Erwerbs-Obstbau (2022) 64:27–35
https://doi.org/10.1007/s10341-021-00552-y

ORIGINAL ARTICLE / ORIGINALBEITRAG

Maturity Stages and MAP Affect the Quality Attributes and Bioactive Compounds of Cornelian Cherry Fruit (*Cornus mas* L.) During Cold Storage

Tarık Yarılgaç[1] · Hayrullah Kadim[1] · Burhan Ozturk[1]

Received: 15 April 2019 / Accepted: 29 January 2021 / Published online: 3 March 2021

Abstract
The present research was conducted to investigate the influence of the harvest maturity stages and modified atmosphere packaging (MAP) on quality of cornelian cherry fruit. The cornelian cherry fruit (*Cornus mas* L.) were used as the plant materials in this study. Weight loss of MAP-treated fruit was lower than the untreated. At harvest and end of the storage, the greatest respiration and ethylene production rates were measured from M-1. MAP-treated fruit were maintained firmness and had lower decay. At the end of the storage, the greatest soluble solids and acidity were obtained from M-2. Also, vitamin C contents of M-1+MAP were greater than M-1, M-2 and M-2+MAP. At harvest and on 15th, 30th and 45th day of the storage, anthocyanin of M-2 was greater than M-1. At the last two periods of the storage, flavonoid contents of MAP-treated fruit were greater than the untreated. During the storage, M-2+MAP had greater phenolic contents than the other. The greatest antioxidant activity at the end of the storage period was measured in M-1+MAP. Cornelian cherry fruit are quite rich in anthocyanins, flavonoids, flavonols, phenolic acids and vitamins. The fruit should be harvested at proper maturity stages because of short harvest and marketing periods. Based on present findings for a prolong storage and shelf life the cornelian cherry fruit should be harvested at M-1 stage and fruit should be cold-stored in MAP.

Keywords Anthocyanin · Color · Decay · Ethylene production · Phenolics · Weight loss

Einfluss von Reifestadien und MAP auf Qualitätsmerkmale und bioaktive Inhaltsstoffe von Früchten der Kornelkirsche (*Cornus mas* L.) während der Kühllagerung

Schlüsselwörter Anthocyanin · Farbe · Fäulnis · Ethylenproduktion · Phenole · Gewichtsverlust

Introduction

Cornelian cherry (*Cornus mas*) is widely seen along the down skirts of Caucasus Mountains, in Turkey, Romania, Bulgaria, Serbia, Italy and inner sections of the Europe. Cornelian cherry fruit have been preferred for daily nutrition of humans since the Neolithic age. Besides fresh consumption, fruit are also used as dried, concentrated pulp, juice, marmalade, jam, compote, wine and syrup (Gunduz et al. 2013; D'antuono et al. 2014).

Cornelian cherry fruit are quite rich in anthocyanins, flavonoids, flavonols, phenolic acids and vitamins. Just because of its rich chemical composition, fruit are known to have antioxidant, antimicrobial, antidiabetic, anti-inflammatory, cytotoxic, cardioprotective, hepatoprotective and neuroprotective activities (Dinda et al. 2016). Therefore, there is an ever-increasing interest of consumers in cornelian cherry fruit.

Consumers usually prefer to consume the fruit as fresh. However, short harvest periods limit the fresh consumption of cornelian cherry. Therefore, it should also be stored in cold storage. However, pre and postharvest applications (hormones, MAP, coatings), storage conditions (tempera-

✉ Burhan Ozturk
burhanozturk55@gmail.com

[1] Faculty of Agriculture, Department of Horticulture, Ordu University, 52200 Ordu, Turkey

ture, relative humidity), pre-harvest plant nutrition, irrigation, thinning, pruning, training systems and fruit maturity stages have significant effects on postharvest performances and quality of the fruit (Kader 2002).

The fruit with short harvest and marketing periods should be harvested at proper maturity stages to prolong the storage and shelf life periods of the fruit (Thewes et al. 2017). However, short harvest periods, manual labor, climate factors, long transportations, longer storage desires limit harvest of fruit at optimal maturity (Kader 1997; Hussein et al. 2018).

Harvest at optimum periods play a key role in reducing postharvest quality losses. As it was stated in earlier researches, maturity stage at harvest played a great role in cold storage performance of persimmons (Ramin and Tabatabaie 2003), sweet cherries (Çalhan et al. 2015), ananas (Kamol et al. 2014), plums (Wang et al. 2016), peaches (Fadda et al. 2017) and apples (Thewes et al. 2017).

Even harvested at optimal maturity, quality losses are evident to some extend during both the storage period and shelf life of the fruit. MAP is commonly used as an efficient tool to reduce or prevent postharvest quality losses in fruit and vegetables and to preserve them for longer durations (Sandhya 2010). MAP treatments were used in several stone fruit (sweet cherry, apricot and plum) to reduce quality losses (Sandhya 2010; Mohebbi et al. 2015). However, number of studies carried out about MAP treatments in cornelian cherry fruit is quite limited.

This study was conducted to investigate the effects of harvest maturity stages and MAP treatments on weight loss, quality attributes and bioactive compounds of the cornelian cherry fruit during the cold storage.

Materials and Methods

Plant Material

Experimental fruit (*Cornus mas* L.) were collected at two different maturity stages from a commercial orchard located in Trabzon, Turkey (41°03′27.43″N latitude, 39°19′44.90″E longitude and 51 m altitude) on 4 August, 2016. Maturity stages were selected as "Maturity (M); M-1: skin red color <10% (firmness: 5.60 N, SSC: 9.4% at harvest) and M-2: skin red color >90%" (firmness: 4.59 N, SSC: 11.2% at harvest). Only the fruit with uniform shape and size and free from visual symptoms of any disease were selected for experiments. Selected fruit were instantly brought to laboratory with frigorific vehicles providing 10 ± 1.0 °C temperature and 80 ± 5.0 relative humidity.

