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COMBINED TREATMENTS OF MODIFIED ATMOSPHERE PACKAGING WITH AMINOETHOXYVINYLGLYCINE MAINTAINED FRUIT QUALITY IN SWEET CHERRY THROUGHOUT COLD STORAGE AND SHELF LIFE

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ABSTRACT

The effects of combined aminoethoxyvinylglycine (AVG) and modified atmosphere packaging (MAP) treatments on quality attributes of '0900 Ziraat' sweet cherry fruit during the cold storage and shelf life were investigated in this study. Significantly lower weight loss and decay ratios were observed in all treatments throughout the cold storage period as compared to the control. A similar case was also observed referring to the shelf life. MAP treatments were found to be more effective in retarding the weight loss and decay ratio. Higher hue angle values were measured from AVG-treated fruit at harvest. Similarly, hue angle of AVG and MAP-treated fruit were also higher than for the control in all periods of cold storage and on the 7th and 21st day of shelf life. AVG-treated fruit had higher firmness values than the control at harvest. However, higher firmness values were measured from MAP-treated fruit during the cold storage and shelf life. At the end of cold storage, lower SSC and higher titratable acidity values were observed in AVG and MAP-treated fruit than in the control. AVG + MAP treatments yielded significantly higher vitamin C, total phenolics and antioxidant activity values than the control. Contrarily, the control fruit had significantly higher total monomeric anthocyanin than the other treatments. Based on current findings, it was concluded that combined AVG + MAP treatments could be used as a beneficial tool to maintain the quality of sweet cherry fruit throughout the cold storage and shelf life.

Key words: antioxidant, color, firmness, phenolics, *Prunus avium*, weight loss

Sweet cherry fruit with their delicious taste and aroma whet the appetite of consumers. Fruit are also rich in nutrients. They are significant export commodity of primary producer countries. Turkey is the leading sweet cherry producer of the world and the leading sweet cherry exporter country worldwide. Sweet cherry fruit have sensitive structure, thus fruit are exposed to serious quality losses during the postharvest storage and shelf life of the fruit. Flesh softening is the greatest quality loss in sweet cherry and such losses greatly limit export of the fruit [Sen et al. 2014].

To preserve fruit quality attributes throughout the postharvest storage and shelf life of the sweet cherry fruit, *Aloe vera* [Martinez-Romero et al. 2006], algi-

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nate [Diaz-Mula et al. 2012], chitosan [Petriccione et al. 2015] and similar coating materials; 1-methylcyclopropene [Yang et al. 2011], gibberellic acid [Einhorn et al. 2013], methyl jasmonate [Castillo et al. 2014], aminoethoxyvinylglycine [Onursal et al. 2013] and similar growth regulators; modified atmosphere packaging [Esturk et al. 2012] and similar post-harvest technologies were used.

Aminoethoxyvinylglycine (AVG) is an ethylene inhibitor. It was used in several fruit including sweet cherry, apple, plum, nectarine etc. to retard fruit ripening, to improve fruit coloration, to reduce pre-harvest fruit drops and to preserve fruit flesh firmness during the postharvest storage of the fruit [Greene 2006; Ozturk et al. 2012]. Positive effects in preservation of flesh firmness have made AVG a potential tool for marketing sweet cherry fruit to further markets.

Modified atmosphere packaging (MAP) is a postharvest technology used to preserve the quality of fresh vegetables and fruit and to prolong their shelf life and marketing period. MAP reduces oxygen concentration around the fruit, reduces respiration rates, retards browning over fruit stalks, slows down aerobic microorganism development and preserves skin color and flesh firmness for longer time [Esturk et al. 2012].

There are some researches indicating that MAP prolonged shelf life of sweet cherry fruit successfully [Remon et al. 2000; Serrano et al. 2005]. However, there aren't any studies about the combined effects of AVG and MAP on postharvest quality attributes of sweet cherry fruit. Therefore, this study was conducted to investigate the effects of AVG treatments applied to fruit while fruit are still on tree combined with postharvest MAP treatments on fruit quality attributes of sweet cherry during cold storage and shelf life.

MATERIAL AND METHODS

Plant material. The study was conducted in 2015 on fruit harvested from 5-year-old '0900 Ziraat' sweet cherry trees (*Prunus avium*) grafted on 'MaxMa 14' (*P. mahaleb* × *P. avium*) rootstock in Sivas, Turkey (40°10'09.67"N latitude, 38°06'37.14"E longitude and 952 m altitude). The trees were planted at 3.5 × 4 m spacing and trained by Spanish Bush system. Standard cultural practices such as pruning, disease control, irrigation, fertilization were regularly implemented during experimental period.

