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RESEARCHARTICLE

Effects of aminoethoxyvinylglycine and modified atmosphere packaging treatments on the color characteristics and antioxidant activity of kiwifruit during cold storage and shelf life

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ABSTRACT

This study was carried out to determine the effects of postharvest aminoethoxyvinylglycine (AVG) and modified atmosphere packaging (MAP) treatments on color characteristics and antioxidant activity of kiwifruit (*Actinidia deliciosa* L.) fruit during cold storage and shelf life. Control, AVG, MAP, and AVG+MAP treatments were designed in the study. During the study, L *, chroma, and hue angles were determined in terms of color characteristics of fruits. Also, the FRAP assay was applied to determine antioxidant activity. L* values (on 60th, 90th, and 120th days) and chroma values (on 120th and 150th days) were higher than the control in cold storage. In shelf life, L* values (90th and 180th days) and chroma values (on 90th, 120th, and 150th days) in all treatments were higher than the control. During cold storage (except for 30th day), higher hue angle values were obtained from fruit treated with MAP. In the last two measurements period of shelf life, the lowest hue angle values were determined in control fruit. At the end of cold storage, the highest antioxidant activity was obtained in AVG treatment. During shelf life, antioxidant activity was higher in AVG and MAP treatments than the control. In the study, it was revealed that the MAP treatment was especially effective in color development, but more effective results were obtained from the combination of MAP and AVG. Also, it was revealed that the AVG and MAP treatments could be used to maintain antioxidant activity.

Keywords: *Actinidia deliciosa*, antioxidant, chroma, FRAP, hue angle.

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INTRODUCTION

Kiwifruit (*Actinidia deliciosa* L.), which is liked and preferred by the consumer due to the vitamins (especially vitamin C), minerals, and antioxidant content in its structure, is a popular climacteric fruit species that rising the importance in Turkey. Therefore, the production amount of this fruit species has increased, in line with the increasing consumer demands, day by day in our country. According to the Turkish Statistical Institute (TUIK) data in 2019, Turkey's kiwifruit production amount increased by 140.26% in the last 10 years and reached 63.798 tons (TUIK, 2020).

The climacteric feature of kiwifruit reveals quality losses as the fruit continues to ripen in the post-harvest period. Especially, given the increasing demand of the consumers for the fruits with high quality, long shelf-life, and preserving the natural

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appearance (Guilbert et al., 1996), it becomes increasingly important to prevent the quality losses that occur in the post-harvest period as much as possible. Avoiding the post-harvest losses can be delayed with different treatments such as calcium treatment, polyamines, 1-methylcyclopropene, coating, hot water treatment, and low temperature conditioning etc. (Meena et al., 2018) and can help the fruit to be marketed for a longer period (Kader, 2013; Ozturk et al., 2019a; Ozturk et al., 2021).

Aminoethoxyvinylglycine (AVG), which is a developmental regulator, has been used by researchers as a retardant of ethylene synthesis in recent years and it is known that pre-harvest and post-harvest treatments of AVG have a positive effect on yield and quality in many climacteric fruits species (Amarante et al., 2002; Ozturk et al., 2019b). Modified atmosphere packaging (MAP) technology restricts the gas permeability, arranges the amount of O_2 and CO_2 in the package, reducing the respiration rate and ethylene production rate, so extending the post-harvest life and maintain the quality of fruits and vegetables (Kader et al., 1989; Elik et al., 2019; Koc Guler et al., 2019; Ozturk and Ozer, 2019). It has been determined that the AVG and MAP treatments in fruit species nectarine (Özkaya et al., 2016), pear (Butar and Çetinbaş, 2017), pomegranate (Candir et al. 2018), cheries (Yıldız et al. 2018; Ozturk et al., 2019b), apple (Doerflinger et al., 2019; Ozturk et al., 2019c), kiwifruit (Ozturk et al. 2019d) have reduced the postharvest loses. Therefore, it was aimed to determine the separate and combined effects of AVG and MAP on the color properties and antioxidant activity of kiwifruit during cold storage and shelf life in this study.

MATERIALS AND METHODS

Plant Materials

In this research, the kiwifruit (*Actinidia deliciosa* cv. 'Hayward') examined were obtained from a producer orchard where located in Kayabaşı district of Altınordu, Ordu province. The fruit was harvested in November when the soluble solids content (SCC) was 6.5%.

