

EFFECT OF PRE-HARVEST AMINOETHOXYVINYLGLYCINE (AVG) APPLICATION ON BIOACTIVE COMPOUNDS AND FRUIT QUALITY OF PLUM (*PRUNUS SALICINA* LINDELL CV. BLACK BEAUTY) AT THE TIME OF HARVEST AND DURING COLD STORAGE

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ABSTRACT

This study aimed at determining the effects of preharvest aminoethoxyvinylglycine (AVG) applications in different doses on the fruit quality of Black Beauty plum during cold storage. Plum trees were applied AVG doses (100 and 200 mgL⁻¹) two weeks before the estimated harvest date. Change in physical, mechanical, chemical and bioactive compounds in fruit samples were determined at weekly intervals. Applications of AVG delayed the parameters related with maturation such as weight loss, color and firmness during storage. At the end of 28 days, the least weight loss was with 200 mgL⁻¹ AVG application, while the highest weight loss (%) was in control treatment. While, the lowest fruit firmness (11.31 N) was recorded in control fruits, the highest (26.78 N) was obtained with 200 mgL⁻¹ AVG application. At the end of the storage duration, all applications were statistically similar in terms of TSSC value. The applications of AVG had a significant effect on the bioactive compounds of the fruits. Overall, both total phenolics and total antioxidant activity exhibited a linear decrease with increasing the storage duration regardless of AVG treatments. A similar decrease with storage was also observed in chlorogenic acid, epicatechin, catechin, caffeic acid, p-coumaric acid, quercetin. Naringenin displayed a significant decrease due to AVG applications during the cold storage.

Keywords: Antioxidant, cold storage, chlorogenic acid, firmness, phenolic, plum.

INTRODUCTION

Plum, a fruit exhibits a typical climacteric ripening behavior. Its quality characteristics vary considerably depending on the stage of harvest. As with other climacteric types, the softening in fruit flesh and the increase in TSSC (total soluble solids content) are the basic parameters indicating the start of maturation (Valero *et al.*, 2003; Jan and Rab, 2012). Excessive softening in plum fruit following harvest limits its market life (Skog *et al.*, 2003; Singh and Khan, 2010). Therefore, plums are kept in cold storage for 2 – 6 weeks to extend postharvest market life (Crisosto *et al.*, 1999; Skog *et al.*, 2003; Demir, 2010).

Producing quality fruits and extending the postharvest shelf life of fruits are among the basic goals of modern fruit growing. Postharvest softening in plums is an important factor limiting the storage span (Skog *et al.*, 2003). Presenting a quality product to market in line with consumer demand calls for the use of plant growth regulators in plum, a perishable fruit kind, so as to extend cold storage duration (Jobling *et al.*, 2003; Khan *et al.*, 2007). Cold storage of fruits and vegetables delays the changes associated with maturation such as softening in fruit flesh, pigment changes, increase in TSSC and decrease in acidity (Zhou *et al.*, 2001; Guerra and

Casquero, 2008). The applications of plant growth regulators such as AVG (1-methylcyclopropene), polyamines, methyl jasmonate, and salicylic acid have come into prominence to maintain the fruit quality under low temperatures for longer periods (Valero *et al.*, 2003; Khan and Singh, 2007; Diaz-Mula *et al.*, 2009; Luo *et al.*, 2009). Plant growth regulators are natural or synthetic compounds affecting one or more physiological events in a plant. AVG is an inhibitor of ethylene. A considerable amount of research has been carried out on ReTain, which is the commercial formulation of AVG, and it has become a product whose use in apple, pear, peach, plum and nectarines in many countries throughout the world was registered (Greene, 2005). AVG extends storage span of fruits by maintaining postharvest fruit firmness (Jobling *et al.*, 2003; Schupp and Greene, 2004).

Although there are many studies on quality parameters in plum, the change in bioactive compounds during harvest and storage has not been studied enough. Therefore, this study aimed at determining the effects of different doses of preharvest applied AVG in 'Black Beauty' plum variety on weight loss and color change, fruit firmness, total soluble solids content, total phenolics, total antioxidant activity and individual phenolics compounds.

MATERIALS AND METHODS

Materials: The study on the effects of aminoethoxyvinylglycine (AVG) on fruit quality characteristics and bioactive compounds at the time of harvest and during cold storage, was conducted at Research Station of Horticulture Department of Gaziosmanpa a University Agricultural Faculty (40° 20' 02.19"N x 36° 28' 30.11"E, 623 m above sea level). As the plant material, 5-years old 9 'Black Beauty' (*Prunus salicina* Lindell) trees grafted on myrobalan (*Prunus cerasifera* Ehrh.) rootstock and trained as modified leader system were selected. The experimental trees were planted with 4 x 4 m spacing. Experimental trees were grouped into 3 blocks with 3 trees in each block. Each AVG dose was applied to one tree in each block and one tree in each block was selected as control application (0 mgL⁻¹ AVG). The trees with homogeneous fruit load were selected for experiment.