Experimental Design

For each maturity stage, 300 g fruit were placed in 24 polyethylene packages (commercial polyethylene terephthalate [PET] containers without clamshell, 1000 mL [190 mm × 118 mm × 104 mm], [V53, Vempi, Manisa, Turkey]). Half of these packages (12) were also placed in passive MAP (Xtend® [815-CH97/a, StePac, Turkey]). Gas composition was determined with gas analyzer (Abiss, model legend, France) inside MAP during storage. Gas compositions were ranged from 6.5 to 7.7% for O_2 and from 8.0 to 10.0% for CO_2. Then, MAP-treated and untreated fruit were stored in a cold storage (0 ± 0.5 °C and 90 ± 5% relative humidity) for 60 days. Fruit samples were analyzed in 15-day intervals (3 packages in each analysis, a package in each replicate).

Weight Loss, Decay Rate and Firmness

Weight loss was considered as difference between initial weight and the weight at the time of analysis and expressed in %. Fruit were weighed with a precise balance (±0.01 g). Decay rate was calculated as the ratio of number of decayed fruit to total number of fruit analyzed and again expresses in %. The fruit with any signs of surface mycelia were assessed as decayed. Fruit flesh firmness (N) was measured with a texture analyzer equipped with 2.0 mm probe and 50 N load cell. The load applied for 3 mm penetration at operational speed of 10 mm s^{-1} was considered as flesh firmness (Koc Guler et al. 2019). Flesh firmness was measured on 10 fruit randomly selected from each replicate.

Respiration Rate and Ethylene Production

The 2 L airtight chambers were used to measure respiration rate. The chambers were fitted with a rubber septum and 10 fruits were sealed in each chamber at 20 ± 1 °C temperature and 90% relative humidity for an hour. The chambers were then connected to a gas sensor and the amount of CO_2 produced by the fruit was considered as the respiration rate. The same chambers were also used to determine ethylene production. One ml gas sample from the chambers was injected into a gas chromatograph (QP2010 Ultra, Shimadzu, Kyoto, Japan) equipped with a flame ionization detector and a capillary column (RTX-5, Restek Corp., Bellefonte, PA, USA) to determine ethylene production rate. Results were expressed in ml CO_2 kg^{-1} h^{-1} for respiration rate and μL C_2H_4 kg^{-1} h^{-1} for ethylene production rate (Karakaya et al. 2020).

Color Characteristics

Color parameters of L*, chroma and hue angle were determined with the aid of a colorimeter (Minolta, CR–400,

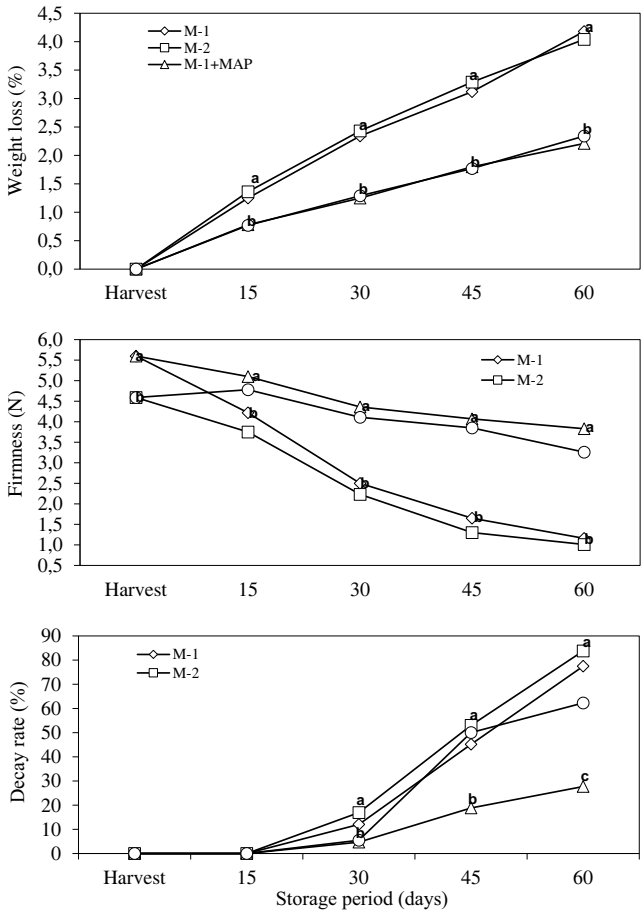

Fig. 1 Effects of MAP and maturity stage on weight loss, firmness and decay rate of cornelian cherry fruit during cold storage. $n = 9$ for the weight loss and decay rate (three replicate × three different measurements for each replicate). $n = 60$ for the firmness (three replicate × ten fruit for each replicate × two different measurements for each fruit). The differences among the treatments indicated with the same letter vertically were not significant according to Tukey's test at $P < 0.05$

Tokyo, Japan). Measurements were performed over the opposite sides of each fruit. A three-dimensional color space was generated with the aid of L^*, a^* and b^* values in accordance with the CIE color system. The equation of $C^* = (a^{*2} + b^{*2})^{1/2}$ was used for chroma and the equation of $h^\circ = \tan^{-1} b^* / a^*$ was used for hue angle (McGuire 1992).