Experimental design. The study was laid out in a randomized complete-block design. A total of 18 trees with homogeneous fruit load were determined and they were separated into 3 blocks with 6 trees per block based on proximity in orchard and crop load. In each block, 225 mg L^{-1} AVG ['ReTain' (containing 15% AVG), Valent BioSciences Crop, USA] was sprayed (at straw color, 3 weeks before the commercial harvest time) on three trees until run-off with a low pressure hand sprayer and three trees in each block were served as control treatment (sprayed only with water).

The fruit were harvested at commercial maturity of color grade 4 according to the color scale developed by CTIFL (Centre Technique Interprofessionnel des Fruit et Legumes, Paris, France), in which 1-light pink and 7-dark mahogany. Fruit were placed into 5 kg capacity plastic boxes. Then, they were immediately transported via a cooled truck to the postharvest laboratory of the Department of Horticulture at Ordu University where they were selected for uniform size, disease-free, with no mechanical damage and healthy greenish stems. Fruit were hydro-cooled and put into plastic boxes (fruit pulp temperature at 1−2°C).

A total of 300 fruit from each tree (replicate) were used to determine quality characteristics at harvest [20 June, 2015, (150 fruit for instant analysis; 150 fruit after 3 days at room temperature)]. For cold storage, treatments were designed as control (obtained from the trees that were not treated with AVG and storing without MAP treatment), MAP (storing fruit, which were obtained from the trees that were not treated with AVG, in MAP), AVG (storing fruit, which were obtained from the trees that were treated with AVG, without MAP treatment) and AVG + MAP (storing fruit, which were obtained from the trees that were treated with AVG, in MAP). MAP bags (5 kg) were Xtend® (815-CH97/a, StePac, Turkey). The fruit were stored in plastic boxes (39 × 29 × 21 cm, Plastas, Turkey) each of which contains 300 fruit. For each treatment, 3 boxes (900 fruit) were used in each storage period. The total number of fruit used in all analyzes except for weight loss during storage was 11700. In addition, 900 fruit were used during storage to determine the weight loss.

Fruit were stored in the same storage together, at 0 ±0.5°C and 90 ±5% RH for 7, 14 and 21 days and

analyzed at the end of each storage period (20 and 27 June, 4 July 2015). After each storage period, fruit were additionally kept 3 days at room temperature (23°C and 90 ±5% RH for 3 days) simulating a shelf-life period. In each analysis date, 3 plastic fruit box (1 plastic box for each replicate) were analyzed for each treatment. Of the fruit in each plastic box, half was used for cold storage analyses and the other half was used for shelf life analyses.

Weight loss. Fruit weights were determined using a digital scale (±0.01 g) (Radvag PS 4500/C/1, Poland). Weight loss was determined by the difference between the initial and final weights of each replicate (box) during cold storage and expressed as percent.

Decay ratio. The fruit decay was visually evaluated during the storage and shelf life. Sweet cherry fruit that showed any sign of surface mycelia development were considered as decayed with naked eye. Decay ratio was expressed as a percentage of infected sweet cherry fruit. Weight loss and decay ratio was replicated three times for each treatment.

Color characteristics. Color characteristics (L*, chroma and hue angle) were measured at opposite sides of each fruit with a colorimeter (Konica-Minolta, model CR–400, Japan). Chromatic analyses were conducted in accordance with the CIE (Commission Internationale de l'Eclairage) system. Values of L*, a* and b* were used to define a three-dimensional color space. The chroma value was calculated with the $C^* = (a^{*2} + b^{*2})^{1/2}$, and the hue angle with the $h° = \tan^{-1} b^*/a^*$. Color characteristics were determined for 20 fruit in each replicate.

Firmness. Texture analyzer, TA-TX Plus (Stable Microsystems, Godalming, UK), fitted with a 2.0 mm penetrometer probe, a 50 N load cell, operating at a penetration speed of 10 mm s^{-1} and a penetration depth of 3 mm, was used to measure flesh firmness (N mm^{-1}). The maximum force needed for penetrating the fruit 3 mm deep was 5 N. Flesh firmness results were the average of 10 measurements in each replicate (30 measurements in each treatment).

