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Improving Storability of Le Conte Pear Fruit Using Aminoethoxyvinylglycine (AVG) and Oxalic Acid (OA) under Cold Storage Conditions

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ABSTRACT

Le Conte pear fruits were dipped in 200 ppm aminoethoxyvinylglycine (AVG) and 5 mM oxalic acid (OA) solution either alone or in combination for 5 min to investigate their effects on delay ripening and prolong storability during cold storage and marketing conditions in 2012 and 2013 seasons. Pear fruits were kept at 0±1°C with 90-95% R.H for 90 days and 5 days after each storage period as marketing at room temperature. The results showed that the physiological effects of AVG and/or OA treatments in decreasing ethylene production were an important contributor to delaying the ripening process and reduced fruit decay incidence compared to the control. Besides, AVG+OA treatment was more effective in reduced respiration rate, showed slight browning and produced a lower fruit sugar. Weight loss percentage was significantly decreased with aminoethoxyvinylglycine (AVG) treatment alone, since, it was more effective to maintain fruit firmness at the end of the storage and preserve a higher green color. Furthermore, dipping fruits with oxalic acid (OA) alone decreased decay and total loss percentage after cold storage and 5 days during marketing. Since, hue angle values decreased in all treatments during cold storage.

Key words: Le Conte pear, aminoethoxyvinylglycine, ReTain®, oxalic acid, cold storage, marketing conditions, respiration rate, delay ripening

INTRODUCTION

Pear fruits (*Pyrus communis* L., CV. Le Conte) grown successfully under Egypt conditions and still need for further studies to improve the quality of the fruit. Fruit softening and other ethylene mediated processes are correlated with an increase in 1-Amino-Cyclopropane-Carboxylate (ACC) synthase (Tonutti *et al*., 1997). To extend the postharvest shelf life of climacteric fruit such as pears, ethylene synthesis or action must be inhibited to slow down the ripening processes. Inhibitors such as AVG and oxalic acid were used with success on produce such as apples, pears and bananas.

Aminoethoxyvinylglycine (AVG) is a vinylglycine analog with a chemical formula of [NH_2-CH_2-CH_2-O-C=CH-CH-(NH_2)-COOH]. Vinylglycine analogs are irreversible inhibitors of pyridoxal phosphate linked enzymes. It is the active ingredient of a commercial product known as ReTain® which containing 150 mg (AVG/g; Valent Bio Science Corp). Aminoethoxyvinylglycine (AVG) is an ethylene-biosynthesis inhibitor approved for field applications in pome fruit orchards. AVG delay fruit softening and prolong the postharvest life of apricots. This delay could allow additional time for transport and marketing and may reduce physical damage to the fruit. It is a human and environmentally friendly organic product registered for use for apple, pear, peach, plum and nectarine in several countries (Greene and Schupp, 2004; Rath and Prentice, 2004).

The mode of action of aminoethoxyvinylglycine (AVG) is the inhibition of ACC-synthase activity, when applied as a pre harvest spray, it inhibited ethylene production during fruit ripening by blocking the conversion of S-adenosylmethionine (SAM) to 1-aminocyclopropane-1-carboxylic acid (ACC). When applied as a postharvest dip treatment on peaches and nectarines, it reduced the rate of fruit softening (Garner *et al*., 2001).

Oxalic acid (OA) is an organic acid naturally occurring in plants and fungi and seems to play different roles in different living organisms. Recently, oxalic acid application for food preservation has received much attention, as it has been shown not only to be an anti-browning agent for harvested vegetables, banana slices (Yoruk *et al*., 2002), but also to be available as a natural antioxidant in the natural and artificial preservation of oxidized materials (Kayashima and Katayama, 2002). Tian *et al*. (2006) have reported that oxalic acid inhibited the progress of *Alternaria rot* in harvested pear fruit associated with an increase in defense related enzymes. The effect of oxalic acid could contribute to maintaining the membrane integrity and delaying the fruit ripening process.