In the study, ReTain (ValentBioScience Corp. Libertyville, III), which is an ethylene inhibitor, was used. ReTain (containing 150 mg aminoethoxyvinylglycine/g) was applied in two different doses (100 and 200 mgL⁻¹ AVG) two weeks before the estimated harvest date (75 days after full bloom). In the preparation of ReTain solution, 'Sylgard 309' surfactant [0.05%, v/v (DowCorning, Canada Inc, Toronto)] was used to reduce the surface tension and increase the effectiveness of the material applied to the plant. Only water (pH=6.48) + surfactant was used in control application (0 mgL⁻¹AVG). AVG was sprayed over trees early in the morning in a day without wind and precipitation. Volume of solution is significant to have the maximum impact of AVG over the fruit. Therefore, amount of solution to be applied was calculated by using the equation developed by researchers (Anonymous, 2011) and 1500 mL solution was sprayed to each tree. Shape (conical or spherical), height and row spacing were taken into consideration to calculate the amount of solution.

A total of 125 fruits were randomly harvested from the tree in each block for each application at the estimated harvest date (July 15, 2011), when the total soluble solids content and fruit firmness of 'Black Beauty' plum were 10% - 35 N, respectively. Of these fruits, 20 were used to determine the fruit quality characteristics (fruit firmness, TSSC) and 5 were used to determine bioactive compounds at the time of harvest. The remaining fruits were placed into cardboard boxes in single rows and transferred to cold storage with 0°C temperature and 90±5% relative humidity. Fruits were stored in cold storage for 4 weeks.

Methods: The harvested fruits were analyzed on the 7th, 14th, 21st, and 28th days (22, 29 July and 5, 12 August, 2011) to determine the changes in fruit quality parameters

and bioactive compounds. For each analysis period, 25 fruits were selected and 20 of them were used to determine the fruit quality characteristics (fruit firmness, TSSC) and 5 were used to determine bioactive compounds at relevant analysis day. Physical and mechanical measurements were performed right away on fruits taken out of cold storage. The fruits used for chemical and bioactive characteristics were kept at 21 °C for 6 hours at post-harvest physiology laboratory, and then the measurements and samplings were performed. Bioactive compounds were only investigated in fruit flesh.

Color characteristics and weight loss change of fruits during cold storage: To evaluate change of color characteristics (L*, C*, h°) and weight loss of plums, 50 fruits from each application were stored in cardboard boxes in single rows on harvest date. The weight loss and color changes of 50 fruits stored on the estimated harvest date were determined on the 7th, 14th, 21st and 28th days. The measurements determined during the storage were obtained from the same fruits. The fruit weight was determined with 0.01 g sensitive digital scale (Radvag PS 4500/C/1). Fruit stalks were cut off before the first measurement. The color characteristics were determined with a color meter (Minolta, model CR-400, Tokyo, Japan) from three different points over the equatorial section of fruit skin. The fruit skin color was determined to be CIE L*, a* and b* type.

Fruit firmness: The fruit skin was cut at two different points along the equatorial part of the fruit and the firmness was measured by using Effegi penetrometer (model FT-327; McCormick Fruit Tech, Yakima, WA) with 7.9 mm penetrating tip. The measurements were expressed in Newton (N/cm).

Chemical characteristic: A sample of juice was also taken from each piece of twenty fruit and the percentage total soluble solids content (%TSSC) was measured using a digital refractometer (PAL-1, McCormick Fruit Tech., Yakima, Wash).

Bioactive compounds: A total of 5 fruits for each tree were taken, washed with distilled water and mashed and kept at room temperature (21 °C) for 6 hours. The fruit samples were kept in 50 mL tubes under -20 °C temperatures for biochemical analysis until they were analyzed. A 1 gram sample was taken from each fruit and 5 mL methanol was added to each sample. The tests were performed at six hour intervals.

Total phenolics: A portion of 300 µL from each sample was diluted with 4.3 mL distilled water and 100 µL Folin-Ciocalteu reagents were added to each one. After an interval of 3 minutes, 2% Na₂CO₃ was added to 300 µL portions, underwent a vortex process and incubated for 30 minutes. Then, the absorbances were read on a

UV-VIS (PerkinElmer, Lambda-1050 spectrophotometer, California, USA) spectrophotometer device at 760 nm. Gallic acid was used as the standard. The results were expressed as mg Gallic acid equivalents (GAE)/g flesh weight.

Total antioxidant activity: *ABTS⁺ radical scavenging activity:* 2 mM of ABTS⁺ (2,2'-azino-bis (3-ethyl benzothiazoline-6-sulfonic acid) diammonium salt) and 2.45 mM of K₂S₂O₈ solutions were prepared by 0.1 M of PO₄³⁻ buffer solution (pH=7.4). The ABTS⁺ and K₂S₂O₈ solutions were mixed in (1:2) ABTS- K₂S₂O₈ and incubated for 6 hours in the dark. The absorbance of the mixture was read at 734 nm and it was diluted with PO₄³⁻ buffer if the value was greater than 0.75. Finally, 20 µL samples were taken out of the mixture into tubes, 1 mL of ABTS⁺ - K₂S₂O₈ solution was added to each and buffer solution was added to make the total sample volume 4 mL. Following a vortex process, they were incubated for 30 minutes and the absorbances were read at 734 nm. The results were expressed as µmol Trolox equivalent (TE) /g flesh weight.