SSC and titratable acidity. For SSC, titratable acidity and vitamin C measurements, 90 fruit were selected from each replicate (1 plastic box for each replicate) and fruit were divided into 3 groups each of with 30 fruit. Stones of each fruit were removed and fruit juices were extracted with an electrical fruit juice extractor (HR1855/70, Philips, Turkey). A digital refractometer (PAL-1, McCormick Fruit Tech., Yakima, Wash., USA) was used to determine SSC (%). For titratable acidity, 10 ml extract was diluted with 10 ml distilled water, and then titrated to pH 8.2 using 0.1 mol L^{-1} sodium hydroxide. Titratable acidity was expressed in malic acid equivalent (g malic acid 100 g^{-1}).

Vitamin C. For vitamin C content, sufficient amount of extract was taken and resultant volume was completed to 5 ml with the addition of 0.5% oxalic acid. Ascorbic acid test strip (Catalog no: 116981, Merck, Germany) was taken from reclose tube, dipped into the solution for 2 seconds and reflectometer set (Merck RQflex plus 10) was started. The test strip was then shaken off to remove excess liquid over it, waited for 8 seconds and reading was performed until the end of 15th second. The resultant value was expressed as mg 100 g^{-1}.

Bioactive compounds

Total phenolics, total antioxidant capacity and total monomeric anthocyanin. For bioactive compounds, 90 fruit were selected from each replicate (1 plastic box for each replicate) in each analysis period. Then stones of these fruit were removed, and the pulp was homogenized with a food blender. The homogenates were placed into 3 different tubes and stored at –20°C for bioactive analyses. Samples were thawed at room temperature (≈21°C) and homogenized in a food-grade blender. The resultant slurry was centrifuged (12.000 × g) at 4°C for 30 min to separate the juice from the pulp. The freshly obtained juice was diluted with distilled water, divided into multiple sample aliquots and refrozen at –20°C until used in phenolics, anthocyanin and antioxidant assay procedures.

Total phenolics (TP): Total phenolics content was measured according to the procedure described by Singleton and Rossi [1965]. Briefly, fruit pulps were extracted with a buffer containing acetone, water and acetic acid (70 : 29.5 : 0.5 v/v) for 2 h at dark. Samples were replicated four times. Extracts were combined with Folin-Ciocalteu's phenol reagent and water, and incubated at room for 8 min followed by the addition of 7% sodium carbonate. After 2 h, the absorbance at 750 nm was measured in an automated UV-Vis spectrophotometer (Model T60U, PG Instruments). Gallic acid was used as the standard. The results were ex-

pressed as micrograms (µg) gallic acid equivalent (GAE) g^{-1} fresh weight (f.w.).

Ferric ions (Fe^{+3}) reducing antioxidant power assay (FRAP): Portions of 120 µL were taken from the samples, 0.2 M of phosphate buffer (PO_4^{-3}) (pH 6.6) was added to obtain a volume of 1.25 mL and then 1.25 mL of 1% potassium ferricyanide ($K_3Fe(CN)_6$) solution was added. After vortexing, they were incubated at 50°C for 1 h. Afterwards, 1.25 mL of 10% TCA (trichloro acetic acid) and 0.25 mL of 0.1% $FeCl_3$ were added to the samples. The absorbances of the extract solution were read on an UV-Vis spectrometer at 700 nm. The results were expressed as µmol Trolox equivalents (TE) per kilogram of f.w. (µmol TE g^{-1}f.w.) [Benzie and Strain 1992].

Trolox equivalent antioxidant capacity (TEAC) assay: 10 mmol/L ABTS (2.2-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid) was dissolved in acetate buffer and prepared with potassium per sulfate as described in Ozgen et al. [2006]. The mixture was diluted using an acidic medium of 20 mM sodium acetate buffer (pH 4.5) to an absorbance of 0.700 ±0.01 at 734 nm for longer stability. For the spectrophotometric assay, 2.90 mL of the $ABTS^+$ solution and 100 µL of fruit extract were mixed and incubated at room temperature and dark conditions for 10 min. The absorbance at 734 nm was then determined. The results were expressed in µmol trolox equivalent (TE) g^{-1} f.w.

