from each replication were first washed with distilled water. The fruits were chopped with a stainless-steel knife, cut into parts, and homogenized by a blender (Model No. Promix HR2653 Philips, Turkey). Then, the homogenate was filtered through cheesecloth, and the juice was obtained. Soluble solids content (SSC) was measured with a portable digital refractometer (Atago PAL-1, USA) and expressed as a percentage. For titratable acidity measurements, 10 mL juice was taken and 10 mL distilled water was added. Then 0.1 N NaOH (sodium hydroxide) was added until the pH of the solution reached to 8.2. Based on the amount of NaOH consumed in titration, titratable acidity was determined and expressed as g citric acid L^{-1} (Ozturk et al., 2019a).

For vitamin C measurements, 0.5 mL juice was taken, and 5 mL of 0.5% oxalic acid was added to it. The ascorbic acid test strip (Catalog no: 116981, Merck, Germany) was taken from a collapsible sealed gas-tight tube. Reflectometer (Merck RQflex plus 10) was started. The test strip was plunged into the solution for 2 s, then removed from the solution. It was then held for 8 s, and the reading was taken at the end of the 15th s. Results were presented as g L^{-1} (Ozturk et al., 2019a).

2.3.5. Total phenolics, total flavonoids, and antioxidant activity

During each measurement period, 5 fruits were taken from each replication of each treatment. The fruits were washed with distilled water and sliced with a stainless-steel knife. Later, the pulp of the fruits was placed in a blender, and homogenized. About 30 mL of homogenate was taken and placed into 50 mL falcon tubes. The tubes were kept at –20 °C until the analyses.

Before the analyses, the frozen samples were dissolved under room temperature (21 °C). Pulp and juice were separated from each other by a centrifuge at 12.000 × g at 4 °C for 35 min. The resultant filtrate was used to determine total phenolics, total flavonoids, and antioxidant activity of the samples.

Spectrophotometric measurements for bioactive compounds were performed in a UV-vis spectrophotometer (Shimadzu, Kyoto, Japan). Total phenolics were measured according to the method described by Beyhan et al. (2010) and were expressed as g kg^{-1} GAE (gallic acid equivalent) fresh weight (fw). Total flavonoids were measured according to the method of Zhishen et al. (1999) and were expressed as g kg^{-1} QE (quercetin equivalent) fw.

The antioxidant activity of kiwifruit was determined according to two different procedures of 1,1-diphenyl-2-picryl-hydrazil (DPPH) (Blois, 1958), and ferric jons (Fe^{3+}) reducing antioxidant power (FRAP) (Benzie and Strain, 1996), and the results were expressed as mmol kg^{-1} trolox equivalent (TE) fw.

2.4. Statistical analysis

Whether the data was normally distributed was checked using the Kolmogrov–Smirnov test. Homogeneity control of the group/subgroup variances was confirmed using Levene's test. After the variance analysis of the data, Tukey's multiple-comparison test was used to check whether there were significant differences ($P < 0.05$) between the treatments. The statistical analyses were performed using SAS software (SAS 9.1 version, USA).

3. Results and discussion

Throughout the cold storage, 0.25 and 1.0 mM MeJA treatments yielded similar weight loss data, but significantly lower values than those of the control and 0.5 mM MeJA treatments. Compared to the control, 0.5 mM MeJA treatment retarded weight losses on days 90, 120, 150, and 180 of storage (Figure 1). Decay did not occur in fruits throughout the experiments (no data were presented about the decays).

The respiration rate of kiwifruit increased until the 60th day of cold storage and shelf life then decreased until the end of the cold storage. Throughout the cold storage, 0.5 and 1.0 mM MeJA-treated fruits exhibited similar decreases in respiration rate, but they had significantly lower values than the control and 0.25 mM MeJA-treated fruits. The respiration rate of 0.25 mM MeJA treatment was not significantly different from the control. In comparison to the control and 0.25 mM MeJA treatments; the 0.5 and 1.0 mM MeJA treatments significantly retarded respiration rates in the last three shelf life measurements (Figure 2).

Weight and quality losses encountered in fresh fruits and vegetables are key problems for both the producers and the consumers. In the present study, entire MeJA doses significantly retarded weight losses. Such retard in weight loss was more remarkable in 0.25 and 1.0 mM MeJA treatments. Complying with the present findings, retarded weight loss after MeJA treatments was reported in strawberries (Asghari and Hasanlooe, 2016) and Japanese plums (Kucuker and Ozturk, 2014). However, Karaman et al. (2013) reported greater weight loss for MeJA-treated 'fortune' plums. In the present study, MeJA-treated fruits (except for 0.5 mM) generally had lower respiration rates than the control fruits. Respiration might have been suppressed by MeJA, as, parallel to lesser use of metabolic production in respiration, a lesser weight loss was observed in MeJA treatments. Similarly, reduced respiration rates and thus lesser weight losses after MeJA treatments were reported in loquat (Cao et al., 2009); apricot (Ezzat et al., 2017), and medlar fruits (Ozturk et al., 2019b). Such effects of MeJA were reported to vary based on fruit species, treatment doses, treatment time, and treatment methods (such as spraying and dipping) (Rohwer and Erwin, 2008; Ozturk et al., 2019b).