Methods

Firstly, the fruit harvested was quickly transported to the laboratory and divided into two groups. The fruits in the first group was treated with AVG solution ['ReTain' (containing 15% AVG), Valent BioSciences Crop, USA] by dipped in 225 mg L^{-1} (2 min), while the fruits in the second group was treated with pure water only (2 min). Then, the fruit was left for dry for an hour under room conditions. After that, treatments were designed as control (non-treated fruit), AVG (only treated with AVG), MAP (Xtend®, StePac, Israel) (only treated with MAP), and AVG+MAP (treated with AVG and MAP combination).

Initially, the harvest period analyzes were done without any delay in the laboratory. Then 18 plastic boxes, which have 20 kiwifruits for each treatment, were prepared for cold storage period. Three of these boxes were used for each analyzes period and each one represented a replication. While half of the kiwifruit in the box was used for cold storage analyzes, the remainders were used for shelf life analyzes. Before the cold storage, all kiwifruit subjected to pre-cooling until the pulp temperature drops to 1.0°C at 90 ± 5% RH. After, the boxes were placed in cold storage (0.0 ± 0.5 °C and 90 ± 5% RH) for 6 months. The cold storage analyzes were performed at 30 days intervals. And the shelf life analyzes were performed after 5 days that kiwifruit was kept at room temperature (21 °C and 65 ± 5% RH).

Color characteristics

Skin and flesh color characteristics of kiwifruit were determined by a colorimeter (Minolta, model CR–400, Tokyo, Japan) as CIE (Commission Internationale de l'Eclairage) L*, a* and b*. Measurements were performed in five fruit each replicate. Chroma and hue angle values were calculated according to $C^*=(a^{*2}+b^{*2})^{1/2}$, $h^\circ = \tan^{-1} \times b^*/a^*$ formulas (Ozer, 2017; Alagöz et al., 2020).

FRAP assay (Ferric ions (Fe^{+3}) reducing antioxidant power assay)

The antioxidant activity of kiwifruit was determined according to Benzie and Strain (1996). Firstly, kiwifruit was sliced and homogenized by a blender, then it was centrifuged (12.000 × g) at 4 °C for 30 min. 120 µL of prepared fruit juice was put into the tubes and completed to 1.25 mL with 0.2 M, pH 6.6 phosphate buffer (PO_4^{-3}). Then 1.25 mL of 1% potassium ferricyanide ($K_3Fe(CN)_6$) solution was added to the samples and vortexed. Tubes were incubated at 50 °C for 20 min. After incubation 1.25 mL of 10% TCA (trichloroacetic acid) and 0.25 mL of 0.1% $FeCl_3$ were added. The absorbance values of the prepared solution at 700 nm was read in the UV-VIS spectrophotometer.

Statistical Analysis

The experiment was performed according to the completely randomized design. SAS Version 9.1 (SAS Institute Inc., Cary, NC, USA) was used in statistical analysis. Data were analyzed by one-way analysis of variance (ANOVA) followed by Tukey's test ($p < 0.05$).

RESULTS AND DISCUSSION

The L* value is a measure of the lightness of an object (Lee et al., 2010). The decrease in the L* value generally refers to the state of blackening on the surface of fruit (Beirao-da-Costa et al., 2006). Fattahi et al. (2010) reported that the decrease in L* value represents the dark color due to the oxidative browning reaction or the increase in brown pigment concentration.

Table 1: Effects of MAP and AVG Treatment On L* Values of Skin of Kiwifruit During Cold Storage and Shelf Life

Treatments	L* (skin)						
	Cold storage (0 °C)						
	Harvest	30	60	90	120	150	180
Control	62.34 a	60.52 a	58.19 b	57.45 b	56.10 b	55.38 b	51.28 a
AVG	62.34 a	60.03 a	59.85 a	59.05 a	57.36 a	56.51 a	50.82 a
MAP	62.34 a	60.68 a	59.17 a	58.36 a	57.83 a	55.35 b	50.86 a
AVG+MAP	62.34 a	60.75 a	59.40 a	58.94 a	57.33 a	55.25 b	50.80 a
	Shelf life (21 °C)						
	Harvest+5	30+5	60+5	90+5	120+5	150+5	180+5
Control	61.26 a	57.50 a	56.85 b	55.80 b	55.36 b	55.14 b	44.46 b
AVG	61.26 a	58.87 a	57.98 a	56.86 a	55.54 b	55.40 b	47.32 a
MAP	61.26 a	57.59 a	56.98 b	56.86 a	56.78 a	56.32 a	47.96 a
AVG+MAP	61.26 a	58.51 a	56.99 b	56.64 a	55.49 b	55.29 b	48.09 a