Total monomeric anthocyanin: Total anthocyanin levels were measured by the pH differential method described in Giusti et al**.** [1999]. Sample extracts were combined in a 1 : 20 ratio (v : v) with potassium chloride and with sodium acetate buffers (pH 1.0 and 4.5, respectively) in separate vessels. After an equilibration period (15 min), the raw absorbance of each solution was measured at 533 and 700 nm. A corrected absorbance value was calculated as [(A520 – A700) pH 1.0 – (A520 – A700) pH 4.5]. The anthocyanin content was calculated using the molar absorptivity (ϵ) and molecular weights (MW) of cyanidin 3-glucoside (ϵ = 26.900; MW = 449.2). Results were expressed as micrograms (µg) of cyanidin 3-glucoside equivalents (µg cy-3-glu g^{-1} f.w.).

Statistical analysis

The percentage values were transformed using the arcsin of the square root before analysis of variance (ANOVA). The normality of the data was confirmed by the Kolmogorov-Smirnov test and the homogeneity of variances by the Levene's test. Data for physical, mechanical and biochemical parameters were subjected to ANOVA by using SAS Version 9.1 (SAS Institute Inc., USA) software. When the F test was significant, means were compared with Tukey's range test. The level of significance was set as 5%.

RESULTS AND DISCUSSION

Weight loss. A weight loss was observed in all treatments throughout the storage period. As compared to the control, MAP and AVG treatments significantly retarded weight loss. But, MAP was found to be more efficient than AVG in retarding weight loss (Tab. 1).

Since MAP slows down respiration and limits water loss in fruit, it might have retarded weight loss

Table 1. Effect of MAP and AVG treatments on weight loss of '0900 Ziraat' sweet cherry fruits during storage at 0°C and 90% RH

Treatments	Weight loss (%)		
	7 day	14 day	21 day
Control	1.03 a	2.01 a	4.24 a
AVG	0.90 b	1.46 b	3.37 b
MAP	0.25 c	0.49 c	0.74 c
AVG + MAP	0.26 c	0.43 c	0.71 c

n = 9 for the weight loss (three replicate × three different measurements for each replicate). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$

Table 2. Effect of MAP and AVG treatments on decay ratio of '0900 Ziraat' sweet cherry fruit during cold storage and shelf life

Treatments	Decay ratio (%)		
	7 day	14 day	21 day
Control	0	2.22 a	4.67 a
AVG	0	1.78 b	2.00 b
MAP	0	0.44 c	1.08 c
AVG + MAP	0	0.22 c	1.11 c
	7 + 3 day	14 + 3 day	21 + 3 day
Control	2.44 a	5.33 a	7.78 a
AVG	1.11 b	3.78 b	5.33 b
MAP	0.34 c	1.47 c	2.39 c
AVG + MAP	0.22 c	1.11 c	2.00 c

nd: not determined. n = 9 for the decay ratio (three replicate × three different measurements for each replicate). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$

Table 3. Effect of MAP and AVG treatments on L* values of '0900 Ziraat' sweet cherry fruit during cold storage and shelf life

Treatments	L*			
	Harvest	7 day	14 day	21 day
Control	33.37 a	32.88 a	31.21 b	31.03 a
AVG	33.34 a	32.31 a	31.43 b	31.27 a
MAP		32.60 a	32.51 a	31.34 a
AVG + MAP		32.85 a	32.64 a	31.47 a
	Harvest+3	7 + 3 day	14 + 3 day	21 + 3 day
Control	32.94 a	31.69 b	30.53 b	30.22 a
AVG	32.77 a	31.74 b	30.34 b	30.19 a
MAP		32.45 a	31.69 a	30.45 a
AVG + MAP		32.47 a	31.74 a	30.57 a

n = 120 for the L* (three replicate × twenty fruit × two different measurements for each fruit). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$

during the cold storage. Thusly, Kappel et al. [2002] carried out a study with different sweet cherry cultivars and Kaynaş et al. [2010] with plums and both researchers reported less weight loss for MAP-treated fruit than for the control fruit. Ethylene regulates fruit ripening and aging. Therefore, ethylene inhibitors (AVG, 1-MCP) play a significant role in retarding ripening of sweet cherry fruit [Yang et al. 2011]. Thus, ripening-retarding effects of AVG might have slowed down metabolic activity and limited water loss in fruit.

Decay ratio. As compared to the control fruit, significantly lower decay ratios were observed in AVG and MAP-treated fruit on 14th and 21st day of cold storage and in all measurements of shelf life. However, lower decay ratios were observed in MAP-treated fruit than in control and only AVG-treated fruit both during the cold storage and shelf life (Tab. 2).