Soluble Solids Content (SSC), Titratable Acidity and Vitamin C

Fruit stones were removed and juice was extracted with the aid of an extractor. Extract SSC values were determined with a refractometer (Atago, PAL-1, ABD). About 10 ml extract was diluted with 10 ml distilled water for titratable acidity and the amount of 0.1 mol L^{-1} NaOH used to titrate the solution to a pH of 8.1 was considered as titratable acidity (g malic acid kg^{-1}). About 0.5 ml extract was supplemented with 0.5% oxalic acid to a final volume of 5 ml. Ascorbic acid test strips were used to determine vitamin C content (mg 100 g^{-1}) of the samples (Ozturk et al. 2019).

Bioactive Compounds

For bioactive compound analyses, again the fruit stones were removed, resultant pulp was homogenized and homogenates were stored at –20 °C until the time of analysis. Before the analyses, samples were thawed at room temperature (≈21 °C), homogenized in a blender, centrifuged at 12.000 × g at 4 °C for 30 min. Resultant juice was diluted with distilled water, separated into multiple aliquots and refrozen at –20 °C.

Total Monomeric Anthocyanin

The pH differential method was used as specified by Giusti et al. (1999) to determine total monomeric anthocyanin levels. Samples were supplemented with potassium chloride (1:20 v:v) and sodium acetate buffer. Following an equilibration period of 15 min, raw absorbance values were measured at 533 and 700 nm. Then, a correction equation was applied to raw absorbance values ([A520 – A700] pH 1.0 – [A520 – A700] pH 4.5). Molar absorptivity ($\epsilon = 26.900$) and molecular weight (MW = 449.2) of cyanidin 3-glucoside were used to determine anthocyanin contents in gram (g) cyanidin 3-glucoside (cy-3-glu) kilogram (kg^{-1}) fresh weight (fw).

Total Flavonoids

Colorimetric method was used to determine total flavonoid contents (Chang et al. 2002). Sample extracts (0.1 g) was dissolved in 1 ml solvent and mixed with 10% $AlCl_3.6H_2O$ and 0.1 ml CH_3COOK. Then sample absorbance was measured as g quercetin kg^{-1} fw at 415 nm.

Total Phenolics (TP)

The method described by Singleton and Rossi (1965) was used to determine the total phenolics content. Sample extracts were obtained with a buffer [acetone, water and acetic acid (70:29.5:0.5 v/v)]. Resultant extracts were then supplemented with Folin-Ciocalteu's phenol reagent and water, incubated at room temperature for 8 min and supplemented with 7% sodium carbonate. Sample absorbance was measured as g gallic acid equivalent (GAE) kg^{-1} fw at 750 nm of UV-Vis spectrophotometer.

ABTS$^+$ Radical Scavenging Activity

To prepare 2 mM $ABTS^+$, 0.1 M of PO_4^{-3} buffer solution was used and mixed with $K_2S_2O_8$ solution (1:2 ABTS-$K_2S_2O_8$).

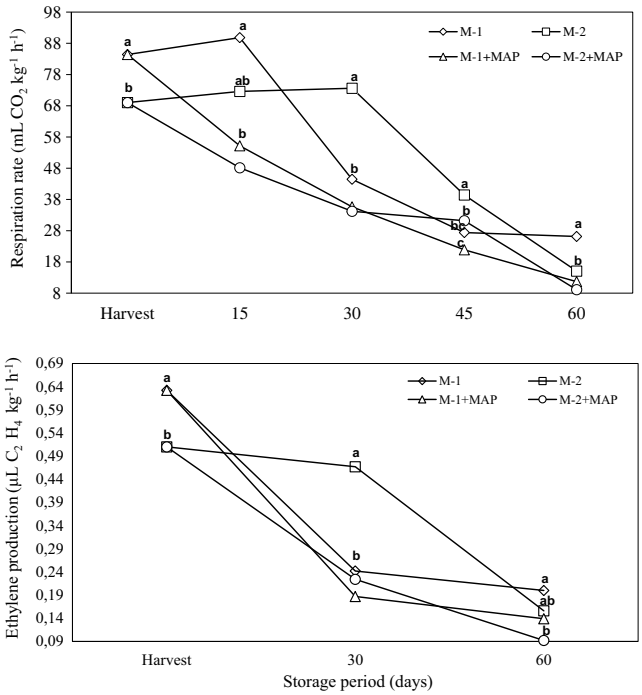

Fig. 2 Effects of MAP and maturity stage on respiration rate and ethylene production of cornelian cherry fruit during cold storage. $n=9$ for the respiration rate and ethylene production (three replicate × three different measurements for each replicate). The differences among the treatments indicated with the same letter vertically were not significant according to Tukey's test at $P<0.05$

Resultant mixture was then incubated at dark for 6 hr. Sample absorbance was measured at 734 nm. If the absorbance value was bigger than 0.75, sample was diluted again with PO_4^{-3} buffer and 20 µL sample was supplemented with 1 ml $ABTS^{+}$-$K_2S_2O_8$ mixture. Total volume was completed to 4 ml with buffer solution. Resultant sample was vortexed, incubated for 30 min and absorbance values were measured as mmol trolox equivalent (TE) kg^{-1} at 734 nm.

Ferric Ions (Fe^{+3}) Reducing Antioxidant Power Assay (*FRAP*)

About 120 µL samples were supplemented initially with 0.2 M of PO_4^{-3} to get a volume of 1.25 ml and then with 1.25 ml 1% $K_3Fe(CN)_6$. Resultant mixture was vortexed and incubated at 50 °C for 1 hr. Incubated samples were supplemented with 1.25 ml 10% TCA and 0.25 ml 0.1% $FeCl_3$ and absorbance values were measured as mmol TE kg^{-1} fw at 700 nm of a UV-Vis spectrometer (Benzie and Strain 1992).