n = 60 for the L* (three replications x ten fruits x 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 study, the L* value in both fruit skin and fruit flesh of kiwifruit was decreased in cold storage and shelf life measurements. On the 60th, 90th, and 120th days measurements of this study, it was found that the L* value in the fruit skin of AVG and MAP treated fruit was higher than the control. But the difference between them in the 180th day measurement was

found to be insignificant. In contrast, the L* value of the skin of AVG and MAP treated fruit was significantly higher than control on the 180th day of shelf life measurements (Table 1). In the AVG and MAP treated kiwifruit, the L* (flesh) value in the first 4 months analyzes period of the cold storage was higher than the control. However, according to measurements that were made on the last day of cold storage, the L* value of the only MAP and AVG+MAP treated fruit was higher than the control. Similarly, the effects of only MAP and AVG+MAP treatments on the L* of fruit flesh were found to be significant at the end of shelf life analyzes (Table 2).

Table 2: Effects of MAP and AVG Treatment On L* Values of Flesh of Kiwifruit During Cold Storage and Shelf Life

Treatments	L* (flesh)						
	Cold storage (0 °C)						
	Harvest	30	60	90	120	150	180
Control	79.18 a	76.54 b	73.31 b	71. 90 b	69.63 b	69.18 b	67.57 b
AVG	79.18 a	77.79 a	75.06 a	73.72 a	71.35 a	71.21 a	67.72 b
MAP	79.18 a	77.30 a	74.49 a	73.19 a	71.50 a	69.14 b	69.06 a
AVG+MAP	79.18 a	77.49 a	74.98 a	73.62 a	71.90 a	69.57 b	69.71 a
	Shelf life (21 °C)						
	Harvest+5	30+5	60+5	90+5	120+5	150+5	180+5
Control	77.44 a	75.71 a	72.36 b	71.10 b	69.09 b	67.00 b	66.20 b
AVG	77.44 a	76.45 a	73.99 a	72.62 a	71.09 a	69.08 a	66.01 b
MAP	77.44 a	75.69 a	73.49 a	73.22 a	69.58 b	68.62 a	67.69 a
AVG+MAP	77.44 a	75.88 a	73.26 a	72.62 a	66.38 b	69.28 a	67.98 a

n = 60 for the L* (three replications x ten fruits x 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.

Chroma value (C*) refers to the saturation of the color. And it describes the vividness or dullness of a color. As can be seen in Table 3, the chroma value of kiwifruit skin decreased during the research. On the 120th and 150th days analyzes of cold storage and shelf life, AVG and MAP treated fruit was higher than control. But 180th day, the differences between them were statistically insignificant. The chroma values of fruit flesh also decreased during the cold storage and shelf life analyzes (Table 4). Generally, the differences between the AVG and MAP treatments and control were not statistically significant.

In almost all cold storage analyzes periods, the hue angle of MAP treated kiwifruit skin was higher values than only AVG treated fruit and control (Table 5). Also, the shelf life measurements from the 90th day with AVG and MAP treated kiwifruit were higher values than the control in terms of the hue angle. According to the measurements that were made on the flesh of kiwifruit, the hue angle of the fruits treated with the MAP was determined to maintain significant levels compared to the only AVG treated fruits and the control during the cold storage (Table 6). In the shelf life, while the difference between treatments and control was not significant during the first three analyzes period. Conversely, the hue angle was found to be significantly higher in MAP and AVG+MAP treated fruits in the last three analyze period.

The color of fruits and vegetables is controlled by natural pigments in their structure, and changes may occur with the maturation period (Barrett et al., 2010). In addition, the color formation has seen as a quality indicator in foods (Hutchings et al., 2012), and

it affects consumer preference in many fruit types. Generally, in the study, it was seen that MAP treatments had a retarding effect on color development in kiwifruit, but the effect of AVG was found insignificant.