The CO_2 in MAP suppresses the development of aerobic bacteria and thus retards the decays in sweet cherry fruit [Petracek et al. 2002]. Therefore, lower decay ratios were observed in MAP-treated fruit in the present study. Colgecen and Aday [2015] in sweet cherry and Cantin et al. [2008] in plums reported lower decay ratios for MAP-treated fruit. Lower decay ratios were also observed in AVG-treated fruit. Since AVG retards ethylene production, it might have slowed down ripening and aging and then resulted in lower decay ratios. Thusly, D'Aquino et al. [2010] in pears and Robison et al. [2001] in tomatoes, reported slowed down mycelia development and reduced decay ratios.

Color characteristics. In measurements made at harvest, AVG had significant effects only on hue angle of the fruit. Generally, in measurements made throughout the cold storage and shelf life, MAP-treated fruit had higher L*, chroma and hue angle values than the control fruit (Tabs 3–5).

Anthocyanins supply red color pigment in fruit and vegetables. Red color development in plants goes on throughout the ripening period. Considering anthocyanin contents of the present study, it was observed that MAP and AVG-treated fruit had slower red color development during the cold storage period. Such an effect might been resulted from ripening and color development-retarding effect of MAP and AVG. Thusly, Crisosto et al. [2009] reported that MAP treatments retarded ripening in sweet cherry and Webster et al. [2006] reported that AVG treatments retarded ripening in sweet cherry fruit and thus retarded red color development.

Firmness. In measurements made at harvest, AVG-treated fruit had higher flesh firmness values than the control fruit. In measurements made throughout cold storage and shelf life, higher flesh firmness values were measured from MAP and AVG + MAP-treated fruit than from the control and only AVG-treated fruit (Tab. 6).

Blazkova et al. [2002] indicated that firmness of sweet cherry fruit should not be less than 2 N (Newton) for marketing them in markets. In our study, firmness values were above this value in all treatments. However, firmness of MAP-treated fruit was better maintained during the cold storage. Limited gas exchange and suppressed respiration in MAP treatments slowed down the metabolic activity and retarded flesh softening. Thusly, Giacalone and Chiabrando [2013] and Sen et al. [2014] reported slowed down respiration and retarded flesh softening in sweet cherry with MAP treatments. Similarly, Kappel et al. [2002] reported that MAP provided higher relative humidity and thus retarded flesh softening. Weight loss was lower in MAP treatments and thus higher firmness values were measured in those fruit. There was a reverse relationship between weight loss and firmness loss. Brummel [2006] also indicated a reverse relationship between weight loss and firmness loss and reported that increasing weight loss speeded up cell wall and membrane disintegration. In the study, AVG treatments better maintained flesh firmness at harvest as compared to control fruit and yielded similar firmness levels with control fruit during the cold storage. Similarly, previous researchers reported that flesh firmness was better maintained at harvest with AVG treatments in different fruit (apples, peaches, plums) [Çetinbaş et al. 2012, Ozturk et al. 2012, Yildiz et al. 2012].

SSC and titratable acidity. In measurements made at harvest, AVG-treated fruit had lower SSC values than the control fruit. SSC values increased in all treatments during the cold storage period. However, titratable acidity values decreased in all treatments throughout the cold storage. At the end of cold storage period, lower SSC values were measured from all treatments than the control treatments. At the last shelf life measurements, lower SSC values were measured only from AVG + MAP treatments. In all measure-

Table 4. Effect of MAP and AVG treatments on chroma values of '0900 Ziraat' sweet cherry fruit during cold storage and shelf life

Treatments	Chroma			
	Harvest	7 day	14 day	21 day
Control	37.42 a	33.09 b	32.78 b	32.23 b
AVG	37.41 a	35.09 a	34.49 a	34.19 a
MAP		35.79 a	34.67 a	34.24 a
AVG + MAP		35.72 a	34.51 a	34.01 a
	Harvest+3	7 + 3 day	14 + 3 day	21 + 3 day
Control	33.46 a	30.51 b	29.16 b	27.33 a
AVG	33.64 a	32.86 a	30.27 a	27.47 a
MAP		32.68 a	30.62 a	27.78 a
AVG + MAP		32.37 a	30.67 a	27.38 a

n = 120 for the chroma (three replicate × twenty fruit × two different measurements for each fruit). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$

Table 5. Effect of MAP and AVG treatments on hue angle values of '0900 Ziraat' sweet cherry fruit during cold storage and shelf life