The objective of this study was to examine the effect of aminoethoxyvinylglycine (AVG) and oxalic acid (OA) treatment each alone or in combination on delay ripening, keep firmness and reduce internal browning to improve Le Conte pear fruits life during cold storage and marketing as long as possible.

MATERIALS AND METHODS

Le Conte pear fruits picked from private orchard at EL-Khatatba city, Monifia, Governorate during 2012 and 2013 seasons, respectively from trees about seven years old grown in sandy soil and spaced at 5 m apart. The fruits were harvested at physiologically matured when the average of fruit firmness reached about 13-14 Ib $inch^{-2}$ and soluble solids in fruits juice reached about 13-14% according to Swindeman (2002).

Fruits were harvested from trees expected common horticultural practices, undamaged and free from any obvious pathogen infection, then transported to the laboratory and washed thoroughly with tap water to remove undesirable particles from the surface. At the beginning of the experiment, samples of 15 fruits were taken to determine the initial fruits properties and then received the following treatments:

Treatments:

- Dipping fruits in AVG 200 ppm for 5 min
- Dipping fruits in oxalic acid 5 mM for 5 min
- Dipping fruits in AVG 200 ppm+oxalic acid 5 mM for 5 min
- Control (Dipping fruits in tap water) for 5 min

For storage study, fruits of all treatments were sorted to remove any infected and damaged ones and then stored in perforated plastic bags (each contains 5 fruits). All bags with fruits were weighted and every three bags were put in ventilated carton box. The boxes were stored 90 days at 0±1°C with 90-95% R.H, fruits for each treatment were taken 30 days intervals to determine fruits characteristics.

For shelf life study, after every cold storage period fruits for each treatment were held 5 days at room temperature conditions as shelf life at 28±2°C with 65-70% relative humidity to determine the following parameters:

Loss in fruit weight: It was determined according to the following equation:

$$\text{Loss in fruit weight (\%)} = \frac{\text{Initial weight} - \text{Weight at sampling date}}{\text{Initial fruit weight}} \times 100$$

Decay: It was determined according to the following equation:

$$\text{Decay (\%)} = \frac{\text{Wight of decayed fruits}}{\text{Initial fruit weight}} \times 100$$

- **Total loss in fruit (%):** It was determined according to the following equation:

$$\text{Total loss in fruit (\%)} = \text{Loss weight (\%)} + \text{Decayed fruits weight (\%)}$$

- **Respiration rate (mg CO_2/kg/h):** Carbon dioxide produced by pear fruits was determined according to AOAC (1970)
- **Skin hue color (h°):** Skin color was measured using a hand-held colorimeter (CR-10; Minolta Co., Ltd., Osaka, Japan). Color changes from green to yellow were indicated by calculating the hue angle (h°), from (a*, b*) using the methods described by McGuire (1992)
- **Fruit firmness (Ib inch^{-2}):** It was determined on the two opposite sides of fruit using a hand Effegi-Penetrometers supplemented and the average was estimated as Ib inch^{-2}
- **Internal browning (IB):** For determination of Internal Browning (IB), five fruits were cut longitudinally and the area of the fruit flesh that was affected by a brown core was compared to the total area. The IB assessment was based on five stages, according to the browning area, as follows: No browning (0), slight browning (I, <30% of the area), moderate browning (II, about 30-70% of the area) and severe browning (III, >70% of the area, with only the cortex fraction just underneath the peel not showing browning). The browning index is the sum of the browning score of the five pears divided by 15 and multiplied by 100% and I, II and III refer to the number of pears in the various browning classes. A browning index value of 0% means no browning; 100% means maximal browning. Results were expressed as the browning index (%) calculated using the following equation (Veltman *et al*., 2000):

$$\text{Browning index} = [I+(2\times II)+(3\times III)]\ 3(0+I+II+III)\times 100$$

- **Soluble solids content (SSC%):** Soluble solids content in fruit juice was measured using a Carl-Zeiss hand refractometer according to AOAC (2005)
- **Titratable acidity (TA %):** It was determined in 10 mL of fruit juice as a percentage of malic acid according to AOAC (2005)
- **SSC/acid ratio:** It was calculated by dividing the value of SSC over the value of titratable acidity of each sample
- **Total sugar (%):** The extract was prepared by taking 0.5 g of fresh pulp and extracting with 80% ethanol according to Ranganna (1979)

Statistical analysis: Data of both seasons of the study was analyzed using analysis of variance (ANOVA). Differences among treatment means were statistically compared using Duncan's multiple tests at a level 0.05, using the CoStat V6.4 program.

