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Harvest and post harvest

Postharvest quality of 'Baigent' apples as a function of single and multiple preharvest spray aminoetoxivinylglycine and ethephon applications

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Abstract - The aim of this work was to evaluate the effect of single and multiple pre-harvest spray aminoethoxyvinylglycine (AVG) applications with or without ethephon, in 'Baigent' apple trees cultivated under anti-hail screen and harvesting date on fruit quality after storage. The experiment was conducted in a commercial orchard in the municipality of Vacaria/RS, in the 2014/15 and 2015/16 harvests. Treatments consisted of: control (plants sprayed with water); AVG (125 mg L^{-1}, 30 days before the predicted harvest date; BPHD); ethephon (120 mg L^{-1}, seven BPHD); AVG (62.5 mg L^{-1} + 62.5 mg L^{-1}, 30 and 20 BPHD); AVG (62.5 mg L^{-1} + 62.5 mg L^{-1}, 30 and 20 BPHD) + ethephon (120 mg L^{-1}, seven BPHD). Fruits of all treatments were harvested at commercial harvest (harvest 1) and after 14 days (harvest 2). Fruits were evaluated after four months of cold storage (0.5 °C ± 0.2 °C and RH 92 ± 5%). The use of AVG, regardless of single or multiple applications, reduced ethylene production rate, skin yellowing, farinaceous pulp and senescent degeneration incidence and maintained higher pulp firmness values and pulp penetration and skin rupture strength. Ethephon provided fruits with higher farinaceous pulp incidence. Fruit treated with AVG, regardless of single or multiple application and combination with ethephon, presents better quality after cold storage.

Index terms: *Malus domestica*, growth regulators, ethylene, cold storage.

Qualidade pós-colheita de maçãs 'Baigent' em função da forma de aplicação de aminoetoxivinilglicina e etefom

Resumo - O objetivo deste trabalho foi avaliar os efeitos da aplicação pré-colheita de aminoetoxivinilglicina (AVG), em dose única ou parcelada, combinado ou não com etefom, em macieiras 'Baigent', e da data de colheita, sobre a qualidade dos frutos, após o armazenamento. O experimento foi conduzido em pomar comercial, no município de Vacaria-RS, nas safras de 2014/2015 e 2015/2016. Os tratamentos constituíram-se em: controle (plantas pulverizadas com água); AVG (125 mg L^{-1}, 30 dias antes da previsão de colheita; DAPC); etefom (120 mg L-1, sete DAPC); AVG parcelado (62,5 mg L^{-1} + 62,5 mg L^{-1}, 30 e 20 DAPC); AVG parcelado (62,5 mg L^{-1} + 62,5 mg L^{-1}, 30 e 20 DAPC) + etefom (120 mg L^{-1}, sete DAPC). Frutos de todos os tratamentos foram colhidos na colheita comercial (colheita 1) e após 14 dias (colheita 2). Os frutos foram avaliados após quatro meses de armazenamento refrigerado (0,5 °C±0,2 °C e UR 92±5%). O uso do AVG, independentemente da forma de aplicação, reduziu a taxa de produção de etileno, o amarelecimento da epiderme, a incidência de polpa farinácea e a degenerescência senescente, e manteve maiores valores de firmeza de polpa e de forças para a ruptura da casca e a penetração da polpa. A aplicação de etefom proporcionou frutos com maior incidência de polpa farinácea. Os frutos tratados com AVG, independentemente da forma de aplicação e da combinação com o etefom, apresentam melhor qualidade após o armazenamento refrigerado.

Termos para indexação: *Malus domestica*, reguladores de crescimento, etileno, armazenamento refrigerado.

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Introduction

In Brazil, apple production is concentrated in the southern region, especially in the states of Santa Catarina and Rio Grande do Sul, producing 1.1 million tons per year (FAOSTAT, 2018). 'Gala' cultivar and its clones represent about 65% of the Brazilian apple production. However, due to the short period in which fruits naturally remain at the correct maturation stage and manually harvested requiring long time (BRACKMANN et al., 2015a, 2015b), the use of technologies to increase the harvest period is necessary. Thus, the application of growth regulators is an alternative to anticipate or delay fruit harvest and to reduce pre- and post-harvest losses.