Ferric ions (Fe⁺³) reducing antioxidant power assay (FRAP): Portions of 120 µL were taken out of the samples, 0.2 M of phosphate buffer (PO₄³⁻) (pH=6.6) was added to obtain a volume of 1.25 mL and then 1.25 mL of 1% potassium ferricyanide (K₃Fe(CN)₆) solution was added. After they underwent a vortex process, they were incubated at 50 °C. Afterwards, 1.25 mL of 10% TCA (Trichloro acetic acid) and 0.25 mL of 0.1% FeCl₃ were added to the samples. The absorbances of the resulting solution were read on an UV-VIS spectrometer at 700 nm. The results were expressed as µmol TE /g flesh weight.

Individual phenolics compounds

Instrumentation and conditions: A Perkin Elmer Series 200 liquid chromatography system (Perkin Elmer, USA) equipped with a quaternary solvent delivery system and UV detector was used at 280 nm. The analytes were separated on a Phenomenex Kromasil 100A C18 (250x4.60 mm, 5 µm) column. The column temperature was maintained at 26 °C using a water bath (Wisebath, WB-22, Korea). The mobile phase was consisted of acetonitrile (A) and water containing 2.5 % formic acid (B). The following gradient conditions were used: initial 0–3 min, held at A–B (5:95, v/v), 3–8 min, linear change from A–B (5:95, v/v) to A–B (10:90, v/v); 8–13 min, linear change from A–B (10:90, v/v) to A–B (15:85, v/v); and 13–15 min, isocratic elution A–B (15:85, v/v); 15–22 min, linear change from A–B (15:85, v/v) to A–B (25:75, v/v); 22–37 min, linear change from A–B (25:75, v/v) to A–B (50:50, v/v); 37–40 min, isocratic elution A–B (100:0, v/v). The mobile phase flow rate was set at 1 mL/min and the injection volume was 20 µL.

Preparation of standard solutions: Accurately weighed solid portions of each standard were dissolved in methanol to prepare stock solutions. Working solutions were obtained by diluting the stock solutions with methanol. The final mixed standard solution contained 100 µg/mL of each standard.

Sample preparation: All crude fruit samples were homogenated and 1000 mg slurry was accurately weighed and extracted with (5 mL) methanol in test tube for 6 hours. After the filtration over syringe type filter (Chromtech, 13 mm, 0.22 µm), the filtrate was injected into HPLC system for analysis. The results were expressed as mg/kg.

Statistical analysis: Experiments were performed using randomized complete-block design. All statistical analyses were performed with SAS. Data were analyzed by means of analysis of variance. Main effects and interactions were analyzed and means were compared by Duncan's multiple range tests at a significance level of 0.05.

RESULTS AND DISCUSSION

Color characteristics and weight loss change of fruits during cold storage: The weight loss (%) during the storage is presented in Figure 1. Both 100 and 200 mgL⁻¹ AVG applications significantly reduced the weight loss. At the end of cold storage period, weight loss obtained from control, 100 and 200 mgL⁻¹ AVG applications was found as 3.44%, 2.34% and 2.56%, respectively. Amarante *et al.* (2005) also reported that different doses of AVG applications in peach decreased weight loss in the fruit. The findings obtained from this study were consistent with findings that AVG applications reduced weight losses during storage by delaying the fruit maturation (Greene and Schupp, 2004; Rath and Prentice, 2004). Fruit texture determines the severity of weight loss and fruit texture is controlled by nutrition, genetic structure, pre-storage cultural practices (growth regulators and etc.) and fruit ripening level (Valero *et al.*, 2003; Yuan and Carbaugh, 2007; Casquero and Guerra, 2009). Krishna *et al.* (2012) stated that the preharvest use of growth regulators protected fruit texture during storage.

Fruit color is directly associated with the fruit quality that influence the commercial value of the fruit (Carreno *et al.*, 1995). L* and hue angle values approaching 0 (zero) in fruits with red skin color indicate an increase in red coloration (Diaz-Mula *et al.*, 2009). During cold storage, L*, chroma and hue angle values showed a decreasing trend. It has been reported that ripening and accumulation of peel color pigments (anthocyanins and carotenoids) might be retarded by inhibition of ethylene synthesis through AVG application in plum (Steffens *et al.*, 2011; Ozturk *et al.*, 2012), peaches

(Belding and Lokaj, 2002), apples (Whale *et al.*, 2008) and pears (Clayton *et al.*, 2000). In contrast to above findings, in this study, when compared to control, a significant effect of AVG applications on color parameters of Black Beauty plum fruits was not observed. This situation suggested that the effect of AVG on color development might be cultivars-dependent.

Fruit firmness: The fruit firmness declined to a great extent in all applications with increase in storage period (Table 1). The decrease in fruit firmness is a physiological behavior occurring during maturation on tree (Abbott, 1999). When compared to control fruit, AVG applications retarded flesh softening during storage. At the end of the storage period, a statistical difference was determined between AVG and control treatment. The highest values (26.78 N) were determined in 200 mgL⁻¹ AVG treatment, whereas the the lowest values (11.31 N) were obtained from control treatment. It was reported that AVG applications protected fruit firmness during storage (Rath and Prentice, 2004; Schupp and Greene, 2004). AVG delays fruit softening by inhibiting the production of ethylene. Thus, a positive correlation between fruit softening and ethylene production is commonly observed in many fruits (Khan and Singh, 2007). Ethylene caused fruit softening by increasing the activity of endo-polygalacturonase, exo-polygalacturonase, pectin esterase ve endo-1,4- -D-glucanase (Khan and Singh, 2010; Khan *et al.*, 2007). Noppakoonwong *et al.* (2005) reported that ReTain applications in peach increased fruit firmness 30-50 %. On the other hand, Rath and Prentice (2004) stated that ReTain applications in nectarines increased fruit firmness 7-58 % compared to that of control application.