Table 3: Effects of MAP and AVG Treatment On Chroma Values of Skin of Kiwifruit During Cold Storage and Shelf Life

Treatments	Chroma (skin)						
	Cold storage (0 °C)						
	Harvest	30	60	90	120	150	180
Control	41.80 a	38.79 b	35.42 b	34.44 a	32.68 b	30.25 b	29.26 a
AVG	41.80 a	38.35 b	35.92 b	34.75 a	33.92 a	31.68 a	29.30 a
MAP	41.80 a	40.49 a	37.31 a	34.41 a	33.73 a	31.43 a	29.09 a
AVG+MAP	41.80 a	38.76 b	36.86 a	33.65 a	33.33 a	31.53 a	29.67 a
	Shelf life (21 °C)						
	Harvest+5	30+5	60+5	90+5	120+5	150+5	180+5
Control	41.61 a	38.64 a	33.53 b	31.14 b	30.91 b	30.12 b	26.35 a
AVG	41.61 a	37.19 a	34.83 b	33.02 a	32.31 a	32.11 a	26.30 a
MAP	41.61 a	37.56 a	36.79 a	33.44 a	32.69 a	31.98 a	26.15 a
AVG+MAP	41.61 a	37.69 a	36.13 a	33.23 a	32.75 a	31.80 a	25.91 a

n = 60 for the chroma (three replications x ten fruits x 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 4: Effects of MAP and AVG Treatment On Chroma Values of Flesh of Kiwifruit During Cold Storage and Shelf Life

Treatments	Chroma (flesh)						
	Cold storage (0 °C)						
	Harvest	30	60	90	120	150	180
Control	30.89 a	30.16 a	29.50 a	28.76 a	28.58 a	26.84 a	26.34 a
AVG	30.89 a	30.07 a	29.71 a	28.65 a	28.60 a	27.18 a	26.42 a
MAP	30.89 a	30.18 a	29.70 a	28.55 a	27.57 b	26.80 a	25.86 a
AVG+MAP	30.89 a	30.15 a	30.00 a	28.40 a	27.23 b	25.96 a	25.85 a
	Shelf life (21 °C)						
	Harvest+5	30+5	60+5	90+5	120+5	150+5	180+5
Control	30.45 a	29.27 a	28.85 a	28.36 a	27.77 a	26.59 a	25.91 a
AVG	30.45 a	29.14 a	28.89 a	28.11 a	27.78 a	26.40 a	24.92 a
MAP	30.45 a	29.87 a	29.47 a	28.44 a	27.31 a	27.08 a	25.04 a
AVG+MAP	30.45 a	29.08 a	28.66 a	28.01 a	26.53 b	25.23 b	25.07 a

n = 60 for the chroma (three replications x ten fruits x 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: Effects of MAP and AVG Treatment On Hue Angle of Skin of Kiwifruit During Cold Storage and Shelf Life

Treatments	Hue angle (skin)						
	Cold storage (0 °C)						
	Harvest	30	60	90	120	150	180
Control	115.8 a	115.3 a	114.3 b	113.8 b	113.2 b	112.9 b	112.6 b
AVG	115.8 a	114.6 b	114.4 b	113.2 b	113.6 b	112.7 b	112.5 b
MAP	115.8 a	115.6 a	115.0 a	114.9 a	114.6 a	113.8 a	113.1 a
AVG+MAP	115.8 a	115.6 a	115.1 a	114.8 a	114.7 a	114.3 a	113.4 a
	Shelf life (21 °C)						
	Harvest+5	30+5	60+5	90+5	120+5	150+5	180+5
Control	115.1 a	114.1 a	113.1 a	111.3 b	109.8 b	106.8 b	106.2 b
AVG	115.1 a	113.0 b	112.9 a	112.5 a	109.9 b	109.7 a	109.1 a
MAP	115.1 a	113.4 b	112.8 a	112.2 a	111.8 a	110.6 a	110.2 a
AVG+MAP	115.1 a	113.2 b	113.1 a	112.3 a	111.3 a	110.7 a	110.1 a

n = 60 for the hue angle (three replications x ten fruits x 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: Effects of MAP and AVG Treatment On Hue Angle of Flesh of Kiwifruit During Cold Storage and Shelf Life