The main growth regulator applied in apple trees to increase the harvest period is aminoethoxyvinylglycine (AVG), which is indicated to delay harvesting and avoid fruit drop, and to improve the maintenance of fruit quality during storage due to reduction in ethylene production (YILDIZ; OZTURK; OSKAN, 2012; BRACKMANN et al., 2014). In the ethylene synthesis route, AVG inhibits the conversion of S-adenosylmethionine (SAM) into 1-aminocyclopropane-1-carboxylic acid (ACC), catalyzed by the ACC synthase enzyme (ACS) (POEL; STRAETEN, 2014). Despite the benefits promoted by AVG application, this compound reduces the development of red color of 'Gala' apple (STEFFENS et al., 2006), impairing its visual appearance.

The increase in the red color of fruits previously treated with AVG can be obtained by pre-harvesting treatment of fruits with ethephon (STEFFENS; BRACKMANN, 2006). According to Steffens et al. (2006), the application of ethephon in apple trees previously treated with AVG cancels out the negative effect on the formation of red color in 'Gala' apples without compromising the effect on maturation delay and maintenance of fruit quality during cold storage. In addition, the isolated application of ethephon is used to anticipate the harvest of apples (BRACKMANN et al., 2015a). However, the application of this growth regulator may decrease fruit storage potential, especially reducing pulp firmness (STEFFENS et al., 2006; SUN et al., 2009; LI et al., 2017; PESTEANU, 2017).

Commercially, AVG application is recommended four weeks before the harvest point (YUAN; CARBAUGH, 2007). However, single or multiple AVG application may have the same benefits on crop maturation delay, without compromising the development of fruit red color (SOETHE et al., 2017). However, there is lack of studies evaluating the effect of AVG application on the storage potential of apples. In addition, the 'Baigent' cultivar, due to the fruit characteristics, especially by the intense red coloration, has been one of the preferred for the implantation of new orchards (FIORAVANÇO et al., 2013) and currently, there is no information regarding the effect of AVG applied in single or multiple doses on the conservation of fruits of this cultivar.

The aim of this study was to evaluate the effect of pre-harvest application of single or multiple AVG doses, combined or not with ethephon, and harvesting date on the maintenance of quality of stored 'Baigent' apples.

Material and methods

The experiment was carried out with 'Baigent' apple cultivar (*Malus domestica*) in the 2014/15 and 2015/16 harvest, in a commercial orchard located in the municipality of Vacaria, RS (50° 42'W, 28° 33' S, 955 m above sea level).

Treatments consisted of pre-harvest spraying of AVG and/or ethephon on plants as follows: control (plants sprayed with water); AVG (125 mg L^{-1}, 30 days before the predicted harvest date; BPHD); ethephon (120 mg L^{-1}, seven BPHD); AVG (62.5 mg L^{-1} + 62.5 mg L^{-1}, 30 and 20 BPHD); AVG (62.5 mg L^{-1} + 62.5 mg L^{-1}, 30 and 20 BPHD) + ethephon (120 mg L^{-1}, seven BPHD). Ethephon treatment (120 mg L^{-1}) was evaluated only in the first harvest. AVG source was the ReTain® product and as ethephon source, Ethrel® product was used. The adhesive spreader used, along with AVG and ethephon, was Break Thru (0.01% v/v) in control treatment plants. Fruits of all treatments were harvested at commercial harvest (harvest 1) and 14 days after commercial harvest (harvest 2). Commercial harvest began when control treatment fruits reached quality characteristics determined by the company. Fruits of the 2014/15 harvest were harvested on February 02 and 16, 2015, for harvests 1 and 2, respectively. Fruits of the 2015/16 harvest were harvested on February 5 and 19, 2016, for harvests 1 and 2, respectively. Fruits were evaluated after four months under cold storage (RS, 0.5 °C ± 0.2 °C and RH 92 ± 5%).

