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# Effect of Methyl Jasmonate Treatments on Fruit Quality and Antioxidant Enzyme Activities of Sour Cherry (*Prunus cerasus* L.) During Cold Storage

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ABSTRACT

The study was carried out to investigate the effect of methyl jasmonate (MeJA) treatments (0.5 and 1.0 mM MeJA) on quality characteristics such as weight loss, respiration rate, ethylene production, color, total phenolic content (TPC), total antioxidant capacity (TAC) and antioxidant enzyme activities of sour cherry fruit (*Prunus cerasus* L. cv. 'Kütahya') during cold storage. Fruit were stored at 0±1 °C and 90±5% RH for 36 days. The results indicated that MeJA treatments showed higher levels of total phenolic content, total antioxidant capacity and quality and were also effective on superoxide dismutase (SOD), catalase (CAT), ascorbate peroxidase (APX), malondialdehyde (MDA), ethylene production and respiration rate. In conclusion, 0.5 mM MeJA treatment showed the best maintaining of fruit quality among the concentrations of MeJA. It can be suggested that sour cherry could be stored successfully for 36 days at 0 °C following treatment of MeJA.

Keywords: Antioxidant enzymes, Ethylene production, MeJA, Respiration rate, Sour cherry



## 1. Introduction

Sour cherry (*Prunus cerasus* L.), a stone fruit species and originated from northeastern Anatolia, belongs to the *Rosaceae* family (Önal 2002; Ferretti et al. 2010). Total annual production of sour cherry was 1.52 million tones worldwide in 2018 (FAO 2020). Turkey is one of important countries in terms of sour cherry production and the fruit has been widely consumed as fruit juice, jam, vine or dried fruit (Eksi & Akdag 2007; Lončarić et al. 2016). The fruit is rich in anthocyanins which known as an antioxidant due to ability to counteract oxygen free radicals. Sour cherry has an important nutritional value because of its high level of vitamins, fibers, and polyphenolids (anthocyanins and other flavonoids), in addition to alkaloids and melatonin (Jia et al. 2012).

Although fresh consumption of this fruit has not been widely common (Lončarić et al. 2016), recent studies showed that there has been an increasing demand for fresh consumption due to its health benefits resulted from regular intake of anthocyanins and polyphenolics (Beattie et al. 2005; Kim et al. 2005; Piccolella et al. 2008).

Methyl Jasmonate (MeJA) is a natural compound used both preharvest (Saracoglu et al. 2017) and postharvest (Öztürk et al. 2019) to extend shelf life, as well as maintain the quality of products. The treatment of MeJA increases antioxidant activity during postharvest period since stimulates the activities of several antioxidant enzymes such as superoxide dismutase (SOD) (Cao et al. 2009a), catalase (CAT) (Asghari & Hasanlooe 2015), ascorbate peroxidase (APX) (Cao et al. 2009b), polyphenol oxidase (PPO) (Asghari & Hasanlooe 2015). Moreover, the treatments of MeJA poise membrane structure and bring down lipid peroxidation (Ziosi et al. 2008). So, the postharvest treatment of MeJA in horticultural crops is remarkable in order to maintaining storage quality, delaying senescence and improving resistant responses.

Unfortunately, there have been no published studies about the effect of MeJA on sour cherry quality and postharvest life. So, the aim of this study was to investigate the effect of MeJA treatments with stretch film on sour cherry quality, ripening and senescence at 0 °C storage temperature and during 36 days.

## 2. Material and Methods

*2.1. Plant materials*

The sour cherry fruit *(Prunus cerasus* L. cv. 'Kütahya') were manually harvested at optimal harvest date (when the entire surface of fruit had light red color) in Gevaş ( 38° 32′ 28″ N, 43° 26′ 03″ E, 1730 m in elevation) district of Van Province, Turkey and used in this study. The samples were pre-cooled for 12 hours at +4 °C temperature.

*2.2. Methods*

The fruit suitable for experiment, as in the same size and free from defects were selected and divided into three groups. Samples in the first group was immersed in distilled water as a control for 10 minutes. The second and third group fruit were immersed in 0.5 and 1.0 mM MeJA (PubChem CID: 5281929, 95% Sigma Aldrich, cat no.392707) solutions for 10 minutes, respectively. After treatments, all fruit were dried on papers at room condition (25 °C). Later, the fruit were placed in foam plates (each package per 400 g) and covered with stretch film having 8 µ thickness, then stored for 36 days at 0 °C temperature and 90-95% relative humidity (RH). During storage period, changes in fruit quality were determined some physical, chemical and physiological analysis mentioned below.

*2.3. Weight loss*

Weight loss during the storage period was measured daily and calculated as percentage of initial weight.

*2.4. Titratable acidity (TA), fruit juice pH, soluble solids content (SSC), color*

Titratable acidity (TA) was measured by titrating of fruit juice by 0.1 N NaOH till pH= 8.1 and the results were assessed in % citric acid (Cemeroğlu 2007). The pH values were measured by a pH meter (AZ 8601, Hengxin Company, China). Soluble solids content (SSC) was detected with a digital hand refractometer (Atago, Tokyo, Japan) and results were presented as percent. Fruit color was measured by a chromameter (Minolta CR-400; Osaka, Japan) in $L^*$, $a^*$, $C^\circ$ and $h^\circ$ color space system and 10 fruits were measured randomly for each replication.

*2.5. Total phenolic content (TPC) and total antioxidant capacity (TAC)*

Total phenolic content was determined with a spectrophotometer (Thermo Scientific Genesys 10S UV-VIS) at 725 nm as described by the Swain & Hillis (1959) and was assessed in gallic acid equivalent (GAE) mg100 $g^{-1}$ FW.

Ferric Reducing Antioxidant Power (FRAP) method was utilized to evaluate the total antioxidant capacity at 593 nm and was assessed in µmol trolox equivalent (TE) $g^{-1}$ FW (Benzie & Strain 1996).

*2.6. Antioxidative enzyme analyzes*

The activity of superoxide dismutase (SOD) and catalase (CAT) enzymes was spectrophotometrically measured according to the methods of Jebara et al. (2005), Bagcı (2010), Alp & Kabay (2019) at 560 nm and 240 nm, respectively. Ascorbate peroxidase (APX) activity was also measured at 290 nm as in Nakano et al. (1981). The levels of lipid peroxidation were assessed with regard to malondialdehyde (MDA) content according to Bagcı (2010)s' method.

*2.7. Respiration rate and ethylene production*

For respiration rate determinations, fruit (each replication an average of 250 g) were kept at room temperature in closed jars for 2 hours and the carbon dioxide ($CO_2$) emission of fruit was detected in headspace gas sample with the Headspace Gas Analyzer GS3/L analyzer. The respiration rate values presented as mL $CO_2$ $kg^{-1}$ $h^{-1}$ (Cavusoglu et al. 2020).

