Journal of Postharvest Technology
2022, **10**(1): 12-18
www.jpht.in

RESEARCHARTICLE

Pre-harvest aminoethoxy vinylglycine (AVG) spray maintains fruit quality of apples (*Malus cominnus* L. cv. Red Chief) during cold storage

Emine Kucuker[1], Erdal Aglar[2*]

[1]Siirt University, Faculty of Agriculture, Department of Horticulture, Siirt-Turkey
[2]Van Yuzuncu Yil University, Faculty of Agriculture, Department of Horticulture, Van-Turkey

Received: 10.10.2021 Accepted: 02.01.2022

ABSTRACT

In the study, the effect of AVG application at different concentrations on the post-harvest fruit quality of apple cultivar (*Malus cominnus L.* cv. Red Chief) was investigated. The study consisted of four applications, 75, 150 and 225 mg/ L^{-1} AVG and control. AVG was applied 4 weeks before anticipated harvest. The effect of AVG application on fruit size was inconsistent. 225 mg L^{-1} dose application increased fruit size while the smaller fruit were harvested on the tress applied 75 mg L^{-1} AVG. It was determined that the weight losses during storage decreased with AVG application. The more firmness fruit were harvested with 125 mg L^{-1}AVG application while there was no significant difference in terms of fruit firmness between other applications. The fruit firmness decreased in proportion to the cold storage period while the highest loss of fruit firmness was recorded with the control application. In the study, fruit with higher acidity but lower Solible Solids Content (SSC) ratio were harvested with AVG application. However, the effect of AVG concentration on titratable acidity and SSC ratio of the fruit was not significant. Depending on the cold storage period, the SSC ratio in the fruit increased while the titratable acidity ratio decreased. There was no difference between the applications in the decrease in the titratable acidity ratio during cold storage. However, it was determined that the ratio of SSC in AVG-applied fruit was lower than the control, but the application dose was not effective.

Keywords: *Malus cominnus* L., Weight loss, acidity, fruit size, fruit firmness

Citation: Kucuker, E., and Aglar, E. 2022. Pre-harvest aminoethoxy vinylglycine (AVG) spray maintains fruit quality of apples (*Malus cominnus* L. cv. Red Chief) during cold storage. *Journal of Postharvest Technology*, **10**(1): 12-18.

INTRODUCTION

In apple, which is a climacteric fruit type, the physiological and structural changes such as softening of the cortex, starch hydrolysis, chlorophyll degradation, and colour changes occur during ripening (Mattheis et al., 1991). In apples, the increase in SSC, loss of acidity and formation of volatile compounds such as aldehydes, alcohols and esters during ripening and storage significantly affect the sensory quality of the fruit. Ethylene, which is effective in all these changes that occur in the ripening and storage processes and is known as the ripening hormone, accelerates the softening, unwanted colour changes and deterioration processes in apples during storage, thus it limits the storage and post-harvest life of the fruit (Mattheis et al., 1991).

Apple fruit is highly sensitive to ethylene, however, it produces large amounts of ethylene during ripening (Giovannoni, 2008). Therefore, the studies to reduce quality losses in fruit during storage generally focus on applications that inhibit ethylene

* *For correspondence*: E. Aglar (Email: erdalaglar@gmail.com)
ISSN2348-4330

production and enzyme activities responsible for ethylene biosynthesis (Martínez-Romero et al., 2007). For this aim, the bioregulators such as silver ions, diazocyclopentadiene, 1-methylcyclopropene, and aminoethoxyvinylglycine (AVG) (Kader, 2002), 1H-cyclopropabenzene and 1H-cyclopropa naphthalene (Singh et al., 2018) can be used. AVG is a naturally occurring amino acid that suppresses ethylene production in plant tissues by inhibiting the enzymatic activity responsible for the conversion of S-adenosylmethionine to 1-aminocyclopropane-L-carboxylic acid (Boller et al., 1979). ReTain is a commercial product containing a proprietary 15% w/w AVG that uses apples, pears, peaches, nectarines and cherries to delay fruit maturity, reduce pre-harvest fruit drop, preserve fruit firmness and increase storage potential (Rath and Prentice, 2004).