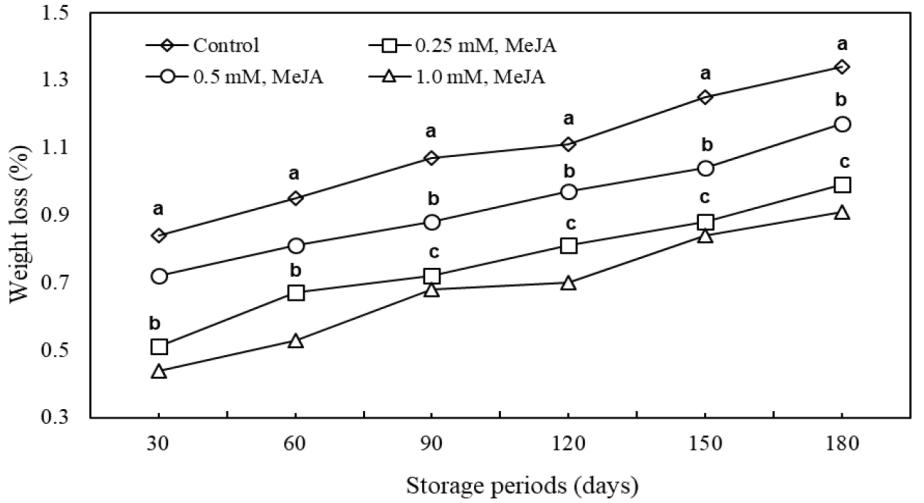

Figure 1. Effect of methyl jasmonate on weight loss of kiwifruits during cold storage. The differences among the means indicated with different lower-case letters vertically are significant (Tukey's test, $P < 0.05$).