The ethylene production of samples was assessed in aforementioned headspace gas samples with a gas-tight syringe and a GC-FID (GC-2010 Plus) as described by Guillén et al. (2013). The ethylene production was presented is assessed as µL $C_2H_4$ $kg^{-1}$ $h^{-1}$.

*2.8. Oxygen and Carbon dioxide concentrations in the packages*

The oxygen ($O_2$) and $CO_2$ concentrations in the packages was detected by Headspace Gas Analyzer GS3 / L analyzer.

*2.9. Statistical analysis*

This study was carried out as completely randomized experimental design with three replications and each package was considered one replication. Descriptive statistics for the studied variables were presented as Mean and Standard Error of Mean (SEM). Two-way Factorial ANOVA was performed to data. Treatments at different MeJA concentrations and storage period were considered as factors. Duncans' Multiple Range Test comparisons were also used to identify different levels of treatment and storage factors. Statistical significance level was considered as 5% and SPSS (Ver. 21) statistical program was used for all statistical computations.

## 3. Results

### *3.1. Weight loss*

The weight loss was 7.33% in control fruit at the end of storage period and, respectively, higher than in sour cherry fruit treated with 1 mM and 0.5 mM MeJA (Table 1). Among the storage periods, weight losses were significant in all the sampling.

**Table 1- The changes in weight loss during storage of 'Kütahya' sour cherry *(Prunus cerasus* L.) fruit during 36 d at 0 °C. Data was presented as means ± SEM**

| *Parameters* | *Storage period* | *Control* | *0.5 mM MeJA* | *1 mM MeJA* | *Means* |
|---|---|---|---|---|---|
| Weight loss | 0 | 0.000 ± 0.000 | 0.000 ± 0.000 | 0.000 ± 0.000 | 0.000± 0.000 F[1] |
| | 5 | 1.001 ± 0.101 | 0.922 ± 0.044 | 0.928 ± 0.009 | 0.950 ± 0.032 E |
| | 10 | 2.523 ± 0.332 | 2.089 ± 0.020 | 2.127 ± 0.405 | 2.246 ± 0.161 D |
| | 15 | 3.577 ± 0.463 | 2.949 ± 0.028 | 2.986 ± 0.409 | 3.170 ± 0.205 C |
| | 25 | 5.685 ± 0.724 | 4.666 ± 0.042 | 4.272 ± 0.014 | 4.874 ± 0.325 B |
| | 36 | 7.331 ± 1.449 | 6.384 ± 0.057 | 6.847 ± 0.003 | 6.853 ± 0.412 A |
| | Means | 3.352 ± 0.795 | 2.834 ± 0.653 | 2.859 ± 0.681 | |
| | Significant effects; Ptreatment = 0.846 | Pstorage = 0.001 | Ptreatment x Pstorage = 0.890 | | |

[1]: Letters show differences among storage periods at P<0.05 error level

### *3.2. Titratable acidity (TA), fruit juice pH, soluble solids content (SSC), Color*

The results in table 2 showed that the fruit treated with MeJA resulted in higher levels of TA compared with untreated fruit. The highest level of TA was detected in fruit treated with 1 mM MeJA followed by fruit treated with 0.5 mM MeJA after 36 days of storage period. Among storage periods, TA values were significantly changed in all treatments. Significant differences were observed between fruit treated with MeJA and control fruit in terms of TA values.

**Table 2- The changes in titratable acidity (TA), pH and soluble solids content (SSC) during storage of 'Kütahya' sour cherry *(Prunus cerasus* L.) fruit during 36 d at 0 °C. Data was presented as means ± SEM**

| *Parameters* | *Storage period* | *Control* | *0.5 mM MeJA* | *1 mM MeJA* | *Means* |
|---|---|---|---|---|---|
| TA | 0 | 2.320 ± 0.144 A a | 2.320 ± 0.144 A a | 2.320 ± 0.144 A a | 2.320 ± 0.064 |
| | 5 | 1.277 ± 0.054 CD c | 1.677 ± 0.205 BC b | 1.725 ± 0.131 BC a | 1.559 ± 0.110 |
| | 10 | 1.568 ± 0.038 BC b | 1.975 ± 0.029 AB a | 1.991 ± 0.134 AB a | 1.844 ± 0.094 |
| | 15 | 1.824 ± 0.288 B a | 1.120 ± 0.032 E c | 1.456 ± 0.029 C b | 1.466 ± 0.148 |
| | 25 | 1.002 ± 0.029 E b | 1.200 ± 0.003 CD a | 1.037 ± 0.006 D b | 1.079 ± 0.039 |
| | 36 | 1.479 ± 0.116 BCD b | 1.527 ± 0.041 CD a | 1.555 ± 0.154 C a | 1.520 ± 0.052 |
| | Means | 1.578 ± 0.132 | 1.636 ± 0.130 | 1.680 ± 0.127 | |
| | Significant effects; Ptreatment = 0.856 | Pstorage = 0.001 | Ptreatment x Pstorage = 0.015 | | |
| pH | 0 | 3.195 ± 0.015 | 3.195 ± 0.015 | 3.195 ± 0.015 | 3,195 ± 0,006 B[1] |
| | 5 | 3.400 ± 0.040 | 3.325 ± 0.015 | 3.405 ± 0.035 | 3,376 ± 0,021 A |
| | 10 | 3.380 ± 0.030 | 3.405 ± 0.005 | 3.365 ± 0.055 | 3,383 ± 0,017 A |
| | 15 | 3.345 ± 0.015 | 3.385 ± 0.015 | 3.310 ± 0.020 | 3,346 ± 0,015 A |
| | 25 | 3.395 ± 0.025 | 3.390 ± 0.020 | 3.365 ± 0.025 | 3,383 ± 0,012 A |
| | 36 | 3.440 ± 0.000 | 3.405 ± 0.005 | 3.410 ± 0.010 | 3,418 ± 0,007 A |
| | Means | 3.359 ±0.024 | 3.350 ±0.022 | 3.341 ±0.023 | |
| | Significant effects; Ptreatment = 0.875 | Pstorage = 0.001 | Ptreatment x Pstorage = 0.260 | | |
| SSC | 0 | 15.900 ± 0.100 A a[1] | 15.900 ± 0.100 BC a | 15.900 ± 0.100 B a | 15.900 ± 0.044 |
| | 5 | 13.000 ± 0.300 C b c | 14.000 ± 0.800 CD b | 19.050 ± 0.650 A a | 15.350 ± 1.216 |
| | 10 | 13.650 ± 1.050 BC b | 16.750 ± 0.050 A a | 16.000 ± 0.100 B a | 15.466 ± 0.650 |
| | 15 | 13.750 ± 0.050 BC a | 13.250 ± 0.050 D a | 12.600 ± 0.200 D b | 13.200 ± 0.217 |
| | 25 | 10.050 ± 0.350 D c | 13.700 ± 0.400 D a | 12.150 ± 0.050 D b | 11.966 ± 0.217 |
| | 36 | 15.100 ± 0.100 AB a | 15.250 ± 0.150 BC a | 14.500 ± 0.000 C b | 14.950 ± 0.152 |
| | Means | 13.575 ± 0.575 | 14.808 ± 0.395 | 15.033 ± 0.705 | |
| | Significant effects; Ptreatment = 0.169 | Pstorage = 0.001 | Ptreatment x Pstorage = 0.001 | | |