Chemical characteristics: The TSSC value in fruits is presented in Table 1. Throughout the storage period, the TSSC did not show a significant change in control and 200 mgL⁻¹ AVG treatments. TSSC of fruit treated with 100 mgL⁻¹ AVG was lower than those of control and 200 mgL⁻¹AVG treatment at harvest time and on 7th, 14th and 21st day of storage. On the other hand, on 28th day of storage, TSSC of control and AVG- treated fruits were similar. Turk *et al.* (1995) stated that the TSSC value in plums increased considerably during storage. Usenik *et al.* (2008) reported that TSSC rate increased in different plum varieties during maturation period. In addition, Guerra and Casquero (2008) asserted that TSSC rate indicated an increase in Green Gage plums during storage. In this study, TSSC value showed a slight increase during storage period, but these increases did not find statistically significant.

Bioactive compounds: The bioactive contents of the plum fruits are presented in Table 2. Total phenolics (TP) decreased linearly in all treatment during storage period. At the end of the storage period, while the lowest TP value was obtained from 100 and 200 mgL⁻¹ AVG (0.42

mg GAE/g fw), the highest TP was obtained from the control application (0.45 mg GAE/g fw). However, the difference between teratments was found statistically insignificant.

According to both ABTS⁺ and FRAP test, linear decline occurred in total antioxidant activity (TAA) of control and AVG-terated fruits during the storage period. At harvest time, TAA of fruits treated AVG was higher than that of control fruits. On the other hand, at the end of the storage, TAA of all treatments was similar level.

In this study, TP and TAA of Black Beauty plum fruits showed a decreasing trend during storage period. This contradicts the reasults by Singh *et al.* (2012), Diaz-Mula *et al.* (2009) and Ozturk *et al.* (2012) that an increase was observed in total phenolics content in plums during maturation.

Earlier studies have reported that plums had significant amounts of antioxidant (Donovan *et al.*, 1998; Chun *et al.*, 2003). Phenolic acids and flavonoid compounds are basic phytochemicals associated with antioxidant activity (Cevallos-Casals *et al.*, 2006) and that the proportion of phenolic phytochemicals in plums are quite high (Stacewicz-Sapuntzakis *et al.*, 2001; Vinson *et al.*, 2001; Gil *et al.*, 2002; Kim *et al.*, 2003; Cevallos-Casals *et al.*, 2006). The plums were rich in chlorogenic acid (Fang *et al.*, 2002) and rutin was an important flavonol in plums (Chun *et al.*, 2003; Kim *et al.*, 2003). Similar results obtained from this study on Black Beauty plum.

When examining individual phenol changes during storage period, chlorogenic acid, caffeic acid, epicatechin, catechin quercetin and naringenin contents showed a linear decreasing, whereas ferulic acid, kaempferol and rutin contents linearly increased in both control and AVG treatments.

At harvest time and in the initial period of storage, AVG treatments caused significant differences in some individual phenol contents (Table 3). On the other hand, at the end of the storage, individual phenol contents of control and AVG treatment were similar, except for rutin, ferulic acid, naringenin and kaempferol. At this time, rutin content of fruit treated 100 mgL⁻¹ AVG was higher than those of control and 200 mgL⁻¹ AVG-terated fruits, and naringenin and kaempferol contents of AVG-treated fruit were lower relatively as compared to control.

Chemical compositions of fruits including phenolic compounds vary based on the variety, growth period, preferred root stock, nutrient contents, environmental conditions, cultural practices, ripening levels of fruits, time of harvest, post-harvest storage conditions and post-harvest fruit processing methods (Spanos and Wrolstad, 1990; Donovan *et al.*, 1998; Kim *et al.*, 2003; Scalzo *et al.*, 2005; Rato *et al.*, 2008). Thus, the analysis methods by different researchers may also yield different results for phenolic compounds (Valero and Serrano, 2010).

In conclusion, AVG applications retained significantly higher fruit firmness and, reduced weight loss during cold storage without significant changes in color development of fruit peel, total phenol and total

antioxidant activity at the end of the storage period. The results of this study showed that AVG can use to decrease quality losses occurring in the storage processes in Black Beauty plum fruits.

Table 1. The effect of AVG treatments on fruit firmness and TSSC of 'Black Beauty plum at the time of harvest and during cold storage. The difference between mean values shown on the same line with same capital letter is not significant. The difference between mean values shown on the same column with same lower letter is not significant (P<0.05)

Fruit Characteristics	Treatment	Analysis Time				
		Harvest	7 Day	14 Day	21 Day	28 Day
Fruit firmness (N)	0 mgL ⁻¹	32.57 A-a	29.07 B-b	26.42 B-b	18.44 C-b	11.31 D-b
	100 mgL ⁻¹	35.87 A-a	34.79 AB-ab	33.19 A-a	29.00 BC-a	24.76 C-a
	200 mgL ⁻¹	38.10 A-a	37.18 A-a	36.62 A-a	29.63 B-a	26.78 B-a
TSSC (%)	0 mgL ⁻¹	11.13 A-a	11.20 A-a	11.43 A-a	11.57 A-a	11.59 A-a
	100 mgL ⁻¹	9.67 B-b	9.80 B-b	10.17 B-b	10.40 B-b	11.53 A-a
	200 mgL ⁻¹	10.53 A-ab	10.73 A-ab	10.77 A-ab	11.13 A-ab	12.10 A-a

n= 3 replicates for TSSC (plum samples were taken from each of twenty fruit), and n=60 (twenty fruit x three replications) for fruit firmness.