RESULTS AND DISCUSSION

Loss in fruit weight percentage: The loss in weight of "Le Conte" pear fruits at cold storage and 5 days during shelf life are presented in Table 1. The data reveal that, the loss in fruit weight increased as storage period advanced under cold storage and at room temperature. Thus, all the applied treatments reduced the loss in fruit weight than the control. Since, the percent of loss in fruit weight of the untreated fruits were 3.22 and 3.44% after 90 days of cold storage and it was 4.69 and 4.93% after five days as marketing in both seasons, respectively. The lowest significant values of weight loss percentage were recorded by the application of AVG at 200 ppm ranged 2.0 and 2.28% after 90 days of cold storage and it were 3.0 and 3.70% after 5 days of marketing in the

Table 1: Effect of AVG and oxalic acid on weight loss, decay and total loss percentage of Le Cont pear fruits during cold storage and under market conditions during 2012 and 2013 seasons

	Storage period	Cold storage (%)			Marketing 5 days after each storage period (%)		
Treatments	(days)	Loss weight	Decay	Total loss	Loss weight	Decay	Total loss
Season 2012							
Control	0	0.00g	0.00h	0.00m	0.00i	0.00j	0.00i
	30	1.97c	0.00h	1.97i	2.60g	0.00j	2.60j
	60	1.83cd	3.50d	5.67e	3.10d	8.48e	11.58e
	90	3.22a	7.05a	10.27a	4.69a	31.10a	35.79a
AVG at 200 ppm	0	0.00g	0.00h	0.00m	0.00i	0.00j	0.00i
	30	1.21f	0.00h	1.21i	2.00k	0.00j	2.00k
	60	1.63de	1.98f	3.61g	2.54h	7.10g	9.64g
	90	2.00c	4.19c	6.19c	3.00e	15.49c	18.49c
OA at 5 mM	0	0.00g	0.00h	0.00m	0.00i	0.00j	0.00i
	30	1.46ef	0.00h	1.46k	2.28j	0.00j	2.28j
	60	1.81cd	1.14g	2.95h	2.80f	6.05h	8.85h
	90	2.40b	3.55d	5.95d	3.40c	10.30d	13.70d
AVG 200 ppm+OA at 5 mM	0	0.00g	0.00h	0.00m	0.00i	0.00j	0.00i
	30	1.70de	0.00h	1.70j	2.40j	0.00j	2.40j
	60	2.00c	2.11e	4.11f	2.97e	8.00f	10.97f
	90	2.97a	5.65b	8.62b	3.90b	25.40b	29.30b
Season 2013							
Control	0	0.00k	0.00i	0.00m	0.00k	0.00i	0.00m
	30	2.11f	0.00i	2.11i	2.94g	0.00i	2.94i
	60	2.98c	3.95d	6.93c	3.87d	9.10e	12.97e
	90	3.44a	7.85a	11.29a	4.93a	32.40a	37.33a
AVG at 200 ppm	0	0.00k	0.00i	0.00m	0.00k	0.00i	0.00m
	30	1.33j	0.00i	1.33i	2.40j	0.00i	2.40i
	60	1.78h	1.00h	2.78h	2.85h	7.35g	10.20g
	90	2.28e	4.33c	6.61d	3.70e	16.00c	19.70c
OA at 5 mM	0	0.00k	0.00i	0.00m	0.00k	0.00i	0.00m
	30	1.59i	0.00i	1.59k	2.58i	0.00i	2.58k
	60	2.00g	1.25g	3.25g	3.00g	6.44h	9.44h
	90	2.77d	3.73e	6.50e	4.05c	11.09d	15.14d
AVG 200 ppm+OA at 5 mM	0	0.00k	0.00i	0.00m	0.00k	0.00i	0.00m
	30	1.95g	0.00i	1.59j	2.81h	0.00i	2.72j
	60	2.29e	2.31f	4.66f	3.49f	8.49f	11.98f
	90	3.14b	5.94b	9.08b	4.41b	26.91b	31.32b