At the end of the RS period, fruits were evaluated at the exit of the chamber and after seven days under room conditions (20 ± 5 ºC and RH 63 ± 2%) to simulate the commercialization period. At the exit of the chamber, after fruits had reached room temperature, they were evaluated for respiratory rates (ηmol of CO_2 kg^{-1} s^{-1}) and ethylene production (pmol C_2H_4 kg^{-1} s^{-1}) and skin color (less red region), according to methodology described in Soethe et al. (2017). After seven days under room conditions (20 ± 5 ºC and RH 63 ± 2%), fruits were evaluated for the following attributes: respiratory rates ηmol of CO_2 kg^{-1} s^{-1}) and ethylene production (pmol C_2H_4 kg^{-1} s^{-1}), skin color (less red region), pulp firmness (N), soluble solids (SS), titratable acidity (TA), SS / TA ratio, farinaceous pulp and senescent degeneration incidence, according to methodology described in Steffens et al. (2006) and Soethe et al. (2017). In this evaluation, texture attributes analysis was also performed, according to methodology described in Steffens et al. (2011).

The experimental design was randomized blocks with four plots, according to a 5x2 factorial. Each plot was composed of eight plants and, at each harvest date, samples were harvested from two plants per plot, the first and the eighth plant being considered as borders. Samples were composed of 20 fruits each. Percentage data were transformed into arc sin $(x/100)^{0.5}$ before statistical analysis. Data were submitted to analysis of variance and the means of treatments compared by the Tukey test ($p<0.05$).

Results and discussion

Any form of pre-harvest AVG application (single or multiple doses, combined or not with ethephon) reduced the ethylene production rate in evaluations performed at the exit of the chamber and after seven days at room conditions (Table 1). The highest ethylene production rate of control treatment fruits, compared to fruits that received pre-harvest AVG application, may be related to a higher activity of the ACC oxidase enzyme and with higher internal ethylene concentration (PAYASI et al., 2009; WEI et al., 2010; BRACKMANN et al., 2015a). According to Brackmann et al. (2004), the rapid loss of quality of ‘Gala’ apples stored under refrigeration is linked to the high ethylene production rates, in addition to the high respiratory rate of this cultivar. The higher the ethylene production and action, the higher the ripening speed and fruit senescence (BRACKMANN et al., 2009b).

At the exit of the chamber, control treatment fruits presented higher respiratory rate than fruits that received pre-harvest AVG application, especially when applied in a single dose. However, in evaluation performed after seven days under room conditions, only pre-harvest AVG application in a single dose presented lower respiratory rate in comparison to control treatment fruits, while the other forms of pre-harvest AVG application presented intermediate values, not differing among treatments (Table 1). The lower respiratory rate may be related to the lower ethylene production of these fruits, since respiration is an ethylene-dependent process (PRE-AYMARD et al., 2003).

For variable $h°$ at the exit of the chamber, pre-harvest AVG application in single dose provided fruits with higher $h°$ in the less red region, followed by fruits that received pre-harvest AVG application in multiple doses, while control treatment fruits showed the lowest $h°$ values, demonstrating that these fruits had more yellowish background color. Pre-harvest AVG application in multiple doses, both at the exit of the chamber and after seven days under room conditions, presented intermediate values (Table 2). In the 2015/16 harvest, pre-harvest AVG application, regardless of application form, both at the exit of the chamber and after seven days of exposure of fruits to room condition, maintained the background color of fruits greener (Table 2). According to Brackmann et al. (2009a), this effect of AVG may be related to the lower activity of chlorophyllase enzymes.

SS and TA contents are attributes responsible for fruit flavor. Regarding the SS content, in the 2014/15 harvest, after cold storage, fruits that received simple or multiple AVG doses combined with ethephon had lower SS values compared to control treatment fruits; however, without differing from the other treatments. In the 2015/16 harvest, the SS content was higher in control treatment fruits and in fruits that received mixed AVG application combined with ethephon (Table 3). According to Steffens et al. (2011), high SS values may be related to high content of soluble pectins, since these fruits had the lowest pulp firmness values and lower pulp penetration and skin rupture strength (Table 4), demonstrating faster ripening of control treatment fruits. On the other hand, after the cold storage period, TA and SS/TA ratio were not influenced by treatments in both harvests (Table 3). Steffens et al. (2005) observed no influence of AVG on TA of ‘Gala’ apples after fruit storage.