Table 2. The effect of AVG treatments on total phenolic and total antioxidant activity of 'Black Beauty' plum at the time of harvest and during cold storage. The difference between mean values shown on the same line with same capital letter is not significant. The difference between mean values shown on the same column with same lower letter is not significant (P<0.05)

Bioactive compounds	Treatment	Analysis Time					
		Harvest	7 Day	14 Day	21 Day	28 Day	
Total phenolic (mg GAE/g fw)	0 mgL ⁻¹	2.78A-c	2.28B-a	1.77C-a	1.64C-a	0.45D-a	
	100 mgL ⁻¹	3.76A-b	1.95B-a	1.38B-b	1.35B-a	0.42C-a	
	200 mgL ⁻¹	4.57A-a	1.39B-b	1.35B-b	1.00B-b	0.42C-a	
Total antioxidant Activity (μmol TE/g fw)	ABTS ⁺	0 mgL ⁻¹	32.03A-a	27.49AB-a	26.41AB-a	24.92B-a	22.76B-a
	100 mgL ⁻¹	33.52A-ab	27.78B-a	27.35B-a	21.21C-a	20.06C-a	
	200 mgL ⁻¹	36.73A-b	20.76B-b	20.36B-b	20.31B-a	18.51C-a	
FRAP	0 mgL ⁻¹	4.05A-c	3.69A-a	2.43B-a	1.72C-a	1.57C-a	
	100 mgL ⁻¹	10.71A-a	2.96B-b	2.37BC-a	2.13C-a	1.40D-a	
	200 mgL ⁻¹	8.51A-b	2.49B-b	1.79C-a	1.74CD-a	1.09D-a	

n= 15 (five fruit x three replications) for total phenolic and total antioxidant activity.

Table 3. The effect of AVG treatments on individual phenolic compounds of 'Black Beauty' plum at the time of harvest and during cold storage. The difference between mean values shown on the same line with same capital letter is not significant. The difference between mean values shown on the same column with same lower letter is not significant (P<0.05)

Individual phenolics (mg/kg)	Treatment	Analysis Time				
		Harvest	7 Day	14 Day	21 Day	28 Day
Chlorogenic acid	0 mgL ⁻¹	35.5 A-a	24.6 B-a	22.5 B-a	12.6 C-a	11.1 C-a
	100 mgL ⁻¹	18.3 A-b	16.5 A-ab	15.4 A-ab	14.2 A-a	10.8 A-a
	200 mgL ⁻¹	24.0 A-b	14.9 B-b	12.1 B-b	11.3 B-a	11.2 B-a
Epicatechin	0 mgL ⁻¹	1.1 A-b	1.0 A-a	0.2 A-a	0.1 A-a	0.0 A-a
	100 mgL ⁻¹	5.7 A-a	1.2 B-a	1.2 B-a	0.1 B-a	0.0 B-a
	200 mgL ⁻¹	1.2 A-b	0.6 A-a	0.2 A-a	0.0 A-a	0.2 A-a
Caffeic acid	0 mgL ⁻¹	61.7 A-a	48.0 AB-a	26.7 B-a	26.0 B-a	23.6 B-a
	100 mgL ⁻¹	61.7 A-a	23.5 B-a	23.0 B-a	23.3 B-a	22.7 B-a
	200 mgL ⁻¹	26.7 A-b	26.2 A-a	24.2 A-a	22.7 A-a	22.6 A-a
Catechin	0 mgL ⁻¹	0.6 A-b	0.6 A-a	0.2 B-a	0.1 C-a	0.1 C-a
	100 mgL ⁻¹	0.8 A-a	0.4 B-b	0.3 C-a	0.2 D-a	0.2 D-a