[1]: Differences among storage periods was shown with capital letters for the same treatment (P<0.05), differences among treatments was shown with small letters for the same storage period (P<0.05)

The level of pH increased in all fruit, regardless of treatment, during the storage period. The least level of pH (3.40) was found in fruit treated with 0.5 mM MeJA at the end of storage period (Table 2). The difference of pH values among the storage periods was significant (P<0.05) in all the sampling times. It was determined that SSC levels decreased at the end compared with the beginning of storage period. The highest value was 15.25% in fruit treated with 0.5 mM MeJA after 36 days of storage (Table 2). Among storage periods, SSC contents were significantly in both fruit treated with MeJA and control fruit. Significant differences were observed between fruit treated with MeJA and control fruit (Table 2).

Although there were fluctuations in all treatments during the storage period, a decrease trend in $L^*$, $a^*$, $C^\circ$ and $h^\circ$ values were observed during storage period. The highest values of $L^*$ observed in fruit treated with 1 mM MeJA. Also, the least values of $a^*$ was found in fruit treated with MeJA at the end of storage period (Table 3). Among storage periods, $L^*$, $a^*$, $C^*$ and hue angle values were significant in in all the sampling.

**Table 3- The changes in $L^*$, $a^*$, $C^\circ$ and $h^\circ$ during storage of 'Kütahya' sour cherry *(Prunus cerasus* L.) fruit during 36 d at 0 °C. Data was presented as means ± SEM**

| *Parameters* | *Storage period* | *Control* | *0.5 mM MeJA* | *1 mM MeJA* | *Means* |
|---|---|---|---|---|---|
| $L^*$ (Lightness) | 0 | 27.215 ± 0.895 | 27.215 ± 0.895 | 27.215 ± 0.895 | 27.215 ± 0.400 C[1] |
| | 5 | 30.475 ± 0.065 | 30.520 ± 0.790 | 30.305 ± 0.435 | 30.433 ± 0.237 A |
| | 10 | 30.010 ± 0.220 | 30.545 ± 0.895 | 30.545 ± 0.565 | 30.366 ± 0.301 A |
| | 15 | 28.940 ± 0.430 | 28.065 ± 0.165 | 25.945 ± 0.495 | 27.650 ± 0.588 C |
| | 25 | 27.910 ± 0.030 | 28.915 ± 0.045 | 28.490 ± 0.450 | 28.438 ± 0.218 B |
| | 36 | 24.365 ± 1.655 | 24.295 ± 1.495 | 26.125 ± 1.655 | 24.928 ± 0.810 D |
| | Means | 28.152 ± 0.657 | 28.259 ± 0.697 | 28.104 ±0.613 | |
| | Significant effects; Ptreatment = 0.986 | Pstorage = 0.001 | Ptreatment x Pstorage = 0.435 | | |
| $a^*$ | 0 | 23.150 ± 0.810 | 23.150 ± 0.810 | 23.150 ± 0.810 | 27.215 ± 0.400 C |
| | 5 | 25.050 ± 0.630 | 23.640 ± 1.060 | 23.210 ± 0.470 | 30.433 ± 0.237 A |
| | 10 | 21.525 ± 1.375 | 23.705 ± 1.245 | 22.195 ± 0.295 | 30.366 ± 0.301 A |
| | 15 | 21.595 ± 0.485 | 17.410 ± 1.200 | 18.185 ± 0.325 | 27.650 ± 0.588 C |
| | 25 | 23.190 ± 0.990 | 22.795 ± 0.225 | 19.765 ± 1.405 | 28.438 ± 0.218 B |
| | 36 | 21.625 ± 1.715 | 19.105 ± 1.875 | 18.880 ±0.700 | 24.928 ± 0.810 D |
| | Means | 22.689 ± 0.504 | 21.634 ± 0.821 | 20.897 ± 0.655 | |
| | Significant effects; Ptreatment = 0.183 | Pstorage = 0.001 | Ptreatment x Pstorage = 0.205 | | |
| $C^\circ$ | 0 | 24.680 ± 0.970 | 24.680 ± 0.970 | 24.680 ± 0.970 | 24.680 ± 0.433 B |
| | 5 | 26.740 ± 0.570 | 25.215 ± 1.445 | 24.960 ± 0.570 | 25.638 ± 0.553 A |
| | 10 | 22.745 ±1.405 | 25.050 ± 1.510 | 22.050 ± 0.950 | 23.281 ± 0.820 C |
| | 15 | 22.785 ± 0.735 | 18.150 ± 1.320 | 19.330 ± 0.040 | 20.088 ± 0.962 D |
| | 25 | 24.255 ± 1.065 | 23.885 ± 0.215 | 20.620 ± 1.540 | 22.920 ± 0.877 C |
| | 36 | 23.085 ± 1.755 | 20.050 ± 1.990 | 19.810 ± 0.700 | 20.981 ± 0.972 D |
| | Means | 24.048 ± 0.549 | 22.838 ± 0.919 | 21.908 ± 0.725 | |
| | Significant effects; Ptreatment = 0.143 | Pstorage = 0.001 | Ptreatment x Pstorage = 0.241 | | |
| $h^\circ$ | 0 | 19.180 ± 0.720 | 19.180 ± 0.720 | 19.180 ± 0.720 | 19.180 ± 0.321 A |
| | 5 | 19.220 ± 0.690 | 18.500 ± 0.910 | 18.950 ± 0.680 | 18.890 ± 0.367 B |
| | 10 | 17.870 ± 0.630 | 17.870 ± 1.190 | 19.415 ± 1.685 | 18.385 ± 0.645 B |
| | 15 | 17.250 ± 0.860 | 16.440 ± 0.060 | 18.740 ± 2.060 | 17.476 ± 0.716 C |
| | 25 | 16.235 ± 0.445 | 16.425 ± 0.315 | 16.835 ± 0.425 | 16.498 ± 0.210 D |
| | 36 | 16.155 ± 0.045 | 17.160 ± 0.240 | 16.600 ± 0.440 | 16.638 ± 0.225 D |
| | Means | 17.651 ± 0.418 | 17.595 ± 0.373 | 18.286 ± 0.494 | |
| | Significant effects; Ptreatment = 0.462 | Pstorage = 0.001 | Ptreatment x Pstorage = 0.894 | | |

[1]: Differences among storage periods was shown with capital letters for the same treatment (P<0.05)

### *3.3. Total phenolic content (TPC) and total antioxidant capacity (TAC)*

The level of total phenolics decreased regularly in all fruit, during storage period. The highest value (22.702 mg100 $g^{-1}$) was determined in fruit treated with 0.5 mM MeJA at the end of storage period (Table 4). Furthermore, similar patterns were found in antioxidant capacity and the antioxidant capacity in fruit treated with MeJA was higher than in the control fruit (Table 4). Among storage periods, total antioxidant capacity (TAC) and total phenolic content (TPC) were significant in all the sampling.