Pulp firmness of fruits from plants treated with AVG was higher in both harvests, regardless of application form and the combination with subsequent ethephon application (Table 4). It is probable that the higher respiratory rate of control treatment fruits (Table 1) resulted in lower pulp firmness due to an increase in metabolism and in the activity of cell wall enzymes (BRACKMANN et al., 2015a). According to Brackmann et al. (2009a), the greater pulp firmness of fruits treated with AVG is related to the reduction in ethylene production, which can be observed in the present study (Table 1). According to Majumder and Mazumdar (2002), the presence of ethylene is necessary for the activity of cell wall degradation enzymes. Majumdar and Mazumder (2002) found that the increase in the activity of the polygalacturonase enzyme is highly correlated with ethylene production. Thus, fruits submitted to treatments with AVG have lower enzymatic activity and lower cell wall degradation (NISHIYAMA et al., 2007).,

According to Harker et al. (2008), apple pulp firmness should be greater than 62 N for maximum consumer acceptance. However, when pulp firmness levels are lower than 53 N, reduction of fruit crispness and succulence and significant increase in the farinaceous pulp incidence are observed, which characteristics are negatively perceived by consumers (HARKER et al., 2002). In the 2015/16 harvest, the application of AVG (single or multiple doses combined or not with ethephon) provided fruits with pulp firmness values higher than 53 N, while control treatment fruits presented pulp firmness below values acceptable by the consumer for both fruits harvested in the commercial harvest and those harvested after 14 BPHD, indicating loss of quality. Thus, apples that received pre-harvest AVG application in single or multiple doses combined or not with ethephon presented lower loss of pulp firmness after cold storage compared to control treatment fruits. Around 20% reduction in pulp firmness was observed for fruits that received pre-harvest AVG application, and around 35% loss of pulp firmness for control treatment fruits. Fruits that received pre-harvest AVG application, regardless of application form and combination with ethephon, can be harvested late (14 BPHD) and sent for storage, while control treatment apples should be destined for immediate commercialization or cold storage for less than four months. Considering the percentage of loss of pulp firmness, control treatment fruits could be stored for three months for apples harvested at commercial harvest and for two months for apples collected 14 BPHD in order to maintain satisfactory pulp firmness after storage and more seven days of fruit exposure under room conditions. According to Mitsuhashi-Gonzalez et al. (2010), the lower pulp firmness of apples does not only result in less sensory appreciation by consumers, but also favors the incidence of pulp degeneration and increases the vulnerability of fruits to mechanical damage and rot.

In the first harvest, AVG application in multiple doses provided fruits with higher skin rupture strength values in relation to control treatment fruits and those that received only pre-harvest ethephon application, but with no difference between fruits that received pre-harvest single-dose AVG application and multiple-dose AVG combined with ethephon. On the other hand, in the 2015/16 harvest, all forms of AVG application showed higher skin rupture strength values. However, fruits that received pre-harvest single-dose AVG application presented the highest value, and fruits that received multiple-dose AVG combined with ethephon showed intermediate values (Table 4). Regarding pulp penetration strength in both harvests, pre-harvest AVG application in single or multiple doses presented the highest values; however, without differing from fruits that received pre-harvest multiple-dose AVG application combined with ethephon (Table 4). Steffens et al. (2006) also found higher pulp firmness in apples treated with AVG. According to Steffens et al. (2011), fruit texture response to AVG treatments is directly related to its effect on reducing ethylene production.

All treatments with AVG caused reduction in the farinaceous pulp incidence in both harvests (Table 5). The lower occurrence of this disturbance can be attributed to the lower pectin degradation in the wall of pulp cells, since fruits treated with AVG were firmer (Table 4). This result is in agreement with Steffens et al. (2005), which indicate that pre-harvest AVG application can reduce the farinaceous pulp incidence. According to Payasi et al. (2009), the farinaceous pulp incidence is associated with ethylene concentration in the fruit, since this plant hormone is important to activate polygalacturonase and pectinamylesterase enzymes, which convert protopectin molecules into soluble pectin and increase the farinaceous pulp incidence.