	200 mgL ⁻¹	0.3 A-c	0.3 A-c	0.3 A-a	0.1 B-a	0.1 B-a
	0 mgL ⁻¹	26.7 A-a	25.3 AB-a	23.7 BC-a	23.3 BC-a	22.2 C-a
P-coumaric acid	100 mgL ⁻¹	22.7 A-b	22.7 A-b	23.1 B-a	23.1 B-a	23.4 B-a
	200 mgL ⁻¹	24.0 A-b	23.7 A-ab	22.6 A-a	22.6 A-a	22.3 A-a
	0 mgL ⁻¹	28.6 D-b	35.7 C-b	37.8 C-b	46.0 B-b	94.8 A-b
Rutin	100 mgL ⁻¹	41.7 D-a	46.6 D-a	56.0 C-a	74.0 B-a	106.0 A-a
	200 mgL ⁻¹	26.7 C-b	41.1 B-ab	43.0 B-b	47.4 AB-b	53.4 A-c
	0 mgL ⁻¹	22.5 D-b	77.9 C-a	90.5 B-c	175.2 A-a	175.5 A-a
Ferulic acid	100 mgL ⁻¹	24.7 D-b	81.5 C-a	102.1 B-b	103.9 B-c	154.8 A-b
	200 mgL ⁻¹	70.3 D-a	85.1 C-a	123.8 B-a	124.7 B-b	168.8 A-a
	0 mgL ⁻¹	66.8 A-a	65.6 A-a	45.0 B-a	21.9 C-a	21.5 C-a
Quercetin	100 mgL ⁻¹	35.7 A-c	34.6 A-b	35.1 A-b	20.6 B-a	20.2 B-a
	200 mgL ⁻¹	39.4 A-b	27.8 B-c	25.0 B-c	21.0 C-a	20.4 C-a
	0 mgL ⁻¹	25.9 A-a	23.3 B-a	21.1 C-a	21.3 C-a	35.8 D-a
Naringenin	100 mgL ⁻¹	24.7 A-a	19.2 B-b	18.9 BC-b	17.5 C-b	14.4 D-b
	200 mgL ⁻¹	19.7 A-b	19.4 AB-b	17.8 BC-b	17.5 C-b	14.5 D-b
	0 mgL ⁻¹	3.0 C-a	3.4 B-a	3.6 B-a	4.1 B-a	4.3 A-a
Kaempferol	100 mgL ⁻¹	3.0 B-a	3.1 B-a	3.2 B-b	3.2 B-b	3.6 A-b
	200 mgL ⁻¹	2.9 D-a	3.1 CD-a	3.2 BC-b	3.4 B-b	3.9 A-b

n= 15 (five fruit x three replications) for individual phenolic compounds.

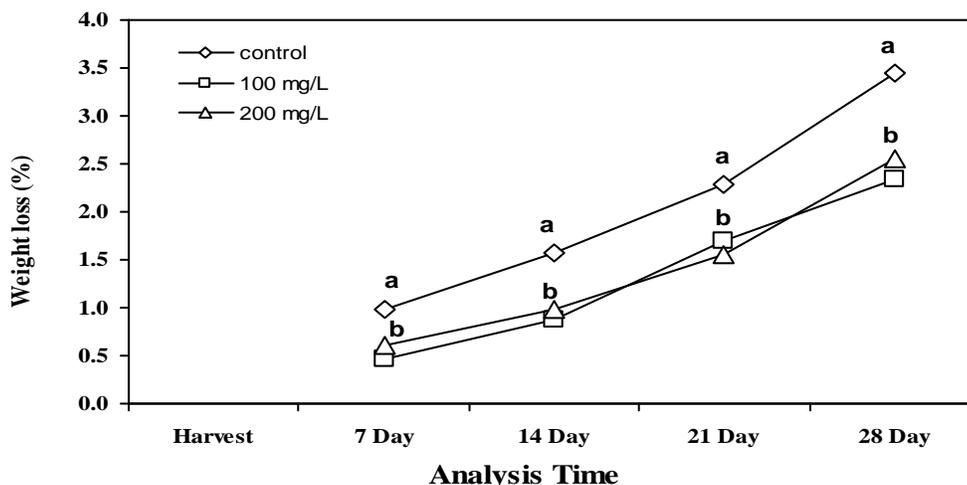


Fig. 1. Effect of AVG treatments on weight loss (%) of 'Black Beauty' plum during cold storage. Each value is mean of 50 fruit. The difference between mean percentage values shown different lower letter is significant (P<0.05)

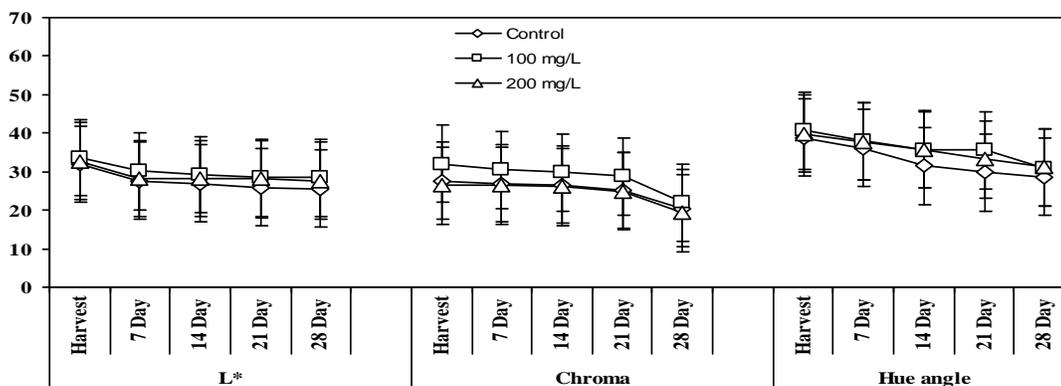


Fig. 2. Effect of AVG treatments on color characteristics (L*, C* and h°) change of 'Black Beauty' plums at the time of harvest and during cold storage. Each value is mean of 50 fruit. Vertical bars represent the LSD (P<0.05).