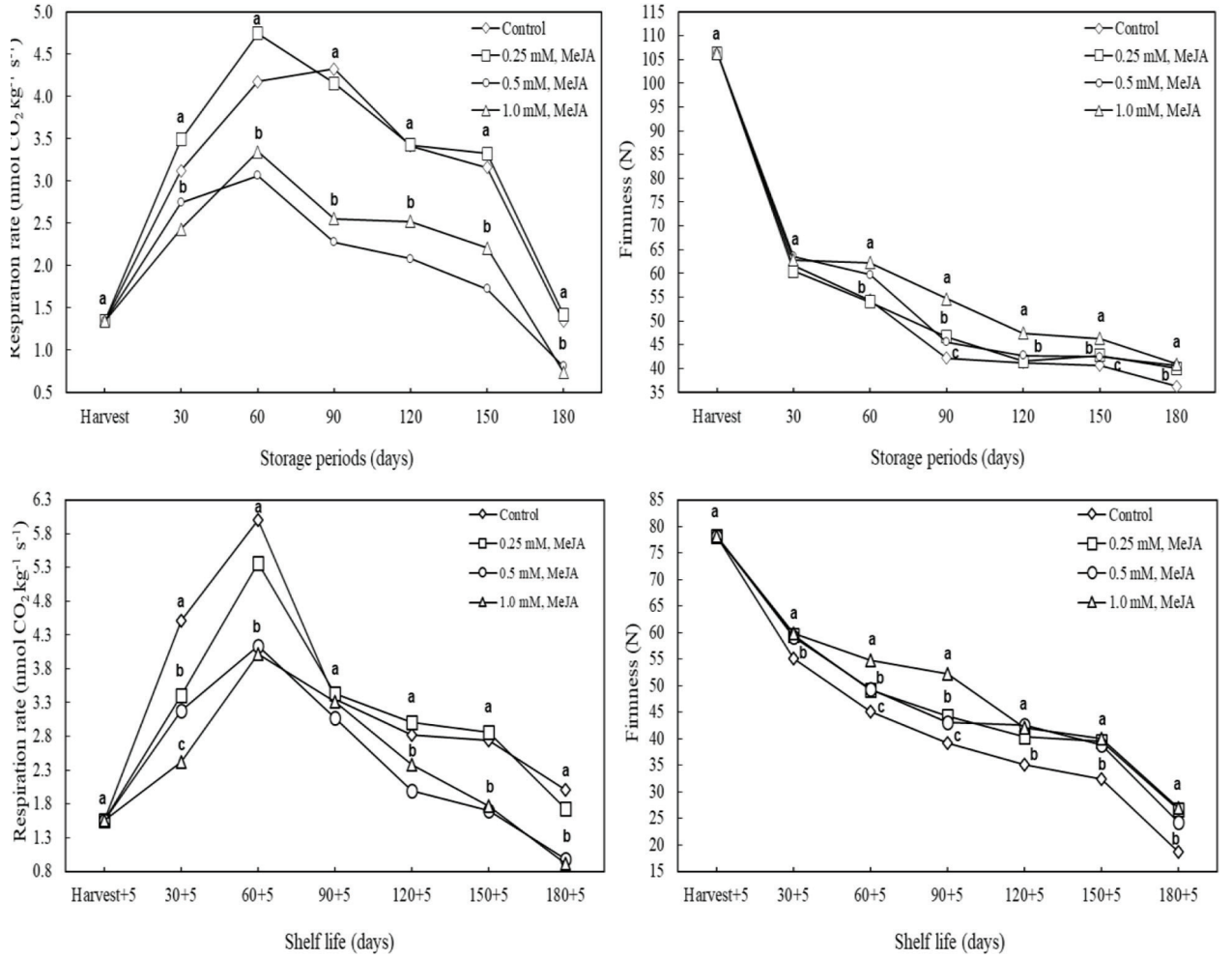

Figure 2. Effect of methyl jasmonate on respiration rate and firmness of kiwifruits during cold storage and shelf life. The differences among the means indicated with the different lower-case letters vertically are significant (Tukey's test, $P < 0.05$).

Fruit firmness decreased in all treatments throughout the storage. In general, effects of 1.0 mM MeJA treatment in retarding flesh softening were more remarkable. Both in all cold storage (except for 30 days) and shelf life measurement periods, 1.0 mM MeJA-treated kiwifruit had significantly slower flesh softening than the control fruits. On days 90, 150, and 180 of cold storage and all measurement periods of shelf life, 0.25 and 0.5 mM MeJA treatments had significantly greater flesh firmness values than the control fruits. In the last measurement period of cold storage and on days 30, 120, 150, and 180 of shelf life measurements, MeJA treatments yielded similar flesh firmness levels (Figure 2).

Firm kiwifruits generally have longer cold storage duration and shelf life. Therefore, both producers and consumers prefer firm kiwifruits. In the present study, MeJA treatments were found to be effective in retarding loss in flesh firmness. Fan et al. (2016) stated that MeJA delayed the fruit ripening by stimulating postharvest antioxidant systems. Also, Kondo et al. (2005) and Rudell et al. (2005) reported that MeJA could have an ethylene-independent effect on fruit ripening. Similarly, in the present study, MeJA treatments might have delayed fruit ripening and thus maintained flesh firmness. The effects of MeJA were more distinct with the progress of storage duration. Fruit firmness was particularly better preserved with 1.0 mM MeJA treatment. MeJA treatments delayed fruit flesh softening in sweet cherry (Saracoglu et al., 2017; Balbontin et al., 2018), apple (Rudell et al., 2005; Altuntas et al., 2012), and medlar fruits (Ozturk et al., 2019b). Ziosi et al. (2008) reported that MeJA regulated the activity of enzymes effective in cell membrane metabolism, thus decreased flesh softening. In the present study, MeJA might have exhibited a similar effect to the aforementioned literature. Contrarily, increasing flesh softening was reported with MeJA treatments in loquat fruits (Jin et al., 2014) and MeJA treatments yielded similar firmness values with the control in oranges (Rehman et al., 2018). Such conflicting outcomes indicated that effects of MeJA might vary with the species and cultivars (Rohwer and Erwin, 2008).

At 30 days of cold storage, 0.5 and 1.0 mM MeJA treatments yielded significantly lower L* values than the control treatment. At 180 days, only 1.0 mM MeJA treatment had significantly greater chroma value than the control treatment. In the same measurement periods, MeJA-treated fruits had significantly greater hue angle values than the control fruits. Color data in the last shelf life measurements revealed that only 1.0 mM MeJA treatment had greater L* values than the control treatment. However, MeJA-treated fruits had significantly greater chroma values than the control fruits (Figure 3).

Its vivid flesh color increases the allure of kiwifruit. The L* value indicates brightness, and the hue angle indicates the green color of fruits (McGuire, 1992). In general, MeJA treatments did not have a distinctive effect on flesh color throughout the cold storage and shelf life. Although the effects of MeJA on color development were reported in different fruit species (Kondo et al., 2005; Rudell et al., 2005; Balbontin et al., 2018), it is impossible herein to mention the direct effects of MeJA on flesh color of kiwifruit. However, Kondo (2006) and Saracoglu et al. (2017) reported retarded color development in cherries with MeJA treatments.