Statistical Analysis

Experiments were performed according to the completely randomized design. Arcsine transformation was applied to percentage values before the variance analysis. Data normality was checked with Kolmogorov-Smirnov test and data homogeneity was checked with Levene's test. SAS Version 9.1 statistical software was used for statistical analyses. Means were compared with Tukey's range test at 5% level.

Results and Discussion

Weight Loss

During the storage, significantly lower weight losses were measured from MAP-treated fruit of both maturity stages than the fruit without MAP treatments. Weight loss (%) of MAP-treated fruit at the end of cold storage was almost half of the untreated fruit (Fig. 1).

Previous studies indicated that the maturity stages had significant effects on quality attributes of several fruit species during the cold storage (Lalel et al. 2003; Wang

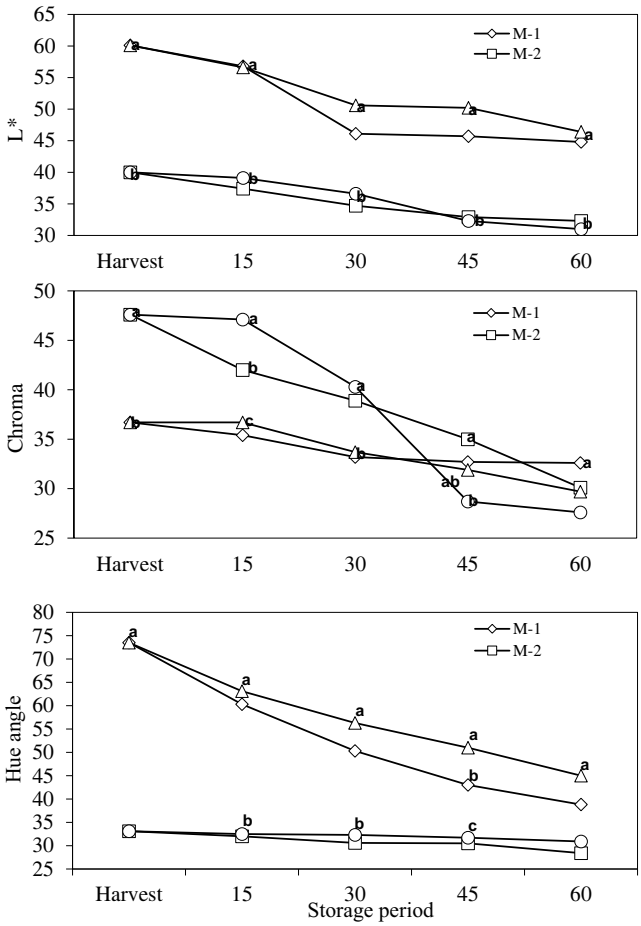

Fig. 3 Effects of MAP and maturity stage on L*, chroma and hue angle of cornelian cherry fruit during cold storage. $n=60$ for the L*, chroma and hue angle (three replicate × ten fruit for each replicate × two different measurements for each fruit). The differences among the treatments indicated with the same letter vertically were not significant according to Tukey's test at $P<0.05$

et al. 2016; Thewes et al. 2017). The primary objective of the present study was to identify the optimum maturity stage for the better preservation of quality attributes of cornelian cherry fruit during the cold storage. Crisosto et al. (1995) reported that the fruit harvested before the optimum maturity stage experience faster and greater postharvest water loss and thus higher weight losses. However, contrary to expectations, maturity stages did not have significant effects on weight loss in present study. MAP treatments significantly retarded weight losses. Weight loss of MAP-treated fruit was almost half of the untreated fruit. Mohebbi et al. (2015) also reported that the weight loss of cornelian cherry fruit was reduced by 50–70% with MAP treatments as compared to untreated control fruit. Weight loss retarding effect of MAP is primarily resulted from limiting effects of MAP on water loss and metabolic activity during the storage (Wani et al. 2014).

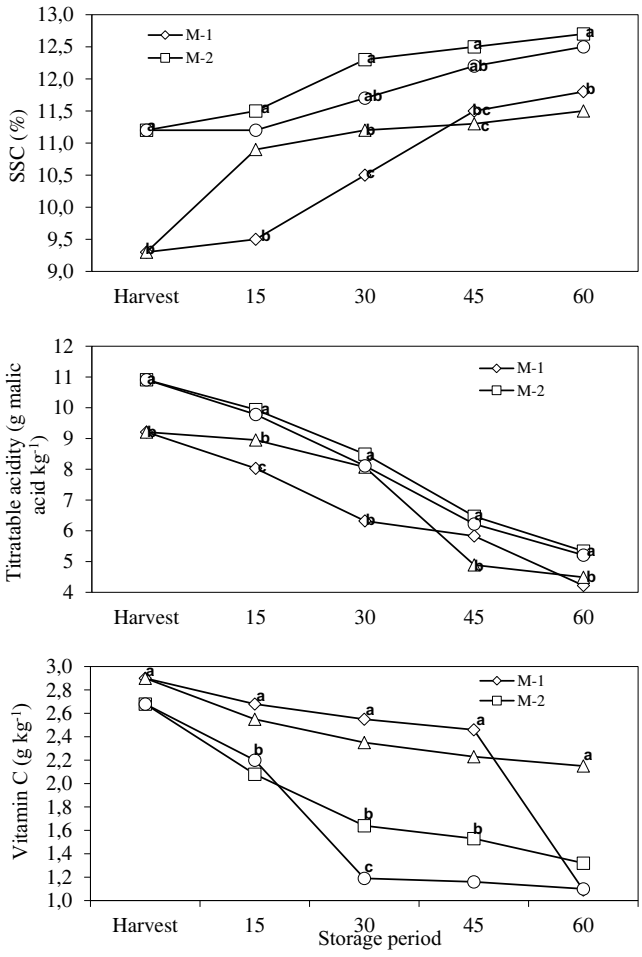

Fig. 4 Effects of MAP and maturity stage on SSC, titratable acidity and vitamin C of cornelian cherry fruit during cold storage. $n = 9$ for the SSC, titratable acidity and vitamin C (three replicate × three different measurements for each replicate). The differences among the treatments indicated with the same letter vertically were not significant according to Tukey's test at $P < 0.05$