**Table 4- The changes in total antioxidant capacity (TAC) and total phenolic content (TPC) during storage of 'Kütahya' sour cherry *(Prunus cerasus* L.) fruit during 36 d at 0 °C. Data was presented as means ± SEM**

| *Parameters* | *Storage period* | *Control* | *0.5 mM MeJA* | *1 mM MeJA* | *Means* |
|---|---|---|---|---|---|
| TPC | 0 | 28.851 ± 1.984 | 28.851 ± 1.984 | 28.851 ± 1.984 | 28.851 ± 0.887 A[1] |
| | 5 | 25.326 ± 0.395 | 26.185 ± 0.079 | 26.309 ± 0.559 | 25.939 ± 0.264 AB |
| | 10 | 23.502 ± 0.214 | 24.766 ± 0.784 | 24.243 ± 0.603 | 24.170 ± 0.349 BC |
| | 15 | 22.872 ± 0.840 | 23.766 ± 0.095 | 23.830 ± 3.131 | 23.489 ± 0.859 BC |
| | 25 | 20.728 ± 2.022 | 23.125 ± 3.634 | 22.484 ± 1.116 | 22.111 ± 1.200 C |
| | 36 | 19.409 ± 0.262 | 22.703 ±0.284 | 21.413 ± 0.001 | 21.174 ± 0.614 C |
| | Means | 23.448 ± 0.998 | 24.898 ± 0.820 | 24.521 ± 0.887 | |
| | Significant effects; Ptreatment = 0.508 Pstorage = 0.001 Ptreatment x Pstorage = 0.997 | | | | |
| TAC | 0 | 0.749 ± 0.033 | 0.749 ± 0.033 | 0.749 ± 0.033 | 0.749 ± 0.014 A |
| | 5 | 0 .682 ± 0.006 | 0.711 ± 0.113 | 0.663 ± 0.091 | 0.685 ± 0.038 B |
| | 10 | 0.638 ± 0.003 | 0.679 ± 0.003 | 0.654 ± 0.011 | 0.656 ± 0.008 C |
| | 15 | 0.565 ± 0.005 | 0.660 ± 0.022 | 0.619 ± 0.017 | 0.614 ± 0.018 D |
| | 25 | 0.541 ± 0.005 | 0.629 ± 0.074 | 0.598 ± 0.008 | 0.589 ± 0.025 E |
| | 36 | 0 .546 ± 0.073 | 0.606 ± 0.041 | 0.575 ± 0.024 | 0.575 ± 0.025 E |
| | Means | 0.619 ± 0.025 | 0.672 ± 0.023 | 0.642 ± 0.021 | |
| | Significant effects; Ptreatment = 0.294 Pstorage = 0.001 Ptreatment x Pstorage = 0.994 | | | | |

[1]:Differences among storage periods was shown with capital letters for the same treatment (P<0.05)

### *3.4. Antioxidative enzyme analyzes*

During the storage period, the enzyme activity of CAT and SOD reached a peak at 15th day in 0.5 mM MeJA treated fruit. In addition, the highest levels of SOD, APX and CAT were found in fruit treated with 0.5 mM MeJA followed by fruit treated with 1 mM MeJA at the end of storage period (Table 5). In addition, the level of MDA increased in all treatments during the storage period. However, the lowest level of MDA was found in fruit treated with MeJA (Table 5).

**Table 5- The changes in CAT (mmol $g^{-1}$ FW), APX (mmol $g^{-1}$ FW), SOD (unit $g^{-1}$ FW) and MDA (nmol $g^{-1}$ FW) enzyme activities during storage of 'Kütahya' sour cherry (*Prunus cerasus* L.) fruit during 36 d at 0 °C. Data was presented as means ± SEM**

| *Parameters* | *Storage period* | *Control* | *0.5 mM MeJA* | *1 mM MeJA* | *Means* |
|---|---|---|---|---|---|
| CAT | 0 | 0.021 ± 0.001 | 0.021 ± 0.001 | 0.021 ± 0.001 | 0.020 ± 0.000 B[1] |
| | 5 | 0.042 ± 0.003 | 0.098 ± 0.058 | 0.069 ± 0.002 | 0.069 ± 0.018 A |
| | 10 | 0.044 ± 0.005 | 0.126 ± 0.000 | 0.075 ± 0.004 | 0.081 ± 0.015 A |
| | 15 | 0.075 ± 0.011 | 0.148 ± 0.002 | 0.089 ± 0.016 | 0.103 ± 0.015 A |
| | 25 | 0.067 ± 0.008 | 0.140 ± 0.001 | 0.072 ± 0.003 | 0.092 ± 0.015 A |
| | 36 | 0.066 ± 0.058 | 0.134 ± 0.001 | 0.074 ± 0.001 | 0.091 ± 0.020A |
| | Means | 0.052 ± 0.009 b[1] | 0.111 ± 0.014 a | 0.066 ± 0.006 b | |
| | Significant effects; Ptreatment = 0.002 Pstorage = 0.010 Ptreatment x Pstorage = 0.709 | | | | |
| SOD | 0 | 150.013 ± 6.652 | 150.013 ± 6.652 | 150.013 ± 6.652 | 150.012 ± 20.975 D |
| | 5 | 171.022 ± 11.733 | 240.633 ± 21.189 | 285.671 ± 26.298 | 232.441 ± 23.023 C |
| | 10 | 213.161 ± 15.863 | 294.347 ± 12.174 | 295.218 ± 21.268 | 267.575 ± 18.786 B |
| | 15 | 268.846 ± 20.070 | 337.808 ± 31.940 | 302.535 ± 6.280 | 303.062 ± 16.001 A |
| | 25 | 195.592 ± 65.981 | 264.959 ± 56.428 | 229.757 ± 21.595 | 230.102 ± 26.344 C |
| | 36 | 137.772 ± 0.814 | 210.237 ± 83.514 | 174.075 ± 0.473 | 174.028 ± 25.299 D |
| | Means | 189.400 ±15.887 | 249.665 ± 22.491 | 239.544 ± 18.783 | |
| | Significant effects; Ptreatment = 0.075 Pstorage = 0.001 Ptreatment x Pstorage = 0.810 | | | | |
| APX | 0 | 0.326 ± 0.014 | 0.326 ± 0.014 | 0.326 ± 0.014 | 0.326 ± 0.006 D |
| | 5 | 0.356 ± 0.007 | 1.243 ± 0.218 | 1.576 ± 0.093 | 1.058 ± 0.238 C |
| | 10 | 0 .804 ± 0.006 | 1.168 ± 0.088 | 1.483 ± 0.716 | 1.151 ± 0.223 C |
| | 15 | 0.881 ± 0.017 | 1.531 ± 0.882 | 1.558 ± 0.185 | 1.323 ± 0.271 C |
| | 25 | 1.678 ± 0.031 | 1.932 ± 0.020 | 1.724 ± 1.384 | 1.777 ± 0.360 B |
| | 36 | 1.958 ± 0.020 | 2.460 ± 0.239 | 2.287 ± 0.134 | 2.234 ± 0.117 A |
| | Means | 1.000 ±0.186 | 1.443 ± 0.231 | 1.492 ± 0.262 | |
| | Significant effects; Ptreatment = 0.261 Pstorage = 0.001 Ptreatment x Pstorage = 0.964 | | | | |
| MDA | 0 | 38.469 ± 2.035 | 38.469 ± 2.035 | 38.469 ± 2.035 | 38.468 ± 0.910 E |
| | 5 | 49.243 ± 2.604 | 47.509 ± 3.573 | 49.490 ± 0.005 | 48.747 ± 1.207 D |
| | 10 | 56.926 ± 1.535 | 50.446 ± 2.419 | 51.772 ± 0.138 | 53.047 ± 1.452 C |
| | 15 | 59.712 ± 2.022 | 53.765 ± 1.839 | 56.590 ± 0.671 | 56.689 ± 1.306 BC |
| | 25 | 63.545 ± 1.778 | 56.847 ± 1.982 | 59.010 ± 6.201 | 59.800 ± 2.143 B |
| | 36 | 69.717 ± 4.927 | 67.400 ± 3.159 | 65.095 ± 7.898 | 67.404 ± 2.674 A |
| | Means | 56.268 ± 3.155 | 52.405 ± 2.775 | 53.404 ± 2.819 | |
| | Significant effects; Ptreatment = 0.629 Pstorage = 0.001 Ptreatment x Pstorage = 0.979 | | | | |