REFERENCES

- Abbott, J. A. (1999). Quality measurement of fruits and vegetables. *Postharvest Biol. Technol.* 15: 207-225.
- Amarante, C. V. T., A. M. F. Drehmer, F. Souza, and P. Francescato (2005). Preharvest spraying with gibberellic acid (GA3) and aminoethoxyvinylglycine (AVG) delays fruit maturity and reduces fruit losses on peaches. *Rev. Bras. Frutic.* 27: 1-5.
- Anonymous. (2011). Block-specific sprayer calibration worksheet. <http://www.umass.edu/fruitadvisor/clements/trvcalculator.html#1>. (accessed to web, February, 2011).
- Belding R. D. and G. R. W. Lokaj (2002). Aminoethoxyvinylglycine treatment of peach fruit reduces ethylene production and softening. *Hortscience.* 37: 1065-1068.
- Carreno, J., A. Martinez, L. Almela, and J. A. Fernandez-Lopez (1995). Proposal of an index for the objective evaluation of the colour of red table grapes. *Food Res. Int.* 28: 373-377.
- Casquero, P. A. and Guerra, M. (2009). Harvest parameters to optimise storage life of European plum 'Oullins Gage'. *Int. J. Food Sci. Technol.* 44: 2049-2054.
- Cevallos-Casals, B. A., D. Byrne, W. R. Okie, and L. Cisneros-Zevallos (2006). Selecting new peach and plum genotypes rich in phenolic compounds and enhanced functional properties. *Food Chem.* 96: 273-280.
- Chun, O. K., D. Kim, H. Y. Moon, H. G. Kang, and C. Y. Lee (2003). Contribution of individual polyphenolics to the total oxidant capacity of plums. *J. Agr. Food Chem.* 51: 7240-7245.
- Clayton, M., W. V. Biasi, S. M. Southwick, and E. J. Mitcham (2000). ReTain affects maturity and ripening of 'Bartlett' pear. *Hortscience.* 35: 1294-1299.
- Crisosto, C. H., F. G. Mitchel, and Z. Ju (1999). Susceptibility to chilling injury of peach, nectarine, and plum cultivars grown in California. *Hortscience.* 34: 1116-1118.
- Demir, A. (2010). The effects of different postharvest applications and different modified atmosphere packaging types on fruit quality of "Angelino" plums. M. Sc. Thesis (unpublished). Dept. of Hortic. Faculty of Agric., Canakkale Onsekiz Mart University.
- Diaz-Mula, H. M., P. J. Zapata, F. Guillen, D. Martínez-Romero, S. Castillo, M. Serrano, and D. Valero (2009). Changes in hydrophilic and lipophilic antioxidant activity and related bioactive compounds during postharvest storage of yellow and purple plum cultivars. *Postharvest Biol. Technol.* 51: 354-363.
- Donovan, J. L., A. S. Meyer, and A.L. Waterhouse (1998). Phenolic composition and antioxidant activity of prunes and prune juice (*Prunus domestica* L.). *J. Agr. Food Chem.* 46: 1247-1252.
- Fang, N., S. Yu, and R. L. Prior (2002). LC/MS/MS Characterization of phenolic constituents in dried plums. *J. Agr. Food. Chem.* 50: 3579-3585.
- Greene, D. W. and J.R. Schupp (2004). Effect of aminoethoxyvinylglycine (AVG) on preharvest drop, fruit quality, and maturation of 'McIntosh' apples. II. Effect of timing and concentration relationships and spray. *Hortscience.* 39: 1036-1041.
- Greene, D.W. (2005). Time of aminoethoxyvinylglycine application influences preharvest drop and fruit quality of 'McIntosh' apples. *Hortscience.* 40: 2056-2060.
- Gil, M. I., F. A. Tomas-Barberan, B. Hess-Pierce, and A. A. Kader (2002). Antioxidant capacities, phenolic compounds, carotenoids, and vitamin C contents of nectarine, peach, and plum cultivars from California. *J. Agr. Food Chem.* 50: 4976-4982.
- Guerra, M. and P. A. Casquero (2008). Effect of harvest date on cold storage and postharvest quality of plum cv. Green Gage. *Postharvest Biol. Technol.* 47: 325-332
- Jan, I. and A. Rab (2012). Influence of storage duration on physico-chemical changes in fruit of apple cultivars. *J. Anim. Plant Sci.* 22: 708-714.
- Jobling, J., R. Pradhan, S. Moris, L. Mitchell, and A. Rath, (2003). The effect of ReTain plant growth regulator on the postharvest storage life of Tegan Blue plums. *Aust. J. Exp. Agr.* 43: 515-519.
- Khan, A. S. and Z. Singh (2007). 1-MCP regulates ethylene biosynthesis and fruit opening during ripening of 'Tegan Blue' plum. *Postharvest Biol. Technol.* 43: 298-306.
- Khan, A. S. and Z. Singh, (2010). Pre-harvest application of putrescine influences Japanese plum fruit ripening and quality. *Food Sci. Tech. Int.* 16: 53-64.
- Khan, A. S., Z. Singh, and N. A. Abbasi (2007). Pre-storage putrescine application suppresses ethylene biosynthesis and retards softening during low temperature storage in 'Angelino' plum. *Postharvest Biol. Technol.* 46: 36-46.
- Kim, D. O., O. K. Chun, Y. J. Kim, H. Y. Moon and C. Y. Lee (2003). Quantification of polyphenolics and their antioxidant capacity of fresh plums. *J. Agr. Food Chem.* 51: 6509-6515.