Firmness and Decay Rate

At harvest, the fruit at M-1 stage had significantly higher flesh firmness than the fruit harvested at M-2 stage. In all periods of storage, firmness of MAP-treated fruit harvested at both maturity stages was similar with each other, but significantly higher than the untreated fruit. Decay rate of MAP-treated fruit were lower than the untreated fruit on 30th and 60th day of the storage (Fig. 1).

The fruit harvested at early maturity stage had greater flesh firmness. Thusly, varying flesh firmness values were reported based on maturity levels by Lalel et al. (2003) for mango, by Jan et al. (2012) for apple, by Çalhan et al. (2015) for sweet cherry, by Echeverria et al. (2015) for nectarine, by Kaur and Dhillon (2015) for pear and by Sarıdaş et al. (2016) for plum. Softening was observed in all treatments with the progress of ripening during the storage. However, maturity stages did not have significant effects on fruit flesh firmness during ripening. On the other hand, MAP treatments had distinctive effects on flesh firmness. MAP treatments retarded the losses in flesh firmness just because of ripening retarding effects of the treatments. Cell wall degradation including especially break down of cellulose and pectin components is the primary factor inducing flesh softening in several fruit (Lazan et al. 1995; Azene et al. 2014). In present study, MAP treatment reduced pectin depolimerization and solubility and thus retarded flesh softening (Azene et al. 2014). Sandhya (2010) also reported that MAP treatments limited enzymatic activity and slowed down respiration, thus reduced decay ratios. Thusly in present study, higher decay ratios were observed in treatments with high respiration rate and ethylene production rate. Khan et al. (2013) indicated that cultivar, age of the tree, pre-harvest weather conditions, fungus inoculation, maturity stage, harvest, process and storage factors might have significant effects on decay ratios of the fruit.

Respiration and Ethylene Production Rate

M-1 fruit had significantly greater respiration rate and ethylene production rate than M-2 fruit at harvest. But on 30th and 45th day of the storage, the respiration rate of M-2 treatment was greater than the other treatments. At the end of the storage, ethylene production of M-2+MAP treatment was lower than the M-1 treatment (Fig. 2).

Fruit ripening goes on after the harvest during the storage (Kader 2002). Respiration rate and ethylene production rate also varied based on maturity stages. Higher values of respiration and ethylene production rates at harvest were measured from M-1 fruit than M-2 fruit. Wang et al. (2016) stored Friar plums harvested at different maturity stages at 0 °C and reported greater respiration rate for the fruit harvested at early maturity stages, but reported insignificant