[1]: Differences among storage periods was shown with capital letters for the same treatment (P <0.05), differences among treatments was shown with small letters for the same storage period (P<0.05)

Among storage periods, CAT, APX, SOD and MDA enzyme activities were significant. On the other hand, significant differences were observed among treatments in CAT enzyme activity.

### *3.5. Respiration rate and ethylene production*

Ethylene production decreased in all treatments during the storage period, whereas respiration rates increased. MeJA treatments were effective on respiration rates especially suppression of ethylene production compared with control fruit (Table 6). Among storage periods, respiration rate and ethylene production were significant in all the sampling.

**Table 6- The changes in respiration rate and ethylene production during storage of 'Kütahya' sour cherry *(Prunus cerasus* L.) fruit during 36 d at 0 °C. Data was presented as means ± SEM**

| *Parameters* | *Storage period* | *Control* | *0.5 mM MeJA* | *1 mM MeJA* | *Means* |
|---|---|---|---|---|---|
| Respiration rate | 0 | 127.769 ± 8.605 | 127.769 ± 8.605 | 127.769 ± 8.605 | 127.769 ± 3.848 A[1] |
| | 5 | 77.448 ± 0.238 | 59.917 ± 18.573 | 103.619 ± 7.263 | 80.328 ± 9.539 CD |
| | 10 | 106.608 ± 9.376 | 101.918 ± 5.384 | 97.414 ± 0.321 | 101.980 ± 3.258 B |
| | 15 | 103.121 ± 1.488 | 100.857 ± 7.738 | 97.242 ± 1.906 | 100.407 ± 2.356 B |
| | 25 | 89.793 ± 1.481 | 95.261 ± 1.412 | 90.426 ± 0.822 | 91.827 ± 1.231 BC |
| | 36 | 80.206 ± 9.769 | 74.474 ± 2.260 | 73.163 ± 0.302 | 75.947 ± 2.929 D |
| | Means | 97.491 ± 5.577 | 93.366 ± 7.078 | 98.272 ± 5.110 | |
| | Significant effects; Ptreatment = 0.806 | | Pstorage = 0.001 | Ptreatment x Pstorage = 0.684 | |
| Ethylene production | 0 | 0.166 ± 0.020 | 0.166 ± 0.020 | 0.166 ± 0.020 | 0.166 ± 0.008 D |
| | 5 | 0.282 ± 0.056 | 0.179 ± 0.084 | 0.235 ± 0.024 | 0.231 ± 0.032 A |
| | 10 | 0.197 ± 0.039 | 0.215 ± 0.066 | 0.227 ± 0.040 | 0.212 ± 0.022 A |
| | 15 | 0 .174 ± 0.004 | 0.123 ± 0.005 | 0.133 ± 0.003 | 0.143 ± 0.010 B |
| | 25 | 0.159 ± 0.018 | 0.113 ± 0.005 | 0 .142 ± 0.017 | 0.137 ± 0.010 B |
| | 36 | 0 .158 ± 0.004 | 0.112 ± 0.004 | 0.107 ± 0.005 | 0.125 ± 0.010 C |
| | Means | 0.189 ± 0.015 | 0.151 ± 0.017 | 0.168 ± 0.015 | |
| | Significant effects; Ptreatment = 0.276 | | Pstorage = 0.001 | Ptreatment x Pstorage = 0.872 | |

[1]: Differences among storage periods was shown with capital letters for the same treatment (P <0.05)

### *3.6. Oxygen and Carbon dioxide concentrations in the packages*

During the storage period, the concentration of $O_2$ decreased inside the packages, while $CO_2$ levels increased, as expected. $CO_2$ levels increased significantly inside the package for the first five days of storage, while, the $O_2$ levels were reduced. At the end of the storage, the lower $CO_2$ levels were reported in fruit treated with MeJA compared with untreated fruit, and also the higher $O_2$ levels were detected in fruit treated with MeJA (Table 7). Among storage periods, concentration of $O_2$ and $CO_2$ inside the packages were significant in all the sampling.

**Table 7- The changes in concentration of $O_2$ and $CO_2$ in the packages during storage of 'Kütahya' sour cherry *(Prunus cerasus* L.) fruit during 36 d at 0 °C. Data was presented as means ± SEM**