All MeJA-treated fruits at 30 days of cold storage, 0.5 and 1.0 mM MeJA-treated fruits at 60 days, and 0.25 and 0.5 mM MeJA-treated fruits at 180 days had significantly lower SSC values than the control fruits. In shelf life measurements, significant differences were observed in SSC values of the treatments only in measurements at 30 days + 5. In this period, 0.5 and 1.0 mM MeJA-treated fruits had significantly lower SSC values than the control fruits. In cold storage measurements, 0.5 mM MeJA-treated fruit had significantly greater acidity than the control fruit. In contrast, in shelf life measurements (except for days 180 + 5), control fruit generally had greater acidity values than the MeJA-treated fruits (Figure 4).

SSC is an important indicator of commercial harvest time for kiwifruit. SSC increases with the progress of ripening. In the present study, MeJA treatments did not have significant effects on SSC throughout both the cold storage and shelf life. However, 0.5 mM MeJA treatment resulted in greater acidity than the control treatment throughout the cold storage. On the other hand, throughout the shelf life (except for day 180 + 5), all MeJA treatments had significantly lower acidity than the control. Contrary to complying findings of the previous studies with the present findings (Kondo et al., 2001; 2005; Saracoglu et al., 2017), significant effects of MeJA treatments on SSC and acidity were reported by some others (Rudell et al., 2005; Ezzat et al., 2017; Ozturk et al., 2019b).

Throughout the cold storage and shelf life, decreases were observed in vitamin C, total phenolics, total flavonoids, and antioxidant activity. On day 180 measurements of cold storage, 1.0 mM MeJA-treated fruits had significantly greater vitamin C, total flavonoids, and antioxidant activity (both DPPH and FRAP assays) than the control fruits. However, only 0.25 mM MeJA-treated fruit had significantly greater total phenolics than the control fruits (Figures 5 and 6).

In shelf life measurements made on day 30 + 5, there were significant differences only in vitamin C contents. All MeJA treatments yielded significantly greater vitamin C contents than the control treatment and 0.5 mM MeJA-treated fruits also had significantly greater vitamin C content than the other MeJA-treated fruits. As compared to the control, significantly greater total phenolics were obtained only from 1.0 mM MeJA treatments on day 30 +