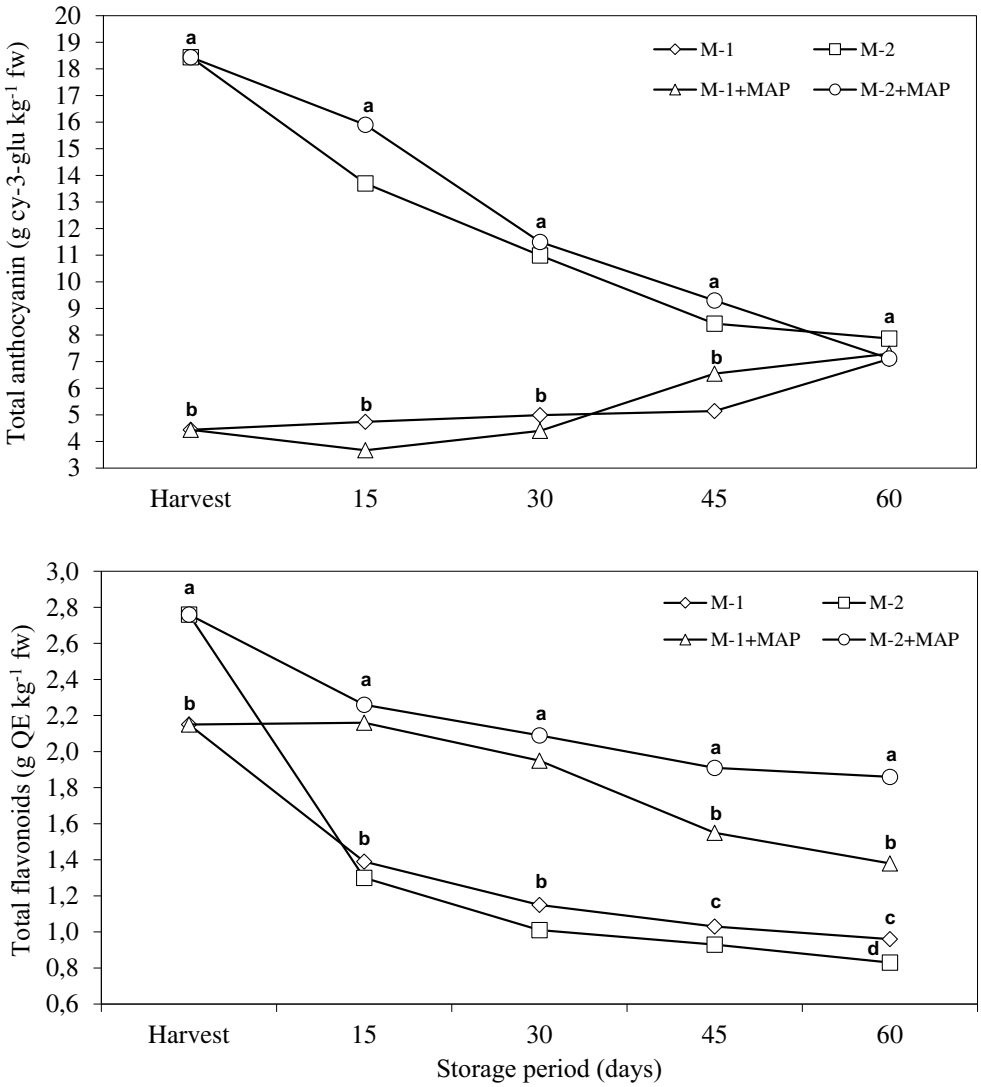

Fig. 5 Effects of MAP and maturity stage on total anthocyanin and total flavonoids of cornelian cherry fruit during cold storage. $n=9$ for the total monomeric anthocyanin and total flavonoids (three replicate × three different measurements for each replicate). The differences among the treatments indicated with the same letter vertically were not significant according to Tukey's test at $P<0.05$

differences in ethylene production rate of the fruit. Lalel et al. (2003) reported differences in ethylene production and respiration rates for mango fruit harvested at different maturity stages and indicated higher values for the fruit harvested at early maturity stage. As it was expected, MAP-treated fruit had lower respiration rate and ethylene production rate than the untreated fruit. However, Mohebbi et al. (2015) reported that ethylene production of cornelian cherry fruit after 35 days of storage in active MAP was not significantly different from the control fruit without any treatments. Retarded respiration rate and resultant ethylene production rate with MAP treatments were also reported for different fruit (Zhang et al. 2003; Erkan and Eski 2012; Çalhan et al. 2015).

Color Characteristics

At harvest and during the storage, significantly greater L* and hue angle values were measured from M-1 and M-1+MAP treatments than from M-2 and M-2+MAP treatments. Contrarily at harvest and on 15th and 30th days of the storage, lower chroma values were observed in M-1 and M-1+MAP treatments (Fig. 3).

Red color development increases in cornelian cherry fruit with the progress of ripening. Hue angle is an indicator of red color development [red color increases as the hue angle approaches to 0] (McGuire 1992) and the values were lower in M-2 (full ripe) fruit. Gunduz et al. (2013) reported the greatest hue angle of cornelian cherry fruit harvested at 4 different maturity stages for the fruit harvested at light yellow stage and the lowest hue angle for the fruit harvested at dark red stage. Lalel et al. (2003) measured lower hue angles from the mango fruit harvested at full ripe.

SSC, Titratable Acidity and Vitamin C

On 60th day of the storage, SSC and titratable acidity values of M-2 and M-2+MAP treatments were significantly higher

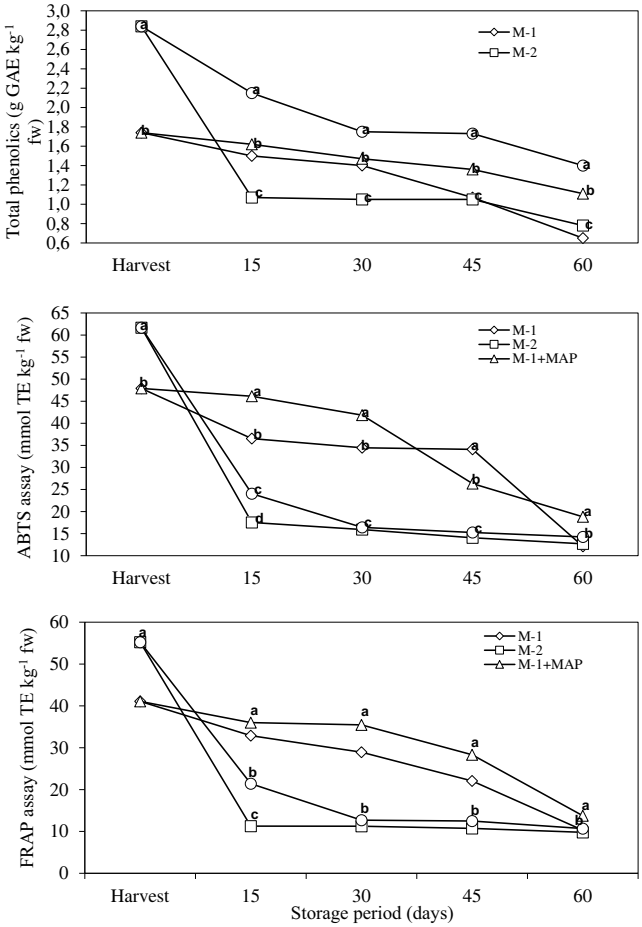

Fig. 6 Effects of MAP and maturity stage on total phenolics and antioxidant activity of cornelian cherry fruit during cold storage. $n=9$ for the total phenolics and antioxidant activity (three replicate × three different measurements for each replicate). The differences among the treatments indicated with the same letter vertically were not significant according to Tukey's test at $P<0.05$

than M-1 and M-1+MAP treatments. On 15th day of the storage, the lowest SSC and acidity was measured in M-1 treatment. At harvest and on 15th, 30th and 45th days of the storage, vitamin C contents of M-1 and M-1+MAP treatments were higher than M-2 and M-2+MAP treatments. At the end of storage, M-1+MAP treatment had significantly higher vitamin C contents than the other treatments (Fig. 4).