| *Parameters* | *Storage period* | *Control* | *0.5 mM MeJA* | *1 mM MeJA* | *Means* |
|---|---|---|---|---|---|
| $O_2$ | 0 | 20.900 ± 0.000 | 20.900 ± 0.000 | 20.900 ± 0.000 | 20.900 ± 0.000 A[1] |
| | 5 | 16.150 ± 0.250 | 16.400 ± 1.200 | 13.400 ± 0.400 | 15.316 ± 0.693 B |
| | 10 | 15.350 ± 0.950 | 16.350 ± 0.150 | 15.800 ± 0.800 | 15.833 ± 0.371 B |
| | 15 | 16.500 ± 1.500 | 15.050 ± 1.550 | 15.700 ± 2.100 | 15.750 ± 0.821 B |
| | 25 | 13.800 ± 0.500 | 13.500 ± 1.600 | 13.550 ± 0.850 | 13.616 ± 0.488 B |
| | 36 | 13.350 ± 1.550 | 15.350 ± 1.550 | 16.350 ± 2.550 | 15.016 ± 1.031 B |
| | Means | 16.008 ± 0.801 | 16.258 ± 0.781 | 15.950 ± 0.865 | |
| | Significant effects; Ptreatment = 0.961 | | Pstorage = 0.001 | Ptreatment x Pstorage = 0.662 | |
| $CO_2$ | 0 | 0.300 ± 0.000 | 0.300 ± 0.000 | 0.300 ± 0.000 | 0.300 ± 0.000 B |
| | 5 | 1.900 ± 0.200 | 1.950 ± 0.650 | 2.600 ± 0.100 | 2.150 ± 0.227 A |
| | 10 | 2.000 ± 0.300 | 2.050 ± 0.550 | 2.250 ± 0.550 | 2.100 ± 0.220 A |
| | 15 | 2.200 ± 0.000 | 2.650 ± 0.250 | 2.550 ± 0.350 | 2.466 ± 0.140 A |
| | 25 | 2.700 ± 0.200 | 2.600 ± 0.400 | 2.950 ± 0.350 | 2.750 ± 0.160 A |
| | 36 | 2.450 ± 0.250 | 2.300 ± 0.100 | 2.150 ± 0.350 | 2.300 ± 0.126 A |
| | Means | 1.925 ± 0.240 | 1.975 ± 0.267 | 2.133 ± 0.278 | |
| | Significant effects; Ptreatment = 0.843 | | Pstorage = 0.001 | Ptreatment x Pstorage = 0.927 | |

[1]: Differences among storage periods was shown with capital letters for the same treatment (P <0.05)

## 4. Discussion

Most commodities come in possession of unmarketable as fresh products with a weight loss more than 10%. Fruit treated with MeJA after harvest has been suggested to have a positive effect on quality parameters such as color, firmness and weight loss (Fan et al. 2016a; Fan et al. 2016b). In our study, fruit treated with MeJA and especially 0.5 mM MeJA had a positive impact in delaying weight loss comparing to control.

It has been suggested that the amount of acidity decreases since fruit use up organic acids through respiration process during the storage period (Jin et al. 2012). Zhang et al. (2009) found that pears treated with MeJA after harvest showed delayed rotting and did not adversely affect quality parameters such as titratable acidity (TA), firmness and soluble solids content (SSC). Researchers suggested that MeJA treatment resulted in higher level of TA compared with untreated fruit and had positive effects on fruit quality (Wang & Zheng 2005; Casado et al. 2014; Akan et al. 2019). In the current study, it was found that the fruit treated with 0.5 mM MeJA have a positive influence in terms of SSC. On the other hand, the fruit treated with 1 mM MeJA t had higher levels of TA. The higher values of pH observed in untreated fruit.

It has been reported that the treatment of MeJA after harvest prevents color changes in the fruit skin (Martínez-Espláa et al. 2014; Öztürk et al. 2014). In addition, many researchers have mentioned that the change of hue angle value is an indicator of the color changes in the fruit skin (Rudell et al. 2005; Greer 2005; Rudell & Mattheis 2008). In the current study, it was observed that MeJA treatments had a positive effect on hue angle values. Moreover, the higher values of $L^*$ was found in fruit treated with 1 mM MeJA.

The antioxidants associated with phenolic compounds are effective against degenerative diseases (Aviram et al. 2008; Mertens-Talcott et al. 2006). Many researchers believed that MeJA treatments generally increased antioxidant capacity and total phenolic content (Wang and Zheng 2005; Chanjirakul et al. 2006; Wang et al. 2008). We also found that antioxidant capacity and total phenolic content enhanced in fruit treated with MeJA comparing to untreated fruit.

Antioxidant enzymes provide an essential role, defending plants from injury caused by the accumulation of reactive oxygen species (ROS) (Groppa & Benavides 2008; Duan et al. 2008; Kıpçak et al. 2019). Ascorbate peroxidase (APX), superoxide dismutase (SOD), catalase (CAT) are important in performing mostly related to antioxidant enzymatic systems actuated in plants to scavenge the detrimental effects of oxidative stress (Gill & Tuteja 2010; Karuppanapandian et al. 2011). Accumulation of ROS could possibly lead to an increase in lipid peroxidation, leading to devastation to membranes, and therefore enhance deposit of MDA (Xie et al. 2008).

Previous studies showed that activities of superoxide dismutase and catalase are effectively impressed by MeJA in postharvest treatments (Chanjirakul et al. 2006; 2007; Meng et al. 2017). In the current study, it was approved that the activities of superoxide dismutase and catalase increased in fruit treated with MeJA comparing to untreated (control) fruit after 36 days of storage. Fan et al. (2016a) suggested that exogenous treatment of MeJA significantly decreased MDA content in cowpea fruit. Our findings revealed similar results. Fruit treated with MeJA had lower level of MDA content than untreated (control) fruit. Moreover, evidence shows that postharvest treatment of MeJA results in higher activities of APX, SOD and CAT during the storage period than control fruit in peach and loquat fruit (Jin et al. 2009; Cao et al. 2009; Zapata et al. 2014). In the present study, we obtained similar findings. That is the fruit treated with MeJA showed the higher level of APX content compared with control fruit.

Previous studies showed that the Modified Atmosphere Packaging (MAP) treatment reduces respiration rate and ethylene production in cherry fruit (Yarılgac et al. 2019). It was reported that MeJA increases the respiration rate, when treated in the beginning of ripening stage and also claimed it has no effect on respiration rate in mango fruit (Lalel et al. 2003). In addition, Öztürk et al. (2019) suggested that MeJA treatment led to a lower respiration rate compared to control fruit. The effect of MeJA on respiration rate (Öztürk et al. 2019) and ethylene production (Zapata et al. 2014) may diverse depending on the maturity period, fruit type or MeJA concentration. In our study, we found that the respiration rate and ethylene production was lower in fruit treated with MeJA comparing to control fruit.

In conclusion, MeJA treatments showed higher levels of total phenolic content, total antioxidant capacity and quality and were also effective on ethylene production and respiration rate. This positive effect of MeJA may be due to stimulation of antioxidant enzyme activity. 0.5 mM MeJA treatment showed the best results among the all of MeJA concentrations. It can be suggested that sour cherry could be stored successfully for 36 days at 0 °C following treatment by MeJA.