Means followed by the same letters are not significantly different by Duncan's multiple range test at 0.05 levels

two seasons, respectively. The AVG can strongly inhibit the S-adenosylmethionine (SAM) to ACC conversion and therefore, can inhibit ethylene production, delay ripening and prolong fresh time of fruits (Capitani *et al*., 2002).

Zheng *et al*. (2007) showed that oxalic acid treatment delayed fruit ripening and reduced fruit decay incidence compared to the control. It was suggested that the physiological effect of oxalic acid in decreasing ethylene production was an important contributor to delaying the ripening process. Oxalic acid treatment might be a promising method for postharvest storage of mango fruits.

Decay percentage: It is clear from Table 1 that all treatments did not present any decayed fruits till 30 days of cold storage through both seasons. Since, all treatments significantly reduced the percent of decayed fruits than the untreated fruits either after 90 days of cold storage or 5 days during shelf life at room temperature in the both seasons. Thus, the percent of decayed fruits for the control were 7.05 and 7.85% after 90 days of cold storage, but it reached about 31.10 and 32.40% through marketing in both seasons. Yet, dipping "Le Conte" pear fruits in oxalic acid alone at 5 mM significantly reduced decay percentage than all treatments applied after 90 days of cold storage (3.55 and 3.73%) however it were 10.30 and 11.09% during marketing in both seasons, respectively.

AVG treatment significantly reduced decay development in European pears (CV 'Camusina di Genova' and 'Camusina di Bonarcado') mainly when it was applied at 250 mg L^{-1}. This effect was related to the delay of ripen and to possible inhibition of ethylene production by the pathogens and/or infected tissues (D'Aquino *et al*., 2010).

Oxalic acid contributes to induce systemic resistance in plants and this may be due to both an increase in peroxidase (POD) activity and synthesis of new POD isoforms. Also, oxalic acid inhibited the progress of *Alternaria* rot in harvested pear fruit associated with an increase in defense related enzymes (Tian *et al*., 2006). Thus, the effect of oxalic acid in decreasing fruit decay incidence might be mainly attributed to the delay of fruit ripening. The application of oxalic acid has already been shown to induce systematic resistance against diseases caused by bacteria, fungi or viruses to affect antioxidant systems in plants (Malencic *et al*., 2004).

Total loss (%): Total loss in fruit weight is mainly due to loss in fruit weight and decay percentages are presented in Table 1. It is clear from Table 1 that dipping "Le Conte" pear fruits in oxalic acid alone at 5 mM significantly reduced the percentage of total loss in fruit weight in both seasons than the other treatments or the control. Since, oxalic acid application alone at 5 mM presented about 5.95 and 6.50% after 90 days of cold storage whereas, the loss percentage reached 13.70 and 15.14% after 5 days at room temperature in the two seasons, respectively.

Moreover, the percentage of total loss in fruit weight was gradually increased during cold storage or at shelf life as storage period advanced. Since, the percentage of total loss of the untreated fruits were about 10.27 and 11.29% after 90 days of cold storage but reached 35.79 and 37.33% when held 5 days at room temperature at the same period in the both seasons.

Guimaraes and Stotz (2004) investigated the mechanism by which OA affects host cells and tissues and found that guard cells treated accumulated potassium and broke down starch, both of which are known to contribute to stomata opening. In general, disease resistance in fruit decreases during ripening as physiological and biochemical changes increases fruit susceptibility to pathogen infection and the linkage between fruit ripening and increasing disease susceptibility is very strong. Thus, the effect of oxalic acid in decreasing fruit decay incidence might be mainly attributed to the delay of fruit ripening.