In the previous studies, it had been reported that the pre-harvest AVG application increased postharvest life by reducing ethylene production by delaying maturation at harvest and storage on apple (Sigal-Escalada and Archbold, 2009), pear (Tarabih, 2014), plum (Ozturk et al., 2012), peach (Çetinbaş et al., 2012), nectarine (McGlasson et al., 2005), sweet cherry (Koc Guler et al., 2019), tomato (Candir et al., 2017) and melon (Hung et al., 2010). It was observed that the effect of AVG to retard ripening and maintaining fruit firmness at harvest and after storage the apple cultivars such as 'Spartan', 'Spencer' (Bramlage et al., 1980), 'Gala', 'Jonagold' (Wang and Dilley, 2001), 'McIntosh' (Stover et al., 2003), Gala' and 'Cripp's Pink'(Phan-Thien et al., 2004). However, it has been determined that the effect varies depending on the application concentration (Schupp and Greene, 2004) and the cultivar (Elfving et al., 2007). In this study, the effect of AVG application at different concentrations on fruit quality in storage in Red Chief apple cultivar was investigated.

MATERIALS AND METHODS

Plant material and experimental design

In the study in which the effect of AVG application at different concentrations on the post-harvest fruit quality of Red Chief apple cultivar was investigated. The 7-year-old apple trees of MM106 x Red Chief rootstock - cultivar combination were used as plant material. The trees were planted with a 4x2 m planting density and trained as Central Leader. The cultural practices such as irrigation, fertilization, pruning and thinning were done on the trees.

The experiments were laid out in a randomized complete-block design with three single-tree replications per treatment. The trees were selected based on proximity in orchard and crop load. The study consisted of four applications, 75, 150 and 225 mg/ L^{-1} AVG and control (0 mg L^{-1}). AVG combined with a Regulaid' surfactant at 0.1% v/v, was applied 4 weeks (on 1th September 2017) before anticipated harvest. For each application, one pair of trees was used in each block. Treatments were applied to run off with a low pressure hand sprayer. For each treatment, one pair of trees was used in each block. The ones wounded, diseased, or damaged from the hand-harvested fruit at the commercial harvest were discarded, and 12 kg of the fruit for each application and 3 kg for each analysis period were harvested. After measuring and analysing of the fruit at harvest, the remaining fruit were stored in the same store with normal atmospheric conditions at 0°C and 90±5% RH for 6 months. The following quality analyses and measurements were made in 3 kg of fruit for each application in two-month periods.

Weight loss and firmness

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 during cold storage and expressed as percent. After the fruit peel has been removed by a cutting tool, flesh firmness (five fruit) was measured on three sides of equatorial line of each fruit

using a press mounted penetrometer (FT-327 MoCormick Fruit Tech., Yakima, ABD) with 11.1 mm tip. The values measured are expressed as Newton (N).

Soluble solids content and titratable acidity

A sample of juice was taken from one piece of each of ten fruit per tree, and 3 different measurements were obtained from each replication. SSC was determined with a digital refractometer (PAL- 1, McCormick Fruit Tech., Yakima, Wash) and the values had been expressed as % (ºBrix). For titratable acidity (TA), 10 mL of extract was taken from each sample, 10 mL distilled water was added and the value corresponding to consumed sodium hydroxide (NaOH) during the titration with 0.1 N NaOH to increase the pH of samples to 8.1 was expressed in malic acid (g malic acid 100 mL-1).

Statistical Analysis

All statistical analyses were performed with SAS Version 9.3 (SAS Institute Inc., Cary, NC, USA). Data were analysed by analysis of variance. Mains of treatments were separated by Duncan's multiple range tests at a significance level of 0.05.

RESULTS AND DISCUSSION

Fruit size is one of the important factors affecting consumer preferences. In our study to determine the effect of preharvest AVG application on postharvest quality losses in fruit, it was determined that the effect of AVG application on fruit size was significant and this effect varied depending on the application dose. 225 mg L^{-1} dose application increased fruit size while the smaller fruit were harvested on the tress applied 75 mg L^{-1} AVG. However, it was observed that 125 mg L^{-1} dose application had no effect on fruit size. However, Aglar et al. (2016) reported that the smaller fruit were obtained in pre-harvest AVG-treated Jersey Mac apple trees compared control.

The weight loss in post-harvest cold storage causes great economic losses. The weight loss in fruit during cold storage is usually due to water loss as a result of the ongoing postharvest physiological activities such as transpiration and respiration (Becker and Fricke, 1996). The weight loss can be reduced by slowing ethylene production and respiration rates with the application of ethylene inhibitors such as AVG (Martínez-Romero et al., 2007). In the study that we carried out for this purpose, it was determined that the weight losses during storage decreased with the AVG application. However, the lower weight loss was noted with 125 mg L-1 at 60 days of storage while there was no significant difference between other treatments. It can be said that the weight loss was lower in AVG-applied fruit in the measurements made at 120 and 180 days of the cold storage, and the effect of the concentration was not significant in the application. The less weight loss was recorded with 125 mg $^{L-1}$ application only at the end of storage (Table 1).