Treatments	Hue angle			
	Harvest	7 day	14 day	21 day
Control	22.86 b	20.08 b	19.16 b	18.39 b
AVG	23.92 a	22.73 a	21.79 a	20.92 a
MAP		23.03 a	22.22 a	20.77 a
AVG+MAP		23.22 a	22.58 a	21.14 a
	Harvest+3	7 + 3 day	14 + 3 day	21 + 3 day
Control	17.55 b	16.54 b	16.28 a	11.34 b
AVG	19.17 a	17.48 a	16.57 a	16.02 a
MAP		17.57 a	16.38 a	15.73 a
AVG+MAP		17.61 a	16.44 a	15.85 a

n = 120 for the hue angle (three replicate × twenty fruit × two different measurements for each fruit). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$

Table 6. Effect of MAP and AVG treatments on firmness of '0900 Ziraat' sweet cherry fruit during cold storage and shelf life

Treatments	Firmness (N)			
	Harvest	7 day	14 day	21 day
Control	6.07 b	4.65 b	4.17 b	3.70 b
AVG	6.75 a	4.75 b	4.24 b	3.79 b
MAP		5.39 a	4.72 a	4.38 a
AVG+MAP		5.60 a	4.97 a	4.49 a
	Harvest + 3	7 + 3 day	14 + 3 day	21 + 3 day
Control	5.15 b	4.54 b	4.06 b	3.27 b
AVG	5.93 a	4.25 b	4.04 b	3.43 b
MAP		5.26 a	4.57 a	3.96 a
AVG+MAP		5.35 a	4.62 a	4.01 a

n = 30 for the firmness (three replicate × ten fruit for each replicate). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$

Table 7. Effect of MAP and AVG treatments on SSC of '0900 Ziraat' sweet cherry fruit during cold storage and shelf life

Treatments	SSC (%)			
	Harvest	7 day	14 day	21 day
Control	11.08 a	11.38 a	12.62 a	13.28 a
AVG	9.47 b	11.13 a	11.37 b	12.40 b
MAP		11.23 a	12.43 a	12.67 b
AVG + MAP		10.53 b	11.03 b	12.10 b
	Harvest + 3	7 + 3 day	14 + 3 day	21 + 3 day
Control	11.68 a	13.17 a	13.38 a	13.83 a
AVG	10.60 b	12.10 b	12.33 b	13.57 a
MAP		12.03 b	12.62 b	13.50 a
AVG + MAP		11.90 b	12.77 b	12.90 b

n = 9 for the SSC (three replicate × three different measurements for each replicate). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$

Table 8. Effect of MAP and AVG treatments on titratable acidity of '0900 Ziraat' sweet cherry fruit during cold storage and shelf life

Treatments	Titratable acidity (g malic acid 100 g^{-1})			
	Harvest	7 day	14 day	21 day
Control	1.13 b	1.12 b	1.05 b	0.99 b
AVG	1.34 a	1.24 a	1.19 a	1.09 a
MAP		1.22 a	1.16 a	1.11 a
AVG + MAP		1.26 a	1.14 a	1.12 a
	Harvest + 3	7 + 3 day	14 + 3 day	21 + 3 day
Control	1.08 b	1.06 b	1.01 b	0.91 b
AVG	1.32 a	1.16 a	1.14 a	1.07 a
MAP		1.16 a	1.11 a	1.03 a
AVG + MAP		1.22 a	1.13 a	1.05 a

n = 9 for the titratable acidity (three replicate × three different measurements for each replicate). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$

Table 9. Effect of MAP and AVG treatments on vitamin C of '0900 Ziraat' sweet cherry fruit during cold storage and shelf life

Treatments	Vitamin C (mg 100 g^{-1} fw)			
	Harvest	7 day	14 day	21 day
Control	10.17 b	8.30 c	7.80 c	7.03 b
AVG	11.30 a	9.93 b	8.57 b	7.22 b
MAP		10.30 b	8.56 b	7.13 b
AVG + MAP		11.27 a	9.82 a	8.77 a
	Harvest + 3	7 + 3 day	14 + 3 day	21 + 3 day
Control	11.87 b	11.00 c	10.48 b	8.38 c
AVG	13.83 a	11.27 c	10.77 b	9.87 b
MAP		12.80 b	10.52 b	9.47 b
AVG + MAP		13.53 a	11.60 a	10.93 a

n = 9 for the vitamin C (three replicate × three different measurements for each replicate). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$