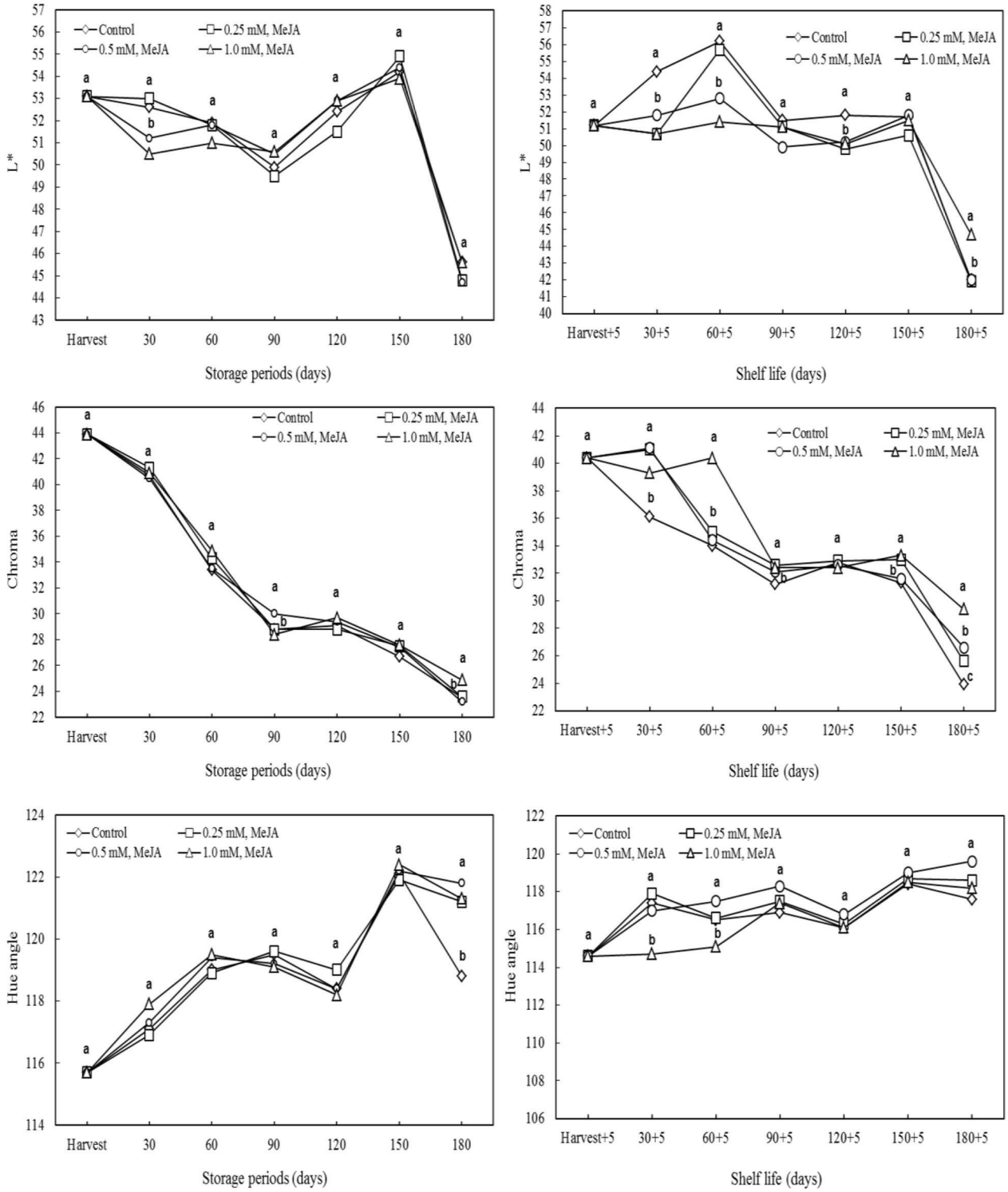

Figure 3. Effect of methyl jasmonate on L*, chroma, and hue angle of flesh of kiwifruits during cold storage and shelf life. The differences among the means indicated with the different lower-case letters vertically are significant (Tukey's test, $P < 0.05$).

5; from 0.25 and 1.0 mM MeJA treatments on day 90 + 5; from only 0.25 mM MeJA treatments on day 120 + 5 and day 150 + 5. On the other hand, in day 180 + 5 measurements, 0.5 and 1.0 mM MeJA treatments yielded significantly greater total flavonoids and antioxidant activity (in FRAP assay) than the control treatment (Figures 5 and 6).