In the 2014/15 harvest, difference between pre-harvest treatments for variable senescent degeneration incidence was not observed. In the 2015/16 harvest, there was interaction between pre-harvest treatments and harvesting date for pulp darkening. Regardless of treatment, fruits harvested in the commercial harvest did not present senescent degeneration, whereas fruits harvested at 14 BPHD, any form of pre-harvest AVG application showed low senescent degeneration incidence in relation to control treatment fruits. Regarding harvesting date, only control treatment fruits showed an increase in the senescent degeneration incidence with harvest delay (Table 5), indicating that pre-harvest AVG application, regardless of form, delays the occurrence of this disorder. The reduction of senescent degeneration in response to AVG application was also observed by D'aquino et al. (2010), who affirm that this result stems from the delay in the ripening process and reduction of the respiratory activity of fruits treated with AVG, which is associated with low levels of endogenous CO_2. According to Argenta et al. (2015), the senescent degeneration incidence may be due to the lower pulp firmness of apples, which can be observed in the present study.

After four months of cold storage and another seven days under room conditions, harvest delay yielded fruits with higher SS content, SS/TA ratio, higher skin yellowing, and lower TA values, pulp penetration strength and pulp firmness in the second harvest. On the other hand, the harvest delay did not influence pulp firmness in the first harvest and in both harvests, the skin rupture strength (Tables 5). In addition, there was an increase in the senescent degeneration and farinaceous pulp incidence in the 2014/15 harvest with harvest delay. On the other hand, in the 2015/16 harvest, there was reduction in the farinaceous pulp incidence with harvest delay (Table 4), which can be justified by the production year factor, since in this harvest, flowering was staggered.

In general, the effect of AVG on the delay of fruit quality loss during storage of 'Baigent' apples produced under anti-hail screen was very similar to that obtained in studies carried out with 'Gala' apples produced in full sun (STEFFENS et al., 2005, 2006; PETRI; LEITE; ARGENTA, 2007, BRACKMANN et al., 2015a). It was evident that the multiple-dose AVG application does not significantly interfere with its positive effect on fruit ripening delay. This aspect is extremely relevant for the production of 'Baigent' apples, since multiple-dose AVG application does not compromise the development of the red color of apples of this cultivar (SOETHE et al., 2017).

Table 1 - Ethylene production rate (pmol C_2H_4 kg^{-1} s^{-1}) and respiratory rate (ηmol CO_2 kg^{-1} s^{-1}) in ‘Baigent’ apple pretreated with aminoethoxyvinylglycine (AVG) and ethephon, harvested at two dates, evaluated at the exit of the chamber and after four months of cold storage and another seven days under room conditions in the 2015/16 harvest.

Pre-harvest treatments	Harvest 1 02/05	Harvest 2 02/19		Harvest 1 02/05	Harvest 2 02/19	
	Ethylene production		Mean	Respiratory rate		Mean
	Chamber exit					
Control	731.4	2479.1	1605.3 A	263.1	119.5	191.3 A*
125 mg L^{-1} AVG (30 BPHD)	5.2	68.5	36.9 B	204.5	85.4	145.0 C
62.5 mg L^{-1} + 62.5 mg L^{-1} AVG (30 and 20 BPHD)	1.5	175.3	88.4 B	220.8	104.1	162.4 B
62.5 mg L^{-1} + 62.5 mg L^{-1} AVG (30 and 20 BPHD) + 120 mg L^{-1} ethephon (7 BPHD)	5.2	697.3	351.3 B	233.0	108.0	170.5 B
Mean	185.8 b	855.1 a		230.4 a	104.3 b	
CV (%)	33.3			3.7		
	After seven days under room conditions					
	Ethylene production		Mean	Respiratory rate		Mean
Control	11567.0	7998.7	9783.0 A	80.2	146.2	113.2 A
125 mg L^{-1} AVG (30 BPHD)	2348.9	3686.7	3018.0 B	62.5	115.3	88.8 B
62.5 mg L^{-1} + 62.5 mg L^{-1} AVG (30 and 20 BPHD)	1725.9	4883.7	3305.0 B	66.6	143.2	104.9 AB
62.5 mg L^{-1} + 62.5 mg L^{-1} AVG (30 and 20 BPHD) + 120 mg L^{-1} ethephon (7 BPHD)	105.7	4152.9	2129.0 B	54.1	136.8	95.5 AB
Mean	3936.9 a	5180.0 a		65.9 b	135.4 a	
CV (%)	51.9			10.7		

*Means not followed of the same letter, uppercase in vertical and lowercase in horizontal, differ by the Tukey test ($p<0.05$). BPHD = Before predicted harvest date. CV = Coefficient of variation.