## References

Akan S, Gunes N T & Yanmaz R (2019). Methyl jasmonate and low temperature can help for keeping some physicochemical quality parameters in garlic (*Allium sativum* L.) cloves. *Food chemistry* 270: 546-553 https://doi.org/10.1016/j.foodchem.2018.07.085

Alp Y & Kabay T (2019). The Effect of drought stress on antioxidative enzyme and nutrient exchange in some tomato genotypes. *Turkish Journal of Agricultural and Natural* Sciences 6(1): 71-77 https://doi.org/10.30910/turkjans.515352 (In Turkish)

Asghari M & Hasanlooe A R (2015). Methyl jasmonate effectively enhanced some defense enzymes activity and total antioxidant content in harvested “Sabrosa” strawberry fruit. Food Sci. Nutr. 4(3): 377-383 https://doi.org/10.1002/fsn3.300

Aviram M, Volkova N, Coleman R, Dreher M, Reddy M K & Ferreira D (2008). Pomegranate phenolics from the peels, arils, and flowers are antiatherogenic: Studies in vivo in atherosclerotic apolipoprotein E-deficient (E0) mice and in vitro in cultured macrophages and lipoproteins. Journal of Agricultural and Food Chemistry 56: 148-1157 https://doi.org/10.1021/jf071811q

Bagcı G (2010). Identification of drought-induced oxidative stress in chickpea with physiological and biochemical parameters. PhD Thesis, Ankara University Faculty of Science (unpublished), Turkey (In Turkish)

Beattie J, Crozier A & Duthie G G (2005). Potential health benefits of berries. Current Nutrition and Food Science 1(1): 71-86

Benzie I F & Strain J J (1996). The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": the FRAP assay. Analytical biochemistry 239(1): 70-76 https://doi.org/10.1006/abio.1996.0292

Cao S, Zheng Y, Wang K & Jin Rui P H (2009a). Methyl jasmonate reduces chilling injury and enhances antioxidant enzyme activity in postharvest loquat fruit. Food Chemistry 115: 1458-1463 https://doi.org/10.1016/j.foodchem.2009.01.082

Cao S, Zheng Y, Wang K, Rui H & Tang S (2009b). Effect of methyl jasmonate on cell wall modification of loquat fruit in relation to chilling injury after harvest. Food Chemistry 118: 64-647 https://doi.org/10.1016/j.foodchem.2009.05.047

Casado F J, Sanche A H, Beato V M, De Castro A & Montano A (2014). Effect of sulfites and sorbates on the preservation and color of pickled blanched garlic under different storage conditions. Journal of Food Processing and Preservation 38: 905-911 https://doi.org/10.1111/jfpp.12045

Cavusoglu Ş, Islek F, Yilmaz N & Tekin O (2020). The effects of methyl jasmonate, cytokinin and lavender oil applications on postharvest physiology in apricot fruit (Prunus armeniaca L.). Yuzuncu Yıl University Journal of Agricultural Sciences 30(1): 136-146 https://doi.org/10.29133/yyutbd.679851 (In Turkish)

Cemeroğlu B (2007). Food Analysis - Gıda analizleri. Gıda Teknolojisi Derneği Yayınları, Ankara, 34: 168-171(In Turkish)

Chanjirakul K, Wang S Y, Wang C Y & Siriphanich J (2006). Effect of natural volatile compounds on antioxidant capacity and antioxidant enzymes inraspberries. Postharvest Biology and Technology 40: 106-115 https://doi.org/10.1016/j.postharvbio.2006.01.004

Chanjirakul K, Wang S Y, Wang C Y & Siriphanich, J (2007). Natural volatile treatments increase free-radical scavenging capacity of strawberries and blackberries. J. Sci. Food Agric. 87: 1463-1472 https://doi.org/10.1002/jsfa.2841

Duan J J, Li J, Guo S & Kang Y (2008). Exogenous spermidine affects polyamine metabolism in salinity-stressed Cucumis sativus roots and enhances short-term salinity. J. Plant Physiol. 165: 1620-1635 https://doi.org/10.1016/j.jplph.2007.11.006

Eksi A & Akdag E (2007). Fruit juice production and consumption in Turkey 2006. 4 Mevsim Meyve Suyu 5: 2-4 (In Turkish)

Fan L, Wang Q, Lv J, Gao L, Zuo J & Shi J (2016a). Amelioration of postharvest chilling injury in cowpea (Vigna sinensis) by methyl jasmonate (MeJA) treatments. Scientia horticulturae 203: 95-101. https://doi.org/10.1016/j.scienta.2016.03.010

Fan L, Shi J, Zuo J, Gao L, Lv J & Wang Q (2016b). Methyl jasmonate delays postharvest ripening and senescence in the non-climacteric eggplant (Solanum melongena L.) fruit. Postharvest Biology and Technology 120: 76-83 https://doi.org/10.1016/j.postharvbio.2016.05.010

FAO (2020). Food and Agriculture Organization of the United Nations. Retrieved in April, 20, 2020 from http://www.fao.org/faostat/en/#data/QC

Ferretti G, Bacchetti T, Belleggia A & Neri D (2010). Cherry antioxidants: From farm to table. Molecules 15(10): 6993-7005 https://doi.org/10.3390/molecules15106993

Gill S & Tuteja N (2010). Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. Plant Physiol. Biochem. 48: 909-930 https://doi.org/10.1016/j.plaphy.2010.08.016

Greer D H (2005). Non-destructive chlorophyll fluorescence and colour measurements of 'Braeburn' and 'Royal Gala' apple (Malus domestica) fruit development throughout the growing season. New Zeal J Crop Hortic Sci, 33: 413-421 https://doi.org/10.1080/01140671.2005.9514378

Groppa M D & Benavides M P (2008). Polyamines and abiotic stress: recent advance. Amino Acids 34: 35-45. https://doi.org/10.1007/s00726-007-0501-8

Guillén F, Díaz-Mula H M, Zapata P J, Valero D, Serrano M, Castillo S & Martínez-Romero D (2013). Aloe arborescens and Aloe vera gels as coatings in delaying postharvest ripening in peach and plum fruit. Postharvest Biol. Technol. 83: 54-57 https://doi.org/10.1016/j.postharvbio.2013.03.011

Jebara S, Jebara M, Limam F & Aouani M E (2005). Changes in ascorbate peroxidase, catalase, guaiacol peroxidase and superoxide dismutase activities in common bean (Phaseolus vulgaris) nodules under salt stress. Journal of Plant Physiology 162(8): 929-936 https://doi.org/10.1016/j.jplph.2004.10.005

Jia G A O, Baogang W A N G, Xiaoyuan F E N G & Yongqing Z H U (2012). Effect of blanching on quality of sour cherry (Prunus cerasus L. CV. CAB) juice. American-Eurasian Journal of Agricultural and Environmental Sciences 12: 123-127

Jin P, Zhen, Y, Tang S, Rui H & Wang C Y (2009). A combination of hot air and methyl jasmonate vapor treatment alleviates chilling injury of peach fruit. Postharvest Biol. Technol. 52: 24-29 https://doi.org/10.1016/j.postharvbio.2008.09.011

Jin P, Zhu H, Wang J, Chen J, Wang X & Zheng Y (2012). Effect of methyl jasmonate on energy metabolism in peach fruit during chilling stress. Society of Chemical Industry 10: 1002-5973 https://doi.org/10.1002/jsfa.5973