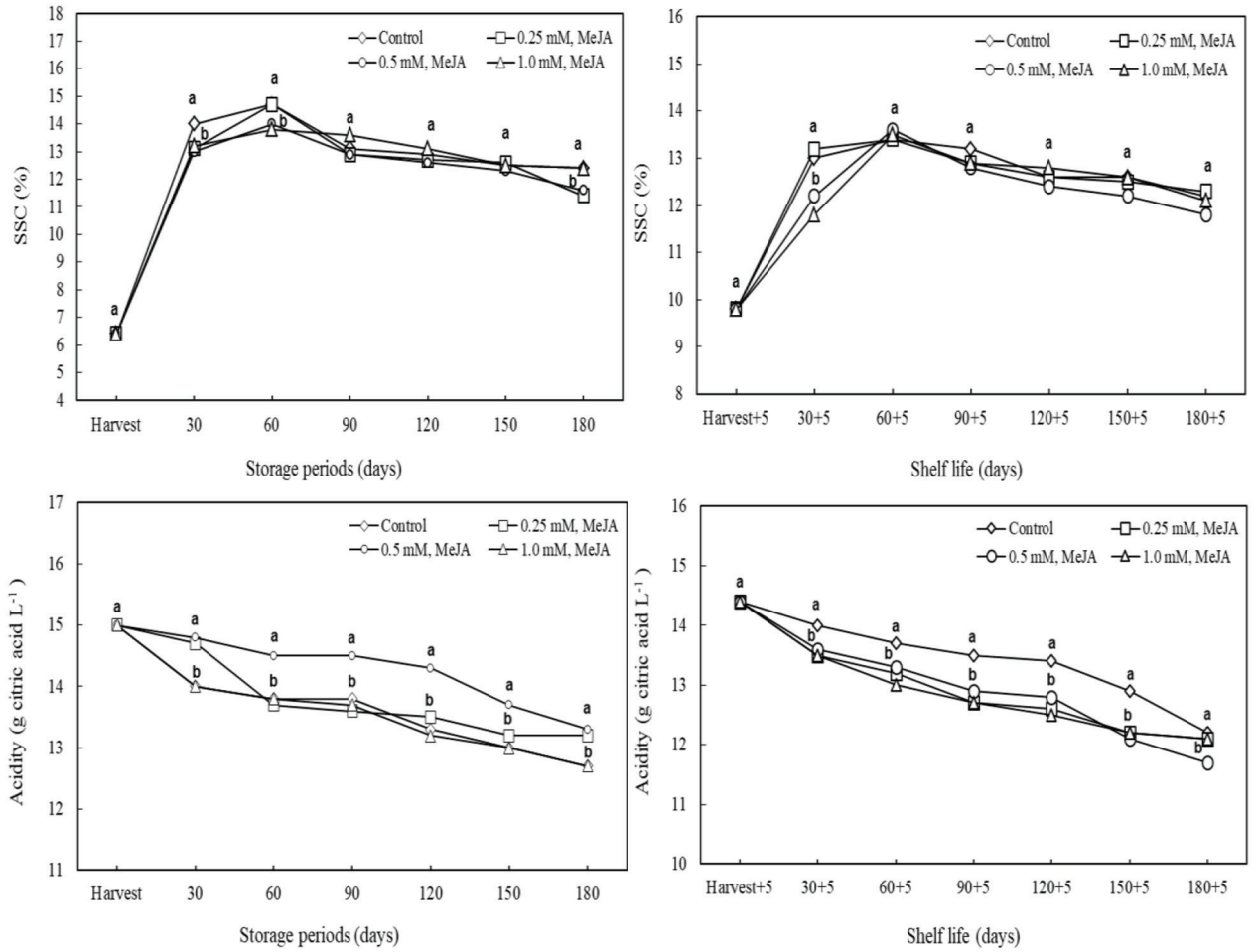

Figure 4. Effect of methyl jasmonate on soluble solids content (SSC) and acidity of kiwifruits during cold storage and shelf life. The differences among the means indicated with the different lower-case letters vertically are significant (Tukey's test, $P < 0.05$).

In daily diets, consumers wish to have fruit and vegetable species rich in vitamins and nutrients. However, significant losses are encountered in nutritional attributes of horticultural crops during the cold storage and shelf life. In the present study, decreases were observed in vitamin C, total phenolics, flavonoids, and antioxidant activity of kiwifruit throughout the cold storage and shelf life. MeJA was used to minimize or prevent such losses in various fruit species (Rudell et al., 2005; Kondo et al., 2005; Balbontin et al., 2018; Ozturk et al., 2019b).

It was observed in the present study that MeJA generally retarded the losses in vitamin C contents throughout the cold storage, but was effective only at day 30 + 5 of shelf life and yielded similar values with the control treatment in the other shelf life measurement periods. It was reported that MeJA treatments retarded the losses in vitamin C contents of pineapple (Boonyaritthongchai and Supapvanich, 2017), mango (Vithana et al., 2019), and pomegranate (Garcia-Pastor et al., 2020) fruits. Contrarily, Rehman et al. (2018) reported lower vitamin C content of MeJA-treated orange fruits.

Effects of MeJA treatments on total phenolics and flavonoids varied with the measurement periods. For instance, while 0.5 mM MeJA treatment yielded similar total phenolics with the control on days 60 and 90 of cold storage, total phenolics of MeJA treatments were significantly lower than the control in the last two measurement periods of the cold storage. Such effects of MeJA on total phenolics and flavonoids may also vary with the dose of application (Asghari and Hasanlooe, 2016). The 0.5 mM MeJA treatment was more effective on total phenolics and 1.0 mM MeJA treatment was more effective on total flavonoids. Thus, it was indicated in previous studies that such effects of MeJA could vary based on treatment doses (Rudell et al., 2005; Asghari and Hasanlooe, 2016; Saracoglu et al., 2017; Pastor-Garcia et al., 2020).

Consumers are generally exposed to stress conditions in their daily life. Consumption of fruits with a high antioxidant capacity in daily diets will help to reduce stress-induced damage on their bodies. Therefore, fruits