Table 2 - Color attributes (hue angle - $h°$) evaluated in the less red fruit region of 'Baigent' apple pretreated with aminoethoxyvinylglycine (AVG) and ethephon, harvested on two dates, after four months of cold storage, evaluated at the exit of the chamber and after seven days under room condition.

Pre-harvest treatments	2014/15 Harvest			2015/16 Harvest		
	Harvest 1 02/02	Harvest 2 02/16		Harvest 1 02/05	Harvest 2 02/19	
	Chamber exit					
	$h°$		Mean	$h°$		Mean
Control	67.0	41.2	54.1 C	85.4	85.8	85.6 B*
125 mg L^{-1} AVG (30 BPHD)	80.7	56.4	70.3 A	98.0	93.8	95.9 A
120 mg L^{-1} ethephon (7 BPHD)	65.4	44.8	56.5 BC	.	.	.
62.5 mg L^{-1} + 62.5 mg L^{-1} AVG (30 and 20 BPHD)	76.0	49.8	62.9 B	99.2	95.7	97.4 A
62.5 mg L^{-1} + 62.5 mg L^{-1} AVG (30 and 20 BPHD) + 120 mg L^{-1} ethephon (7 BPHD)	71.0	37.1	56.5 BC	97.6	90.6	95.0 A
Mean	72.3 a	46.1 b		95.1 a	91.5 a	
CV (%)	7.3			4.0		
	After seven days under room conditions					
	$h°$		Mean	$h°$		Mean
Control	70.8	46.5	58.7 B	85.5	85.5	85.5 B
125 mg L^{-1} AVG (30 BPHD)	84.0	57.1	70.6 A	93.4	94.3	93.9 A
120 mg L^{-1} ethephon (7 BPHD)	68.7	49.3	59.0 B	.	.	.
62.5 mg L^{-1} + 62.5 mg L^{-1} AVG (30 and 20 BPHD)	76.9	58.2	67.6 AB	97.9	93.0	95.4 A
62.5 mg L^{-1} + 62.5 mg L^{-1} AVG (30 and 20 BPHD) + 120 mg L^{-1} ethephon (7 BPHD)	73.6	48.8	61.2 AB	97.2	89.0	93.1 A
Mean	74.8 a	52.0 b		93.5 a	90.4 b	
CV (%)	11.2			3.2		

*Means not followed of the same letter, uppercase in vertical and lowercase in horizontal, differ by the Tukey test ($p<0.05$). BPHD = Before predicted harvest date. CV = Coefficient of variation.

Table 3 - Soluble solids (SS), titratable acidity (TA) and SS / TA ratio in 'Baigent' apple pretreated with aminoethoxyvinylglycine (AVG) and ethephon, harvested on two dates after four months of cold storage and seven days under room condition.