Table 10. Effect of MAP and AVG treatments on total phenolics of '0900 Ziraat' sweet cherry fruit during cold storage and shelf life

Treatments	Total phenolics (µg GAE g^{-1} fw)			
	Harvest	7 day	14 day	21 day
Control	603.2 b	764.2 b	797.0 b	837.2 b
AVG	671.6 a	816.2 a	849.5 a	963.4 a
MAP		775.3 b	803.0 b	855.3 b
AVG + MAP		805.0 a	858.4 a	1001.8 a
	Harvest + 3	7 + 3 day	14 + 3 day	21 + 3 day
Control	803.4 b	849.1 b	853.2 b	914.1 b
AVG	841.8 a	976.8 a	999.6 a	1056.8 a
MAP		861.1 b	850.6 b	897.9 b
AVG + MAP		954.7 a	995.1 a	1031.4 a

n = 12 for the total phenolics (three replicate × four different measurements for each replicate). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$

Table 11. Effect of MAP and AVG treatments on total monomeric anthocyanin of '0900 Ziraat' sweet cherry fruit during cold storage and shelf life

Treatments	Total monomeric anthocyanin (µg cy-3-glu g^{-1} fw)			
	Harvest	7 day	14 day	21 day
Control	8.42 a	15.68 a	15.93 a	25.59 a
AVG	6.07 b	13.45 b	14.61 b	20.07 b
MAP		11.04 c	12.10 c	16.60 c
AVG + MAP		10.21 c	11.83 c	13.55 d
	Harvest + 3	7 + 3 day	14 + 3 day	21 + 3 day
Control	13.29 a	18.31 a	31.08 a	38.34 a
AVG	10.47 b	16.05 b	27.52 b	34.53 b
MAP		13.10 c	20.76 c	27.01 c
AVG + MAP		13.83 c	14.52 d	16.84 d

n = 12 for the total monomeric anthocyanin (three replicate × four different measurements for each replicate). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$

Table 12. Effect of MAP and AVG treatments on antioxidant activity (according to FRAP) of '0900 Ziraat' sweet cherry fruit during cold storage and shelf life

Treatments	FRAP (μmol TE g^{-1} fw)			
	Harvest	7 day	14 day	21 day
Control	1.66 b	1.93 b	2.04 b	2.23 b
AVG	1.88 a	2.31 a	2.53 a	2.90 a
MAP		1.95 b	2.58 a	2.97 a
AVG + MAP		2.23 a	2.76 a	3.24 a
	Harvest + 3	7 + 3 day	14 + 3 day	21 + 3 day
Control	1.90 b	2.02 b	2.72 b	3.09 b
AVG	2.12 a	2.57 a	3.19 a	3.37 a
MAP		2.15 b	2.79 b	3.06 b
AVG + MAP		2.86 a	3.23 a	3.42 a

n = 12 for the antioxidant activity according to FRAP (three replicate × four different measurements for each replicate). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$

Table 13. Effect of MAP and AVG treatments on antioxidant activity (according to TEAC) of '0900 Ziraat' sweet cherry fruit during cold storage and shelf life

Treatments	TEAC (μmol TE g^{-1} fw)			
	Harvest	7 day	14 day	21 day
Control	1.71 b	2.01 b	2.08 b	2.19 b
AVG	1.96 a	2.47 a	2.87 a	3.09 a
MAP		1.99 b	2.46 a	2.96 a
AVG + MAP		2.38 a	2.62 a	2.92 a
	Harvest + 3	7 + 3 day	14 + 3 day	21 + 3 day
Control	1.87 b	2.69 b	2.59 b	2.75 b
AVG	2.41 a	2.98 a	3.08 a	3.35 a
MAP		2.93 a	3.04 a	3.30 a
AVG + MAP		2.91 a	3.19 a	3.40 a

n = 12 for the antioxidant activity according to TEAC (three replicate × four different measurements for each replicate). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$

ments (throughout cold storage and shelf life), titratable acidity of all treatments were significantly higher than the control treatments (Tabs 7, 8).