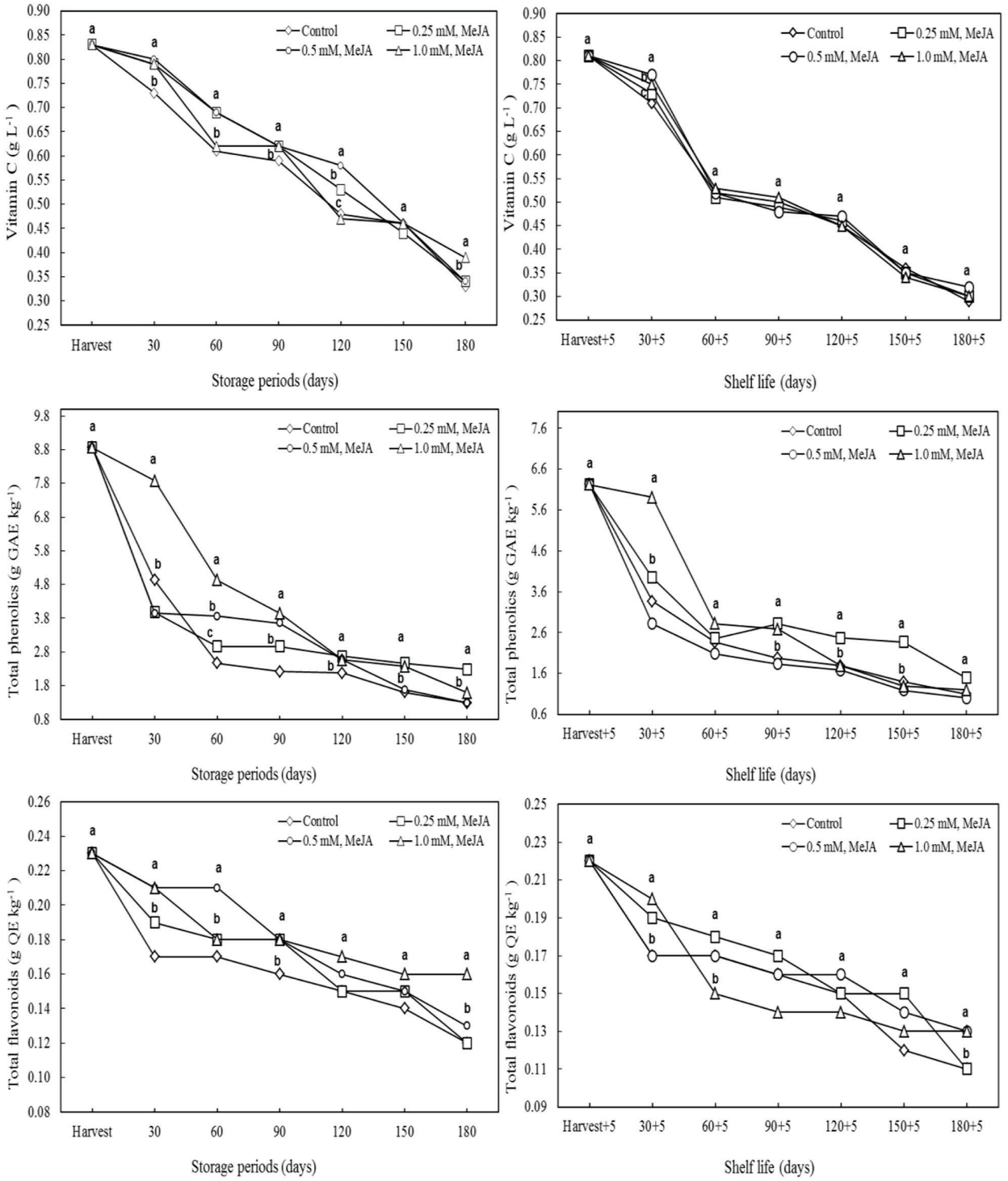

Figure 5. Effect of methyl jasmonate on vitamin C, total phenolics, and total flavonoids of kiwifruits during cold storage and shelf life. The differences among the means indicated with the different lower-case letters vertically are significant (Tukey's test, $P < 0.05$).

are desired to maintain their antioxidant capacities after the harvest. In all measurement periods of cold storage, 1.0 mM MeJA treatments generally yielded greater antioxidant activity (both in DPPH and FRAP tests) than the control treatment. In all measurement periods of shelf life (except for day 180 + 5 of 0.5 mM MeJA), MeJA-treated fruits had greater antioxidant capacity (in FRAP test) than the control fruits. As can be inferred from these findings, MeJA