Pre-harvest treatments	2014/15 Harvest			2015/16 Harvest		
	Harvest 1 02/02	Harvest 2 02/16		Harvest 1 02/05	Harvest 2 02/19	
	SS (°Brix)		Mean	SS (°Brix)		Mean
Control	11.5	12.7	12.1 A*	12.5	12.8	12.7 A
125 mg L^{-1} AVG (30 BPHD)	11.4	12.0	11.7 AB	11.7	11.6	11.6 B
120 mg L^{-1} ethephon (7 BPHD)	11.9	11.8	11.8 AB	.	.	.
62.5 mg L^{-1} + 62.5 mg L^{-1} AVG (30 and 20 BPHD)	10.8	11.9	11.3 AB	11.3	12.2	11.8 B
62.5 mg L^{-1} + 62.5 mg L^{-1} AVG (30 and 20 BPHD) + 120 mg L^{-1} ethephon (7 BPHD)	10.6	11.9	11.2 B	11.6	12.8	12.2 AB
Mean	11.2 b	12.1 a		11.9 b	12.3 a	
CV (%)	4.5			3.0		
	TA (% malic acid)			TA (% malic acid)		
Control	0.264	0.183	0.223ns	0.226	0.208	0.217ns
125 mg L^{-1} AVG (30 BPHD)	0.263	0.196	0.229	0.234	0.209	0.222
120 mg L^{-1} ethephon (7 BPHD)	0.258	0.178	0.218	.	.	.
62.5 mg L^{-1} + 62.5 mg L^{-1} AVG (30 and 20 BPHD)	0.278	0.189	0.234	0.260	0.216	0.238
62.5 mg L^{-1} + 62.5 mg L^{-1} AVG (30 and 20 BPHD) + 120 mg L^{-1} ethephon (7 BPHD)	0.268	0.185	0.226	0.241	0.234	0.237
Mean	0.266 a	0.186 b		0.240 a	0.217 b	
CV (%)	6.66			11.20		
	SS/TA			SS/TA		
Control	43.3	69.6	56.4ns	55.6	61.3	58.5ns
125 mg L^{-1} AVG (30 BPHD)	43.5	61.1	52.3	51.4	55.4	53.4
120 mg L^{-1} ethephon (7 BPHD)	46.0	66.0	56.0	.	.	.
62.5 mg L^{-1} + 62.5 mg L^{-1} AVG (30 and 20 BPHD)	38.7	62.9	50.8	43.0	56.3	49.7
62.5 mg L^{-1} + 62.5 mg L^{-1} AVG (30 and 20 BPHD) + 120 mg L^{-1} ethephon (7 BPHD)	39.4	64.1	51.7	48.3	55.1	51.7
Mean	42.2 b	64.7 a		49.6 b	57.0 a	
CV (%)	10.3			10.8		

*Means not followed of the same letter, uppercase in vertical and lowercase in horizontal, differ by the Tukey test ($p<0.05$) ns: not significant. BPHD = Before predicted harvest date. CV = Coefficient of variation.

Table 4 - Pulp firmness, skin rupture and pulp penetration strength in 'Baigent' apple pretreated with aminoethoxyvinylglycine (AVG) and ethephon, harvested on two dates after four months of cold storage and seven days under room condition.

Pre-harvest treatments	2014/15 Harvest Harvest 1 02/02	2014/15 Harvest Harvest 2 02/16		2015/16 Harvest Harvest 1 02/05	2015/16 Harvest Harvest 2 02/19	
	Pulp firmness (N)		Mean	Pulp firmness (N)		Mean
Control	47.4	43.0	45.2 B*	51.1	45.3	47.7 B
125 mg L^{-1} AVG (30 BPHD)	53.8	53.7	53.7 A	62.1	62.7	62.4 A
120 mg L^{-1} ethephon (7 BPHD)	51.3	48.4	49.8 AB	.	.	.
62.5 mg L^{-1} + 62.5 mg L^{-1} AVG (30 and 20 BPHD)	52.6	52.4	52.5 A	59.5	58.2	58.8 A
62.5 mg L^{-1} + 62.5 mg L^{-1} AVG (30 and 20 BPHD) + 120 mg L^{-1} ethephon (7 BPHD)	54.4	50.1	52.2 A	67.7	56.7	62.2 A
Mean	51.9 a	49.5 a		61.11 a	55.7 b	
CV (%)	7.8			6.3		
	Skin rupture strength (N)			Skin rupture strength (N)		
Control	10.5	10.4	10.5 B	10.9	10.5	10.7 C
125 mg L^{-1} AVG (30 BPHD)	11.2	11.2	11.2 AB	13.9	13.9	13.9 A
120 mg L^{-1} ethephon (7 BPHD)	10.4	10.7	10.5 B	.	.	.
62.5 mg L^{-1} + 62.5 mg L^{-1} AVG (30 and 20 BPHD)	11.7	11.5	11.6 A	12.2	12.3	12.3 B
62.5 mg L^{-1} + 62.5 mg L^{-1} AVG (30 and 20 BPHD) + 120 mg L^{-1} ethephon (7 BPHD)	11.5	10.4	11.0 AB	13.07	11.9	12.5 B
Mean	11.1 a	10.8 a		12.5 a	12.2 a	
CV (%)	6.0			3.6		
	Pulp penetration strength (N)			Pulp penetration strength (N)		
Control	2.1	1.8	1.9 B	2.1	1.9	2,0 C
125 mg L^{-1} AVG (30 BPHD)	2.2	2.2	2.2 A	2.7	2.7	2.7 A
120 mg L^{-1} ethephon (7 BPHD)	1.9	1.9	1.9 B	.	.	.
62.5 mg L^{-1} + 62.5 mg L^{-1} AVG (30 and 20 BPHD)	2.2	2.1	2.2 A	2.5	2.3	2.4 B
62.5 mg L^{-1} + 62.5 mg L^{-1} AVG (30 and 20 BPHD) + 120 mg L^{-1} ethephon (7 BPHD)	2.3	2.0	2.1 AB	2.7	2.4	2.5 AB
Mean	2.1 a	2.0 b		2.5 a	2.3 b	
CV (%)	6.3			4.7		