Treatments	Hue angle (flesh)						
	Cold storage (0 °C)						
	Harvest	30	60	90	120	150	180
Control	110.5 a	108.9 b	108.5 b	107.4 b	107.0 b	106.4 b	106.3 b
AVG	110.5 a	108.9 b	108.3 b	107.9 b	107.4 b	106.2 b	105.9 b
MAP	110.5 a	109.7 a	109.3 a	109.1 a	108.7 a	107.9 a	107.6 a
AVG+MAP	110.5 a	109.8 a	109.0 a	108.9 a	108.5 a	107.6 a	107.4 a
	Shelf life (21 °C)						
	Harvest+5	30+5	60+5	90+5	120+5	150+5	180+5
Control	109.0 a	108.3 a	107.6 a	107.1 a	106.6 b	106.2 b	106.0 b
AVG	109.0 a	107.9 a	107.6 a	106.8 a	106.2 b	105.9 b	105.6 b
MAP	109.0 a	108.2 a	107.8 a	107.5 a	107.4 a	107.3 a	107.1 a
AVG+MAP	109.0 a	108.7 a	108.3 a	107.7 a	107.6 a	107.5 a	107.4 a

n = 60 for the hue angle (three replications x ten fruits x 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.

However, more successful results were obtained with the AVG+MAP combination for delaying the color development in our study. The effects of AVG and MAP treatments on fruit coloring have been determined in different studies. Aglar et al. (2017), reported that the MAP treatments retarded the color development during cold storage and shelf life period in sweet cherry, and

Ali et al. (2019)**,** reported that MAP treatments delayed enzymatic browning at litchi fruit. Also, it has been stated that AVG delays fruit coloration **(**Wang and Dilley, 2001; Butar and Çetinbaş, 2017**)**. As with other researchers, similar results were obtained with MAP treatment, but the effect of AVG was limited in our study. This may be because of the effect of AVG varies in fruit species and cultivars. As in our research findings, Ozturk et al. (2019d), reported that the only AVG treatment did not have a significant effect on fruit quality in kiwifruit.

Table 7: Effects of MAP and AVG Treatment On Antioxidant Activity of Kiwifruit During Cold Storage and Shelf Life

Treatments	Antioxidant Activity (mmol TE kg^{-1})						
	Cold storage (0 °C)						
	Harvest	30	60	90	120	150	180
Control	14.10 a	12.32 b	11.05 b	10.54 b	9.97 b	9.77 b	8.33 b
AVG	14.10 a	13.49 a	11.90 a	11.12 a	10.95 a	10.58 a	9.59 a
MAP	14.10 a	13.19 a	11.95 a	11.40 a	11.16 a	9.75 b	8.28 b
AVG+MAP	14.10 a	13.60 a	12.22 a	11.38 a	11.02 a	9.87 b	8.40 b
	Shelf life (21 °C)						
	Harvest+5	30+5	60+5	90+5	120+5	150+5	180+5
Control	13.12 a	11.19 b	10.15 b	9.98 b	8.86 b	7.91 b	4.47 b
AVG	13.12 a	12.73 a	11.57 a	10.75 a	10.19 a	8.63 a	6.45 a
MAP	13.12 a	12.50 a	11.81 a	10.82 a	10.25 a	8.44 a	6.33 a
AVG+MAP	13.12 a	12.62 a	11.76 a	10.97 a	10.07 a	8.97 a	6.21 a

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

The antioxidant activity found in fruits has effects such as scavenging free radicals, preventing cardiovascular diseases and cancer in the human body (Griffiths et al. 2016; Suleman et al. 2019). Therefore, it is very important the preserving the antioxidant level of fruit during the storage period (Sharma et al. 2017). During the study, it was observed that the antioxidant activity of kiwifruit decreased in the measurement days. However, from the harvest to the 120th day of cold storage, antioxidant activity was higher in treated fruit than control. On the 150th and 180th days, only AVG treated fruit has the highest antioxidant activity. In all shelf life analyzes period, all treated kiwifruit has a significant difference against the control (Table 7). This may have been caused by the retarding effect of fruit ripening during the cold storage of AVG and MAP treatments. Similarly, Ozturk et al. (2019d), reported that AVG and MAP treatments in kiwifruit have a positive effect on antioxidant activity during the cold storage and shelf life.

CONCLUSION

As a results, the effects of AVG and MAP treatments on the color development and antioxidant activity of kiwifruit kept in the cold storage for 180 days in the study period were determined. It was observed that the color and antioxidant activity of the kiwifruit changed as the storage period increased. The results obtained showed that MAP treatment had a significant effect on the delay of color formation. However, it was seen that MAP treatment gave more effective results in combination with AVG. In

the study, it was also determined that AVG and MAP treatments can be used effectively for maintaining the antioxidant activity in kiwifruit.

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