Lower SSC and higher titretable acidity values than the control fruit at harvest may be resulted from ripening-retarding effect of AVG. Thusly, in a previous study, AVG suppressed ethylene production and retarded fruit ripening [Ozturk et al. 2012]. Just because of ripening-retarding effects of AVG and MAP, higher titretable acidity values were measured from AVG and MAP-treated fruit of the present study than from the control fruit during the cold storage and shelf life. Acidity decreases with the progress of ripening. Erkan and Eski [2012] in plums and Giacalone and Chiabrando [2013] in sweet cherry, reported that MAP treatments better maintained acidity of the fruit. Reduced respiration rates with MAP treatments might have also reduced the organic acid quantities used in respiration. Higher acidity levels of AVG and MAP-treated fruit can be explained with this process.

Vitamin C. Higher vitamin C contents were measured from AVG and MAP-treated fruit in the first two measurement periods of cold storage. In the last measurement period of the cold storage, only AVG + MAP treatments yielded significantly higher vitamin C contents than the control treatments. As compared to control treatments, significantly higher vitamin C contents were measured from MAP-treated fruit on 7th day shelf life measurements, from AVG + MAP-treated fruit on 14th day and from all treatments on 21st day measurements (Tab. 9).

A decrease can be observed in vitamin C contents of fresh fruit and vegetables during the cold storage. Serrano et al. [2006] indicated that such decreases in vitamin C contents could be reduced with MAP treatments. Similar findings were also observed in present study. Petriccione et al. [2015] reported that modified atmosphere created with chitosan coating prevented oxidation in sweet cherry and thus retarded loss in vitamin C contents. In present study, MAP treatments might have limited oxygen quantities converting ascorbic acid into dehydroascorbic acid.

Total phenolics, total monomeric anthocyanin and antioxidant activity. In measurements made at harvest, higher total phenolics and antioxidant activity and lower anthocyanin contents were measured from AVG-treated fruit than from the control fruit. In all measurements made throughout the cold storage and shelf life, significantly higher total phenolics were measured from AVG and AVG + MAP-treatments than the other treatments (Tab. 10). Anthocyanin contents were significantly lower in all treatments than the control treatments in measurements made throughout the cold storage and shelf life. MAP treatments significantly retarded anthocyanin accumulation (Tab. 11). In all cold storage and shelf life measurements, significantly higher FRAP and TEAC-based antioxidant activity levels were measured from all treatments than from the control treatments (except for MAP-treated fruit at harvest measurements) (Tabs 12, 13).

Total phenolics and total monomeric anthocyanin levels increased with the progress of ripening. Then, antioxidant activity of the fruit increased accordingly. Previous researchers also reported increased phenolic compounds during the cold storage [Goncalvez et al. 2004, Serrano et al. 2009]. As compared to control treatments, AVG treatments better maintained phenolic compounds during both the cold storage and shelf life. During the ripening of fruit, pectin chain width is shortened and pectin esterase and polygalacturonase enzyme activity increases [Yaman and Bayındırlı 2001]. AVG might have retarded ripening and thus slowed down these activities and consequently better maintained phenolic compounds. Similar effects were also observed in MAP-treated fruit. With the retarded ripening, anthocyanin pigment formation was also slowed down. Low oxygen and high carbon dioxide concentrations retarded the formation of PAL (phenylalanine ammonia-lyase), chalcone synthase and anthocyanin synthase enzymes, and consequently retarded anthocyanin formation [Guillen et al. 2013]. MAP might have these impacts. Similarly, Artes et al. [2006] also reported that MAP treatments retarded anthocyanin pigment formation.

There may be a positive relationship between phenolic compounds and antioxidant activity during the cold storage [Vieira et al. 2016]. Present findings support this idea. The loss in antioxidant activity was slowed down with retarded ripening in our study. Antioxidant activity of the fruit may vary based on storage conditions, fruit species and cultivars, processing conditions and ripening levels [Ramadan 2011]. Similar with the present findings, Serrano et al. [2009] reported that MAP treatments retarded the losses in

antioxidant activity. Higher antioxidant activity of AVG-treated fruit than the control fruit may be resulted from retarded ripening.

CONCLUSIONS

It was observed in present study that weight loss and decay ratios of '0900 Ziraat' sweet cherry could significantly be reduced with AVG and MAP treatments. It was determined that AVG and MAP treatments retarded ripening and slowed down red color formation. Although AVG treatments better maintained flesh firmness at harvest, such effects of AVG treatments were not observed during the cold storage and shelf life. Both AVG and MAP treatments retarded the losses in vitamin C, total phenolics, anthocyanin and antioxidant activity. It was concluded based on present findings that MAP and AVG could be used as a potential tool to maintain bioactive compounds of sweet cherry fruit.

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