* Means not followed of the same letter, uppercase in vertical and lowercase in horizontal, differ by the Tukey test ($p<0.05$). BPHD = Before predicted harvest date. CV = Coefficient of variation.

Table 5 - Farinaceous pulp and senescent degeneration incidence of 'Baigent' apple pretreated with aminoethoxyvinylglycine (AVG) and ethephon, harvested on two dates after four months of cold storage and seven days under room condition.

Pre-harvest treatments	2014/15 Harvest: Harvest 1 02/02	Harvest 2 02/16		2015/16 Harvest: Harvest 1 02/05	Harvest 2 02/19	
	Farinaceous pulp (%)		Mean	Farinaceous pulp (%)		Mean
Control	53.8	77.4	65.6 A*	63.8	48.5	56.1 A
125 mg L-1 AVG (30 BPHD)	13.7	46.0	29.9 C	43.0	0.0	21.5 B
120 mg L-1 ethephon (7 BPHD)	34.1	72.8	53.4 AB	.	.	.
62.5 mg L-1 + 62.5 mg L-1 AVG (30 and 20 BPHD)	19.3	48.1	33.7 C	47.2	10.6	28.9 B
62.5 mg L-1 + 62.5 mg L-1 AVG (30 and 20 BPHD) + 120 mg L-1 ethephon (7 BPHD)	27.4	52.2	39.8 BC	26.1	14.9	20.5 B
Mean	29.6 b	59.3 a		45.1 a	18.5 b	
CV (%)	27.7			37.1		
	Senescent degeneration (%)			Senescent degeneration (%)		
Control	20.0	49.7	34.4ns	0.0 Ab	23.3 Aa	.
125 mg L-1 AVG (30 BPHD)	7.9	24.8	16.4	0.0 Aa	0.0 Ba	.
120 mg L-1 ethephon (7 BPHD)	15.8	43.5	29.7	.	.	.
62.5 mg L-1 + 62.5 mg L-1 AVG (30 and 20 BPHD)	8.9	22.3	15.6	0.0 Aa	0.3 Ba	.
62.5 mg L-1 + 62.5 mg L-1 AVG (30 and 20 BPHD) + 120 mg L-1 ethephon (7 BPHD)	11.2	46.2	28.7	0.0 Aa	3.3 Ba	.
Mean	12.6 b	37.3 a		.	.	
CV (%)	76.0			69.0		

*Means not followed of the same letter, uppercase in vertical and lowercase in horizontal, differ by the Tukey test ($p<0.05$) ns: not significant. BPHD = Before predicted harvest date. CV = Coefficient of variation.

Conclusions

Aminoethoxyvinylglycine, regardless of single- or multiple-dose application, and the harvesting date, maintains the quality of 'Baigent' apples stored under refrigeration for four months and seven days under room conditions, as it delays the ripening of fruits and reduces the farinaceous pulp and senescent degeneration incidence. Multiple-dose aminoethoxyvinylglycine application (62.5 mg L^{-1} + 62.5 mg L^{-1} at 30 and 20 days before commercial harvest), with or without ethephon, after cold storage, regardless of harvesting date, showed lower pulp firmness loss and reduced skin yellowing of 'Baigent' apple cultivated under anti-hail screen, similarly to the single-dose application (125 mg L^{-1} 30 days before harvest). Ethephon application provides fruits with higher farinaceous pulp incidence; however, without influencing pulp firmness.

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