SSC values of the cornelian cherry fruit increased, but titratable acidity and vitamin C contents decreased during the storage. Mohebbi et al. (2015) also reported decreasing titratable acidity and vitamin C contents of cornelian cherry fruit during the cold storage. Çalhan et al. (2015) reported increasing SSC, but decreasing acidity values for cherries during the cold storage. In present study, rather than MAP treatments, significant effects of maturity stages were observed on SSC, acidity and vitamin C contents. In general, greater SSC and titratable acidity and lower vitamin C contents were obtained from M-2 fruit. Similar findings were also reported by Lalel et al. (2003) for mango, by Jan et al. (2012) for apple, by Gunduz et al. (2013) and Mohebbi et al. (2015) for cornelian cherry fruit and by Çalhan et al. (2015) for sweet cherry.

Total Monomeric Anthocyanin, Total Phenolics, Total Flavonoids and Antioxidant Activity

At harvest and on 15th, 30th and 45th days of the storage, total monomeric anthocyanin contents of M-2 and M-2+MAP treatments were higher than the contents of M-1 and M-1+MAP treatments. At harvest, higher flavonoids were obtained from M-2 fruit. At the last two periods of the storage, flavonoid contents of MAP-treated fruit were significantly greater than that of untreated fruit (Fig. 5).

At harvest, M-2 fruit had significantly higher phenolics and antioxidant activity than the M-1 fruit. In all measurement periods of the storage, M-2+MAP treatment had significantly higher total phenolics than the other treatments. On 15th, 30th and 60th days of the storage, the highest antioxidant activity according to ABTS assay was obtained from M-1+MAP treatments. Similarly, at the end of the storage, antioxidant activity of M-1+MAP treatments according to FRAP assay was higher than the other treatments (Fig. 6).

In present study, M-2 fruit had greater anthocyanin and flavonoid levels and thus greater phenolics and antioxidant activity at harvest measurements. Contrary to present findings, Gunduz et al. (2013) reported that cornelian cherry fruit harvested at dark red stage had lower phenolics and antioxidant activity, but had similar higher anthocyanin content with the present study. Sarıdaş et al. (2016) reported increasing phenolics content and antioxidant activity for the plums with the progress of ripening. On the other hand, Fadda et al. (2017) reported that maturity levels did not have significant effects on total phenolics of peaches. In present study, bioactive compounds (except for M-1 fruit) generally decreased during the cold storage. In M-1 fruit (early maturity) anthocyanin contents slightly increased during the storage since red color development went on. Thusly, red skin color development increases in cornelian cherry fruit harvested at early maturity stage with the progress of ripening (Gunduz et al. 2013). At the end of storage, anthocyanin contents did not change with MAP treatments. However, MAP-treated fruit had greater total flavonoid, total phenolics and antioxidant activity. Mohebbi et al. (2015) and Serrano et al. (2006) reported that MAP treatments slowed down the losses in total phenolics and antioxidant activity of the fruit. MAP-treated fruit usually have lower respiration rate, thus the losses in biochemical contents are retarded (Azene et al. 2014). Similarly, MAP-treated fruit of the present study had lower respiration rate.

Conclusion

Present findings clearly revealed that MAP treatments could be used as an efficient postharvest tool to preserve quality attributes of the cornelian cherry fruit during the cold storage and to reduce postharvest losses in quality attributes. It was observed that maturity stages did not have significant effects on quality attributes when the fruit were MAP-treated. When the fruit were not MAP-treated, the quality attributes significant for human health (especially vitamin C, total phenolics, total flavonoids and antioxidant activity) were higher in fruit harvested at M-1 stage. Therefore, it can be recommended based on present findings that cornelian cherry fruit should be harvested at M-1 stage and fruit should be cold-stored in MAP packages.

Acknowledgements This study was supported by the Scientific Research Project Unit of Ordu University (Project number: TF-1526).

Conflict of interest T. Yarılgaç, H. Kadim and B. Ozturk declare that they have no competing interests.

References

Azene M, Workneh TS, Woldetsadik K (2014) Effect of packaging materials and storage environment on postharvest quality of papaya fruit. J Food Sci Technol 51:1041–1055

Benzie IFF, Strain JJ (1992) The ferric reducing ability of plasma (FRAP) as a measure of 'antioxidant power': The FRAP assay. Anal Biochem 239:70–76

Çalhan Ö, Onursal CE, Güneyli A, Eren I (2015) Effect of harvest date on postharvest quality of 'Kordia' sweet cherry during MAP storage. Acta Hortic 1071:667–674

Chang CC, Yang MH, Wen HM, Chern JC (2002) Estimation of total flavonoid content in propolis by two complementary colorimetric methods. J Food Drug Anal 10:178–182

Crisosto CH, Mitchell FG, Johnson S (1995) Factors in fresh market stone fruit quality. Postharvest News Inf 6:17–22

D'antuono LF, Kolesnov A, Fedosova K, Jorjadze M, Boyko N, Mudryk M, Bignami C (2014) Cornelian cherry: an important local resource and promising health promoting fruit plant of the Black Sea area. Acta Hortic 1017:299–307

Dinda B, Kyriakopoulos AM, Dinda S, Zoumpourlis V, Thomaidis NS, Velegraki A, Markopoulos C, Dinda M (2016) Cornus mas L. (Cornelian cherry), an important European and Asian traditional food and medicine: Ethnomedicine, phytochemistry and pharmacology for its commercial utilization in drug industry. Ethnopharmacol 193:670–690

Echeverria G, Cantin CM, Ortiz A, Lopez ML, Lara L, Graell J (2015) The impact of maturity, storage temperature and storage duration on sensory quality and consumer satisfaction of 'Big Top' nectarines. Sci Hortic 190:179–186