Table 1: Effect of AVG treatments on weight loss of apple (*Malus cominnus* L. cv. Red Chief) during storage

Treatments (mg L^{-1})	Harvest Fruit weight (g)	Weight loss (%)		
		60 day	120 day	180 day
0	244.17b	1.02a	2.01a	2.43a
75	213.83c	1.07a	1.37b	2.00b
125	252,97b	0.05b	1.26b	1.57c
225	296.53a	1.06a	1.51b	1.91b

Means in columns with the same letter do not differ according to Duncan's test at $P < 0.05$.

The decrease in fruit flesh firmness during the cold storage is due to the loss of cell turgor pressure and cell wall hydrolysing enzymes (Cosgrove, 2001). Ethylene plays an important role in fruit softening with the activity of these functions in the fruit ripening process (Giovannoni, 2008). Wei et al. (2010) were determined that the fruit exposure to ethylene in Golden Delicious' and 'Fuji' apple cultivars increased the activity of fruit softening enzymes such as β-galactosidase (β-Gal), α-L-arabinofuranosidase (α-L-Af), polygalacturonase (PG), and pectin methylesterase (PME) increased, but the activity of these enzymes decreased with the use of ethylene inhibitors such as AVG, BC, NC and 1-MCP, and the fruit firmness was maintaining during the cold storage. The higher fruit firmness in apple fruit treated with ethylene inhibitors can be attributed to the reduction in the rate of ethylene production, which reduces the activity of fruit softening enzymes (Giovannoni, 2008). In our study that is carried to determine the effect of AVG on ethylene production, the more firmness fruits were harvested with 125 mg L^{-1} AVG application while there was no significant difference in fruit firmness between other applications. The fruit firmness decreased in proportion to the cold storage period while the highest loss of the fruit firmness was recorded with the control application. At the end of the cold storage, the loss in the fruit firmness of the control application was recorded as 44%. In the measurements made during the cold storage, it was determined that AVG-applied fruit were more firmness, but the difference between the application doses was not significant. However, considering the fruit firmness losses in AVG-applied fruit at the end of the cold storage, the lowest loss (13%) was recorded with 125 mg L^{-1} application while the fruit firmness in 75 mg L^{-1} and 225 mg L^{-1}-applications were decreased by 27% and 24%, respectively (Table 2). In support of our results, in previous studies, it was observed that the effect of AVG to retard ripening and maintaining fruit firmness at harvest and after storage the apple cultivars such as 'Spartan', 'Spencer' (Bramlage et al., 1980), 'Gala', 'Jonagold' (Wang and Dilley, 2001), 'McIntosh' (Stover et al., 2003), Gala' and 'Cripp's Pink'(Phan-Thien et al., 2004). However, it has been determined that the effect varies depending on the application concentration (Schupp and Greene, 2004) and the cultivar (Elfving et al., 2007).

Table 2: Effect of AVG treatments on fruit firmness of apple (*Malus cominnus* L. cv. Red Chief) during storage

Treatments (mg L^{-1})	Fruit firmnes (N)			
	Harvest	60 day	120 day	180 day
0	73.9b	59.8b	51.7b	44.0b
75	86.7a	73.0a	68.3a	63.3a
125	75.3b	71.0a	70.0a	65.3a
225	79.7ab	73.3a	65.7a	60.7a

Means in columns with the same letter do not differ according to Duncan's test at $P < 0.05$.

In the study, fruit with higher acidity but lower SSC ratio were harvested with AVG application. However, the effect of AVG concentration on acidity and SSC ratio of the fruit was not significant. However, Yildiz et al. (2012) reported that the fruit with lower SSC ratio were harvested with pre-harvest AVG application in Red Chief apple cultivar, and the change in SSC ratio occurred depending on the application dose, and the effect of AVG application on acidity was not significant. However, Wang et al. (2016) determined that pre-harvest AVG application had no effect on SSC and acidity in 'Bartlett' pear cultivar. SSC and acidity ratios in the cold storage fruit are significant criteria that determine the quality of the cold storage. Depending on the storage period, the SSC ratio in the fruit increased while the acidity ratio decreased. There was no difference between the applications in the decrease in the acidity ratio during storage. However, it was determined that the ratio of SSC in AVG-applied fruit was lower than the control, but the application dose was not effective. In line with this explanation, it can be concluded that AVG application delays fruit ripening and thus may prolong post-harvest life (Table 3). AVG applications, which delay ripening

and fruit softening in the cold storage, prolong the post-harvest life of the fruit. The fact that, in the previous studies, it had been reported that the pre-harvest AVG application increased postharvest life by reducing ethylene production by delaying maturation at harvest and storage on apple (Sigal-Escalada and Archbold, 2009), pear (Tarabih, 2014), plum (Ozturk et al., 2012), peach (Çetinbaş et al., 2012), nectarine (McGlasson et al. ., 2005), sweet cherry (Koc Guler et al., 2019), tomato (Candir et al., 2017) and melon (Hung et al., 2010).