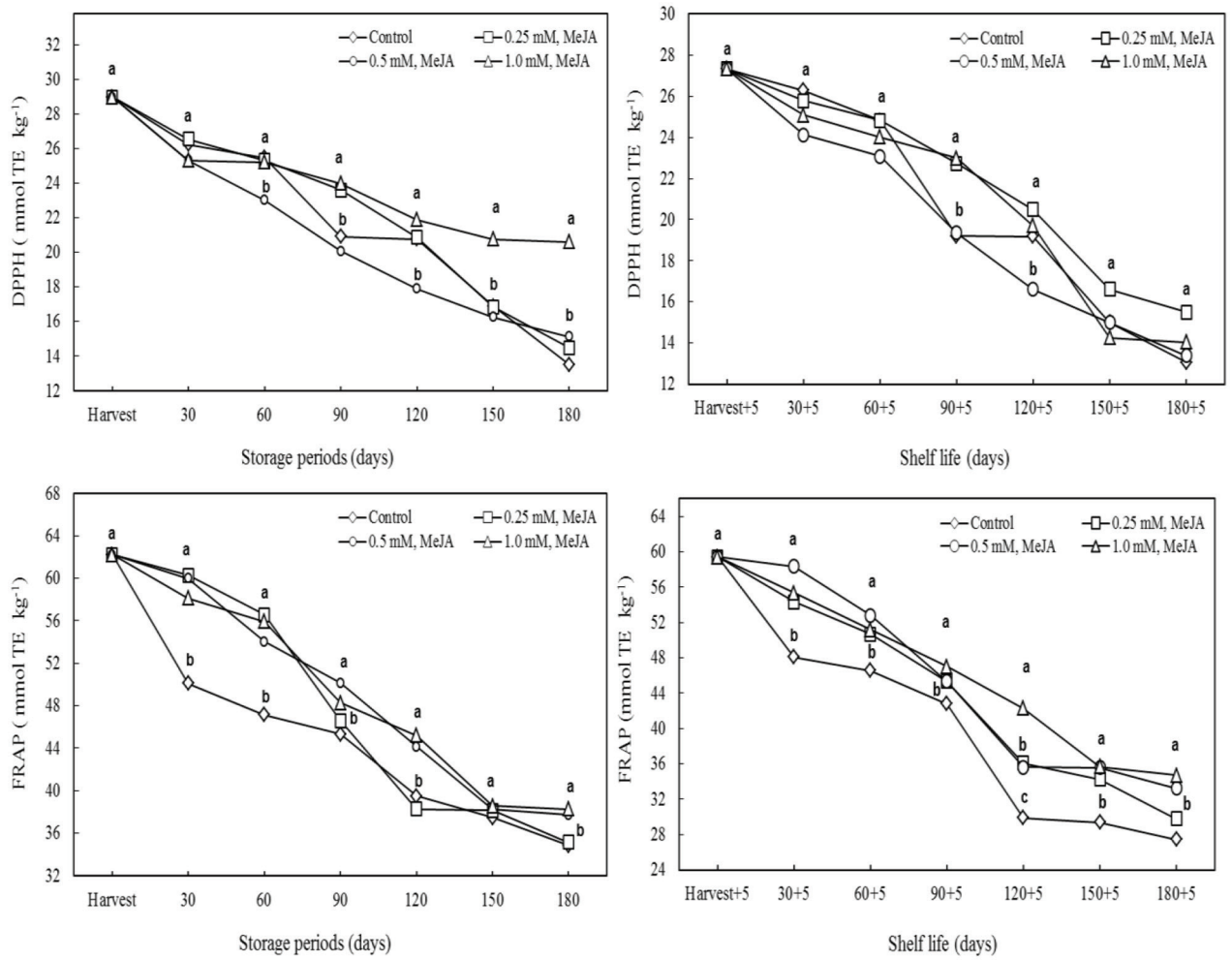

Figure 6. Effect of methyl jasmonate on antioxidant activity (DPPH and FRAP assay) of kiwifruits during cold storage and shelf life. The differences among the means indicated with the different lower-case letters vertically are significant (Tukey's test, $P < 0.05$).

treatments had significant contributions to preservation of antioxidant activity of the fruits (Ozturk et al., 2019b; Pastor-Garcia et al., 2020). It was reported in previous studies that MeJA treatments significantly preserved total phenolics and thus antioxidant activity of raspberry (Wang and Zhang, 2005), loquat (Cao et al., 2009), pomegranate (Garcia-Pastor et al., 2020), plum (Martinez-Espla et al., 2014), apple (Ozturk et al., 2014), and medlar fruits (Ozturk et al., 2019b). Contrarily, Kucuker et al. (2015) and Saracoglu et al. (2017) in sweet cherry and Rehman et al. (2018) in orange, reported significantly lower total phenolics, total flavonoids, and antioxidant activity for MeJA-treated fruits than for the control fruits. Similarly, Boonyaritthongchai and Supapvanich (2017) in pineapple and Portu et al. (2016) in 'Tempranillo' grape, reported insignificant effects of MeJA treatments on total phenol, total flavanols, and antioxidant activity. Such delaying effects of MeJA in loss of bioactive compounds can be attributed to increase in activity of the enzymes like phenylalanine ammonia-lyase responsible for polyphenol synthesis by MeJA (Ruiz-Garcia et al., 2012). Differences in study findings were mostly attributed to differences in fruit species, cultivars, application times, and doses. Thus, bioactive compounds of fruits may vary with the harvest time, ripening stage, environmental conditions (temperature, light), genetic differences, irrigation, fertilization, and the other cultural practices (plant growth regulators and etc.) (Asghariand Hasanlooe, 2016; Saracoglu et al., 2017; Pastor-Garcia et al., 2020).

4. Conclusion

It was concluded, based on present findings that methyl jasmonate (MeJA) could be used as an efficient postharvest tool to decrease weight loss and to minimize the losses in vitamin C, total phenolics, and total flavonoids-like bioactive compounds with a great contribution to antioxidant activity throughout the cold storage and shelf life of kiwifruit. Also, in the future, research on the effect of

MeJA, which is applied to intact kiwifruits, on fruit quality during cold storage and shelf life should be detailed.

Author contribution statement

Burhan Ozturk: methodology, investigation, conceptualization, validation, writing - original draft, visualization. Furkan Yucedag: methodology, investigation, formal analysis, data curation, review and editing.

Conflict of interest

The authors declare that they have no conflict of interest.

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