Karuppanapandian T, Moon J C, Kim C, Manoharan K & Kim W (2011). Reactive oxygen species in plants: their generation, signal transduction, and scavenging mechanisms. Aust. J. Crop. Sci. 5: 709-725

Kim D O, Heo H J, Kim Y J, Yang H S & Lee C Y (2005). Sweet and sour cherry phenolics and their protective effects on neuronal cells. Journal of Agricultural and Food Chemistry 53(26): 9921-992 https://doi.org/10.1021/jf0518599

Kıpçak S, Ekincialp A, Erdinç Ç, Kabay T & Şensoy S (2019). Effects of salt stress on some nutrient content and total antioxidant and total phenol content in different bean genotypes. Yuzuncu Yıl University Journal of Agricultural Sciences 29(1): 136-144 https://doi.org/10.29133/yyutbd.504748 (In Turkish)

Lalel H J D, Singh Z & Ta S C (2003). The role of methyl jasmonate in mango ripening and biosynthesis of aroma volatile compounds. The Journal of Horticultural Science and Biotechnology 78(4): 470-484 https://doi.org/10.1080/14620316.2003.11511652

Lončarić A, Pichler A, Trtinjak I, Piližota V & Kopjar M (2016). Phenolics and antioxidant activity of freeze-dried sour cherry puree with addition of disaccharides. LWT-Food Science and Technology 73: 391-396 https://doi.org/10.1016/j.lwt.2016.06.040

Martínez-Espláa A, Zapataa P J, Castilloa S, Guilléna F, Martínez-Romeroa D, Valeroa D & Serranob M (2014). Preharvest application of methyl jasmonate (MeJA) in two plumcultivars. 1. Improvement of fruit growth and quality attributes at harvest. Postharvest Biology and Technology 98: 98-105 https://doi.org/10.1016/j.postharvbio.2014.07.011

Meng D M, Zhang Y X, Yang R, Wang J, Zhang X H, Sheng J P & Fan Z C (2017). Arginase participates in the methyl jasmonate-regulated quality maintenance of postharvest Agaricus bisporus fruit bodies. Postharvest Biology and Technology 132: 7-14 https://doi.org/10.1016/j.postharvbio.2017.05.018

Mertens-Talcott S U, Jilma-Stohlawetz P, Ríos J, Hingorani L & Derendorf H (2006). Absorption, metabolism and antioxidant effects of pomegranate (Punica granatum L.) polyphenols after ingestion. Journal of Agricultural and Food Chemistry 54: 8956-8961 https://doi.org/10.1021/jf061674h

Nakano Y & Asada K (1981) Hydrogen peroxide in spinach chloroplasts. Plant Cell Physiology 22: 860-867 https://doi.org/10.1093/oxfordjournals.pcp.a076232

Önal K (2002). Evaluation of Sour Cherry (Prunus cerasus L.) Genetic resources collected from aegean region. Medıterranean Agrıcultural Scıences, 15(2): 39-44(In Turkish)

Öztürk B, Özkan Y & Yıldız K (2014). Methyl jasmonate treatments influence bioactive compounds and red peel color development of Braeburn apple. Turkish Journal of Agriculture and Forestry 38: 688-699 https://doi.org/10.3906/tar-1312-43

Öztürk A, Yildiz K, Ozturk B, Karakaya O, Gun S, Uzun S & Gundogdu M (2019). Maintaining postharvest quality of medlar (Mespilus germanica) fruit using modified atmosphere packaging and methyl jasmonate. LWT. 111: 117-124 https://doi.org/10.1016/j.lwt.2019.05.033

Piccolella S, Fiorentino A, Pacifico S, D'Abrosca B, Uzzo P & Monaco P (2008). Antioxidant properties of sour cherries (Prunus cerasus L): Role of colorless phytochemicals from the methanolic extract of ripe fruits. Journal of Agricultural and Food Chemistry 56(6): 1928-1935 https://doi.org/10.1021/jf0734727

Rudell D R & Mattheis J P (2008). Synergism exists between ethylene and methyl jasmonate in artificial light-induced pigment enhancement of 'Fuji' apple fruit peel. Postharvest Biol Technol. 47: 136-140 https://doi.org/10.1016/j.postharvbio.2007.05.021

Rudell D R, Fellmann J K & Mattheis J P (2005). Preharvest application of methyl jasmonate to 'Fuji' apples enhances red coloration and affects fruit size, splitting, and bitter pit incidence. Hortscience 40: 1760-1762 https://doi.org/10.21273/hortsci.40.6.1760

Saracoglu O, Ozturk B, Yildiz K & Kucuker E (2017). Pre-harvest methyl jasmonate treatments delayed ripening and improved quality of sweet cherry fruits. Scientia Horticulturae 226: 19-23 https://doi.org/10.1016/j.scienta.2017.08.024

Swain T & Hillis W E (1959). The phenolic constituents of Prunus domestica. I.The quantitative analysis of phenolic constituents. Journal of the Science of Food and Agriculture 10(1): 63-68 https://doi.org/10.1002/jsfa.2740100110

Wang S Y & Zheng W (2005). Preharvest application of methyl jasmonate increases fruit quality and antioxidant capacity in raspberries. International Journal of Food Science and Technology 40: 187-195 https://doi.org/10.1111/j.1365-2621.2004.00930.x

Wang S Y, Bowman L & Ding M (2008). Methyl jasmonate enhances antioxidant activity and flavonoid content in blackberries (Rubus spp.) and promotes antiproliferation of human cancer cells. Food Chemistry 107: 1261-1269 https://doi.org/10.1016/j.foodchem.2007.09.065

Xie Z X, Duan L S, Tian X L, Wang B M, Eneji A E & Li Z H (2008). Coronatinealleviates salinity stress in cotton by improving the antioxidative defense system and radical-scavenging activity. J. Plant Physiol. 165: 375-384 https://doi.org/10.1016/j.jplph.2007.06.001

YarılgacT, Kadim H & Ozturk B (2019). Role of maturity stages and modified atmosphere packaging on the quality attributes of cornelian cherry fruits (Cornus mas L.) throughout shelf life. Journal of the Science of Food and Agriculture 99: 421-428 https://doi.org/10.1002/jsfa.9203

Zapata P J, Martínez-Esplá A, Guillén F, Díaz-Mula H M, Martínez-Romero D, Serrano M & Valero D (2014). Preharvest application of methyl jasmonate (MeJA) in two plum cultivars. 2. Improvement of fruit quality and antioxidant systems during postharvest storage. Postharvest Biology and Technology 98: 115-122 https://doi.org/10.1016/j.postharvbio.2014.07.012

Ziosi V, Bregoli A, Fregola F, Costa G & Torrigiani P (2008). Jasmonate-Induced ripening delay is associated with up-regulation of polyamine levels in peach fruit. J. Plant Physiol. 166: 938-946 https://doi.org/10.1016/j.jplph.2008.11.014