Table 3: Effect of AVG treatments on soluble solids content of apple (*Malus cominnus* L. cv. Red Chief) during storage

Treatments (mg L^{-1})	Soluble solids content (%)			
	Harvest	60 day	120 day	180 day
0	15.34a	15.63a	15.81a	16.07a
75	12.77c	13.00bc	13.30bc	13.67bc
125	13.44b	13.64b	13.86b	14.14b
225	12.20c	12.38c	12.60c	18.11c

in columns with the same letter do not differ according to Duncan's test at $P < 0.05$.

Table 4: Effect of AVG treatments on titratable acidity of apple (*Malus cominnus L.* cv. Red Chief) during storage

Treatments (mg L^{-1})	Titratable acidity (% malic acid)			
	Harvest	60 day	120 day	180 day
0	0.44 b	0.43a	0.41a	0.40a
75	0.46 ab	0.44a	0.42a	0.41a
125	0.48 a	0.47a	0.45a	0.42a
225	0.49 a	0.46a	0.45a	0.42a

Means in columns with the same letter do not differ according to Duncan's test at $P < 0.05$.

As a result, it has been revealed that pre-harvest AVG application can be used to prevent quality losses in storage with its effects such as reducing weight losses in post-harvest storage, maintaining fruit firmness, delaying ripening by limiting the SSC ratio. For this purpose, 125 mg $^{L-1}$ dose can be recommended as an application dose.

REFERENCES

Aglar, E., Yildiz, K., Ozkan, Y., Ozturk, B., and Erdem, H. 2016. The effects of aminoethoxyvinylglycine and foliar zinc treatments on pre-harvest drops and fruit quality attributes of Jersey Mac apples. Scientia Horticulturae, 213:173-178.

Becker, B. R, and Fricke, B. A. 1996. Transpiration and respiration of fruits and vegetables. Science et Technique du Froid. 6:110-121.

Boller, T., Herner, R., and Kende, H. 1979. Assay for and enzymatic formation of an ethylene precursor,1-aminocyclopropane-1-carboxylic acid. Planta, 145, 293–303.

Bramlage, W.J ., Greene, D. W., Autıo, W. R., and Mclaughlin, J. M. 1980. Effects of aminoethoxyvinilglycine on internal ethylene concentrations and storage of apples. Journal of American Society of Horticultural Science, 105, 847–851.

Candir, E., Candir, A., and Sen, F. 2017. Effects of aminoethoxyvinylglycine treatment by vacuum infiltration method on postharvest storage and shelf life of tomato fruit. Postharv Biology and Technology, 125, 13–25.

Cetinbas, M., Butar, S., Onursal, C. E., and Koyuncu, M. A. 2012. The effects of pre-harvest ReTain [aminoethoxyvinylglycine (AVG)] application on quality change of 'Monroe'peach during normal and controlled atmosphere storage. Scientia Horticulturae, 147, 1–7.

Cosgrove, D. J. 2001. Wall structure and wall loosening. A look backwards and forwards. Plant Physiology, 125: 131-134.

Elfving, D. C., Drake, S. R., Reed, A. N., and Visser, D. B. 2007. Preharvest applications of sprayable 1-methylcyclopropene in the orchard for management of apple harvest and postharvest condition. HortScience, 42, 1192–1199.

Giovannoni, J. J. 2008. Fruit Ripening and its Manipulation Annual Plant Reviews Volume 26: Senescence Processes in Plants (pp.278 - 303). DOI:10.1002/9780470988855.ch12

Hung, D., Mcconchie, R., and Morris, S. 2010. Pre-harvest treatment with aminoethoxyvinylglycine Influences fruit ripening and post-storage quality of benzothiadiazole-treated rockmelon (Cucumis melo L.). Horticulture, Environment, and Biotechnology, 51. 288-294.

Kader, A. A. 2002. Postharvest Technology of Horticultural Crops, 3rd Ed.

Koc-Guler, S., Karakaya, O., Karakaya, M. Ozturk, B., Aglar, E., Yarılgac, T., and Gun, S. 2019. Combined treatments of modified atmosphere packaging with aminoethoxyvinylglycine maintained fruit quality in sweet cherry throughout cold storage and shelf life. Acta Scientiarum Polonorum Hortorum Cultus, 18(5), 13-26.