- Krishna, H., B. Das, B. L. Attri, A. Kumar, and N. Ahmed (2012). Interaction between different pre and postharvest treatment on shelf life extension of Oregon Spur apple. *Fruits*. 67: 31-40.
- Luo, Z., J. Xie, T. Xu, and L. Zhang, (2009). Delay ripening of 'Qingnai' plum (*Prunus salicina* Lindl.) with 1-methylcyclopropene. *Plant Sci*. 177: 705-709.
- Noppakoonwong, U., P. Sripinta, A. C. Rath, A. P. George, and R. J. Nissen (2005). Effect of Retain and potassium chloride on peach fruit quality in the subtropical highlands of Thailand. Production technologies for low-chill temperate fruits. Reports from the Second International Workshop, 19-23 April, Chiang Mai, Thailand.
- Ozturk, B., E. Kucuker, S. Karaman, and Y. Ozkan (2012). The effect of cold storage and aminoethoxyvinylglycine (AVG) on bioactive compounds of plum (*Prunus salicina* Lindell cv. 'Black Amber'). *Postharvest Biol. Technol.* 72: 35-41.
- Rath, A.C. and A.J. Prentice (2004). Yield increase and higher flesh firmness of 'Arctic Snow' nectarines both at harvest in Australia and after export to Taiwan following pre-harvest application of retain plant growth regulator (aminoethoxyvinylglycine, AVG). *Austr. J. Exp. Agr.* 44: 343-351.
- Rato, A. E., Agulheiro, A. C. Barroso, J. M. and F. Riquelme (2008). Soil and rootstock influence on fruit quality of plums (*Prunus domestica* L.). *Sci. Hortic.* 118: 218-222.
- Scalzo, J., A. Politi, N. Pellegrini, B. Mezzeti, and M. Battino (2005). Plant genotype affects total antioxidant capacity and phenolic content in fruit. *Nutrition*. 21: 207-213.
- Schupp, J.R. and D.W. Greene (2004). Effect of aminoethoxyvinylglycine (AVG) on preharvest drop, fruit quality and maturation of 'McIntosh' apples. I. concentration and timing of dilute applications of AVG. *Hortscience*. 39: 1030-1035.
- Singh, Z. and A. S. Khan (2010). Physiology of plum fruit ripening. *Stewart Posthar. Rev.* 2: 3.
- Singh, S. P., Z. Singh, and E.E. Swinny (2012). Climacteric level during fruit ripening influences lipid peroxidation and enzymatic and non-enzymatic antioxidative systems in Japanese plums (*Prunus salicina* Lindl.). *Postharvest Biol. Technol.* 65: 22-32.
- Spanos, G.A. and R.E. Wrolstad (1990). Influence of processing and storage on the phenolic composition of Thompson seedless grape juice. *J. Agric. Food Chem.* 38: 1565-1571.
- Stacewicz-Sapuntzakis, M., P. E. Bowen, E. A. Hussain, B. I. Damayanti-Wood, and N. R. Farnsworth (2001). Chemical composition and potential health effects of prunes: a functional food? *Crit. Rev. Food Sci.* 41: 251-286.
- Steffens, C. A., C. V. Talamini do Amarante, R. Chechi, O. Z. Zanardi, B. P. Espindola, and A. L. Meneghini (2011). Preharvest spraying with aminoethoxyvinylglycine or gibberelic acid improves postharvest fruit quality of "Laetitia" plums. *Bragantia*. 70: 222-227.
- Skog, L. J., B.H. Schaefer, and P. G. Smith (2003). Effect of ripeness at harvest on response of plum to treatment with 1-methylcyclopropene. *Acta Hortic.* 599: 49-52.
- Turk, R., K. Kocak, and B. Akbudak (1995). The effect of modified atmosphere on storage period in plums. II National Horticulture Congress. 3-6 September, 1995, pp. 203-208, Adana, Turkey.
- Usenik, V., D. Kastelec, R. Veberic, and F. Stampar (2008). Quality changes during ripening of plums (*Prunus domestica* L.). *Food Chem.* 111: 830-836
- Valero, D., Martinez-Romeroa, D., Valverde, J. M., Guillen, F. and Serrano, M. (2003). Quality improvement and extension of shelf life by 1-methylcyclopropene in plum as affected by ripening stage at harvest. *Innov. Food Sci. Emerg.* 4: 339-348.
- Valero, D. and M. Serrano (2010). Postharvest biology and technology for preserving fruit quality. CRC-Taylor & Francis, Boca Raton, pp. 269.
- Vinson, J. A., X. Su, L. Zubik, and P. Bose, (2001). Phenol antioxidant quantity and quality in foods: *Fruits. J. Agr. Food Chem.* 49: 5315-5321.
- Whale, S. K., Z. Singh, M. H. Behboudian, J. Janes, and S. S. Dhaliwal (2008). Fruit quality in "Cripp's Pink" apple, especially colour, as affected by preharvest sprays of aminoethoxyvinylglycine and ethephon. *Sci Hortic.* 115: 342-351.
- Yuan, R. and D. H. Carbaugh (2007). Effects of NAA, AVG and 1-MCP on ethylene biosynthesis, preharvest fruit drop, fruit maturity and quality of 'Golden Supreme' and 'Golden Delicious' apples. *Hortscience*. 42: 101-105.
- Zhou, H. W., L. Dong, A. R. Ben, and S. Lurie (2001). The role of ethylene in prevention of chilling injury in nectarines. *J. Plant Physiol.* 158: 55-61.