Erkan M, Eski H (2012) Combined treatment of modified atmosphere packaging and 1-methylcyclopropene improves postharvest quality of Japanese plums. Turk J Agric For 36:563–575

Fadda C, Usai G, Sanguinetti AM, Mascia I, Del Caro A, Satta D, Piga A (2017) Effect of ripening stage at harvest, cold storage, and simulated marketing conditions on quality and antioxidant activity of peach fruit. Acta Aliment 46:275–282

Giusti MM, Rodriguez-Saona LE, Griffin D, Wrolstad RE (1999) Electrospray and tandem mass spectroscopy as tools for anthocyanin characterization. J Agric Food Chem 47:4657–4664

Gunduz K, Saracoglu O, Özgen M, Serce S (2013) Antioxidant, physical and chemical characteristics of cornelian cherry fruit (*Cornus mas* L.) at different stages of ripeness. Acta Sci Pol Hortorum Cult 12:59–66

Hussein Z, Fawole OA, Opara UL (2018) Preharvest factors influencing bruise damage of fresh fruit. Sci Hortic 229:45–58

Jan I, Rab A, Sajid M (2012) Storage performance of apple cultivars harvested at different stages of maturity. J Anim Plant Sci 22:438–444

Kader AA (1997) Fruit maturity, ripening, and quality relationships. Acta Hortic 485:203–208

Kader AA (2002) Postharvest technology of horticultural crops, 3rd edn. University of California (System). Division of Agriculture and Natural Resources. ANR Publications,

Kamol SI, Howlader J, Sutra Dhar GC, Aklimuzzaman M (2014) Effect of different stages of maturity and postharvest treatments on quality and storability of pineapple. Bangladesh J Agril Univ 12:251–260

Karakaya O, Aglar E, Ozturk B, Gun S, Ates U, Öcalan ON (2020) Changes of quality traits and phytochemical components of jujube fruit treated with preharvest GA_3 and Parka during cold storage. Turk J Food Agric Sci 2(2):30–37

Kaur K, Dhillon WS (2015) Influence of maturity and storage period on physical and biochemical characteristics of pear during post cold storage at ambient conditions. J Food Sci Technol 52:5352–5356

Khan MS, Zeb A, Rahatullah K, Ihsanullah Ahmed N, Ahmed S (2013) Storage life extension of plum fruit with different colored packaging and storage temperatures. Iosr J Environ Sci Toxicol Food Technol 7:86–93

Koc Guler S, Karakaya O, Karakaya M, Ozturk B, Aglar E, Yarılgac T, Gün S (2019) Combined treatments of modified atmosphere packaging with aminoethoxyvinylglycine maintained fruit quality in sweet cherry throughout cold storage and shelf life. Acta Sci Pol Hortorum Cult 18 (5):13–26

Lalel HJD, Singh Z, Tan SC, Agusti M (2003) Maturity stage at harvest affects fruit ripening, quality and biosynthesis of aroma volatile compounds in 'Kensington Pride' mango. J Hortic Sci Biotechnol 78:225–233

Lazan H, Kasim M, Ali ZM (1995) β-Galactosidase, polygalacturonase and pectin esterase in differential softening and cell wall modification during papaya fruit ripening. Plant Physiol 95:106–112

McGuire RG (1992) Reporting of objective colour measurement. HortScience 27:1254–1255

Mohebbi S, Mostofi Y, Zamani Z, Najafi F (2015) Influence of modified atmosphere packaging on storability and postharvest quality of cornelian cherry (*Cornus mas* L.) fruit. Not Bot Hortic Agrobo 7:116–122

Ozturk 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-Food Sci Technol 111:117–124

Ramin AA, Tabatabaie F (2003) Effect of various maturity stages at harvest on storability of persimmon fruit (Diospyros kaki L.). J Agr Sci Techol 5:113–123

Sandhya S (2010) Modified atmosphere packaging of fresh produce: Current status and future needs. LWT Food Sci Technol 43:381–392

Sarıdaş MA, Kafkas E, Zarifikhosroshahi M, Bozhaydar O, Paydaş Kargı S (2016) Quality traits of green plums (*Prunus cerasifera* Ehrh.) at different maturity stages. Turk J Agric For 40:655–663

Serrano M, Martinez-Romero D, Guillen F, Castillo S, Valero D (2006) Maintenance of broccoli quality and functional properties during cold storage as affected by modified atmosphere packaging. Postharvest Biol Technol 39:61–68

Singleton VL, Rossi JL (1965) Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. Am J Enol Viticult 16:144–158

Thewes FR, Brackmann A, Anese RO, Ludwing V, Schultz EE, Santos LF, Wendt LM (2017) Effect of dynamic controlled atmosphere monitored by respiratory quotient and 1-methylcyclopropene on the metabolism and quality of 'Galaxy' apple harvested at three maturity stages. Food Chem 222:84–93

Wang J, Pan H, Wang R, Hong K, Cao J (2016) Patterns of flesh reddening, translucency, ethylene production and storability of 'Friar' plum fruit harvested at three maturity stages as affected by the storage temperature. Postharvest Biol Technol 121:9–18

Wani AA, Singh P, Guld K, Wani MH, Langowski HC (2014) Sweet cherry (*Prunus avium*): Critical factors affecting the composition and shelf life. Food Packag Shelf Life 1:86–99

Zhang M, De Baerdemaeker J, Schrevens E (2003) Effects of different varieties and shelf storage conditions of chicory on deteriorative colour changes using digital image processing and analysis. Food Res Int 36:669–676