Martínez-Romero, D., Bailen, G., Serrano, M., Guill´en, F., Valverde, J. M., Zapata, P., Castillo, S., and Valero, D. 2007. Tools to maintain postharvest fruit and vegetable quality through the inhibition of ethylene action: a review. Critical Reviews in Food Science and Nutrition, 47 (6), 543–560. https://doi.org/10.1080/10408390600846390.

Mattheis, J. P., Buchanan, D. A., and Fellman. J. K. 1991. Changes in apple fruit volatiles after storage in atmospheres inducing anaerobic metabolism. Journal of Agricultural and Food Chemistry, 39:1602–1605.

McGlasson, W. B., Rath, A. C., and Legendre, L. 2005. Preharvest application of aminoethoxyvinylglycine (AVG) modifies harvest maturity and cool storage life of 'Arctic Snow'nectarines. Postharv Biology and Technology, 36, 93–102.

Ozturk, B., Kucuker, E., Karaman, S., and Ozkan, Y. 2012. The effects of cold storage and aminoethoxyvinylglycine (AVG) on bioactive compounds of plum fruit (Prunus salicina Lindell cv.' Black Amber'). Postharv Biology and Technology, 72, 35–41. https://doi.org/ 10.1016/j.postharvbio.2012.04.015.

Phan-Thien, K. Y., Wargo, J. M., Mitchell, L. W., Collett, M. G., and Rath, A. C. 2004. Delay inripening of 'Gala' and 'Pink Lady' apples in commercial orchards following pre-harvest applications of aminoethoxyvinylglycine. Australian Journal of Experimental Agriculture, 44, 807–812.

Rath, A. C., and Prentice, A. J. 2004. Yield increase and higher flesh firmness of' Arctic Snow' nectarines both at harvest in Australia and after export to Taiwan following preharvest application of ReTain Plant Growth Regulator (aminoethoxyvinylglycine, AVG). Australlian Journal of Experimental Agriculture, 44 (3), 343–351.

Schupp, J. R., and Greene, D. W. 2004. Effect of aminoethoxyvinylglycine (AVG)onpreharvest drop, fruit quality, and maturation of `McIntosh' apples. I. Concentration and timing of dilute applications of AVG. HortScience, 39, 1030–1035.

Sigal-Escalada,V., and Archbold, D. D. 2009. Prehatvest aminoethoxyvinylglycine plus postharvest heat treatments influence apple fruit ripening after cold storage. HortScience, 44, 1637-1640.

Singh, Z., Payne, A. D., Khan, S. A. K. U., and Musa, M. M. A. 2018. Method of retarding an ethylene response. U.S. Patent Application No. 15/772,324, filed November 15, 2018.

Stover, E., Fargione, M. J., Watkins, C. B., and Iungerman, K. A. 2003. Harvest management of Marshall `McIntosh' apples: effects of AVG, NAA, ethephon, and summer pruning on preharvest drop and fruit quality. HortScience, 38, 1093–1099.

Tarabih, M. E. 2014. Improving storability of Le Conte pear fruit using aminoethoxyvinylglycine (AVG) and oxalic acid (OA) under cold storage conditions. Asian Journal of Crop Science, 6, 320–333.

Wang, Y., Xie, X, and Song, J. 2016. Preharvest aminoethoxyvinylglycine spray efficacy in improving storability of 'Bartlett' pears is affected by application rate, timing, and fruit harvest maturity. Postharvest Biology and Technology, 119:69-76. DOI:10.1016/j.postharvbio.2016.04.023

Wang.Y., Diley, D. R. 2001. Aminoethoxyvinylglycine, combined with ethephon, can enhance red color development without over-ripening apples. HortScience, 36, 328-331.

Wei, J., Ma, F., Shi, S., Qi, X., Zhu, X., and Yuan, J. 2010. Changes and postharvest regulation of activity and gene expression of enzymes related to cell wall degradation in ripening apple fruit. Postharvest Biology and Technology, 56 (2), 147–154. https://doi.org/10.1016/j.postharvbio.2009.12.003.

Yildiz, K., Ozturk, B., and Ozkan, Y. 2012. Effects of aminoethoxyvinylglycine (AVG) on preharvest fruit drop, fruit maturity, and quality of 'Red Chief' apple. Scientia Horticulturae, 144, 121–124.

© The Author(s)

This is an Open Access article licensed under a Creative Commons license: Attribution 4.0 International (CC-BY).