Respiration rate (mg CO_2/kg/h): Results of Table 2 and Fig. 1 show that, all evaluated treatments succeeded in reducing respiration rate of "Le Cont" pear fruits during durations in comparison with the control treatment. Whereas, fruits dipping in AVG at 200 ppm+OA at 5 mM proved to be the most efficient treatment (20.50 and 19.20 mg CO_2/kg/h) till 90 days under cold storage and (26.33 and 26.46 mg CO_2/kg/h) 5 days during marketing in both seasons, respectively. On the other hand, the highest respiration rate were obtained by treatments of control (27.60 and 27.20 mg CO_2/kg/h) till 90 days under cold storage and (33.23 and 34.70 mg CO_2/kg/h) 5 days during marketing in both seasons, respectively.

Table 2: Effect of AVG and oxalic acid on respiration rate (mg CO_2/kg/h), firmness (Ib $inch^{-2}$) and internal browning (%) of Le Cont pear fruits during cold storage and under market conditions during 2012 and 2013 seasons

		Cold storage			Marketing 5 days after each storage period		
Treatments	Storage period (days)	Respiration rate	Firmness	Internal browning	Respiration rate	Firmness	Internal browning
Season 2012							
Control	0	29.30a	13.51a	0.00g	29.43b	13.51a	0.00I
	30	22.20c	12.47d	2.10e	25.33e	8.31f	3.40d
	60	21.50d	10.14j	4.40b	24.30f	6.06k	6.70b
	90	27.60b	8.89k	7.60a	33.23a	4.59i	8.53a
AVG at 200 ppm	0	29.30a	13.51a	0.00g	29.43b	13.51a	0.00I
	30	20.70e	13.00b	0.00g	24.23f	10.04b	0.00i
	60	19.60f	12.41d	2.00e	24.30f	8.86e	2.83f
	90	22.30c	11.69g	3.40c	29.46b	7.75h	4.06c
OA at 5 mM	0	29.30a	13.52a	0.00g	29.43b	13.51a	0.00I
	30	19.60f	12.92b	0.00g	23.40g	9.90c	0.00i
	60	18.70g	12.15e	1.90e	22.50h	8.79e	2.53g
	90	21.80cd	11.46h	3.10d	27.30c	7.20i	3.60d
AVG 200 ppm+OA at 5 mM	0	29.30a	13.51a	0.00g	29.43b	13.51a	0.00I
	30	17.70h	12.64c	0.00g	23.40g	9.33d	0.00i
	60	17.90h	11.80f	1.40f	22.46h	8.00g	2.30h
	90	20.50e	10.95i	2.90d	26.33d	6.86j	3.13e
Season 2013							
Control	0	28.2a	13.00a	0.00f	28.60b	13.00a	0.00h
	30	22.4c	12.14d	1.90e	24.33g	8.10f	3.13e
	60	20.9de	9.98j	4.90b	25.46f	6.00j	6.60b
	90	27.2b	8.15k	7.90a	34.70a	4.10k	8.56a
AVG at 200 ppm	0	28.2a	13.00a	0.00f	28.60b	13.00a	0.00h
	30	20.4ef	12.35c	0.00f	22.30h	9.90b	0.00h
	60	18.5i	11.80e	1.90e	21.50i	8.96d	2.50g
	90	21.4d	11.20g	3.10c	28.13c	7.99f	3.90c
OA at 5 mM	0	28.2a	13.00a	0.00f	28.60b	13.00a	0.00h
	30	19.4gh	12.62b	0.00f	22.40h	9.70c	0.00h
	60	19.9fg	12.00d	2.00e	21.66i	8.59e	2.70f
	90	20.3ef	11.05h	2.90c	26.83d	7.45h	3.43d
AVG 200 ppm+OA at 5 mM	0	28.2a	13.00a	0.00f	28.60b	13.00a	0.00h
	30	20.63e	12.30c	0.00f	22.40h	9.00d	0.00h
	60	18.9hi	11.65f	1.80e	20.30j	7.85g	2.40g
	90	19.2h	10.40i	2.30d	26.46e	6.13i	3.16e

Means followed by the same letters are not significantly different by Duncan's multiple range test at 0.05 levels

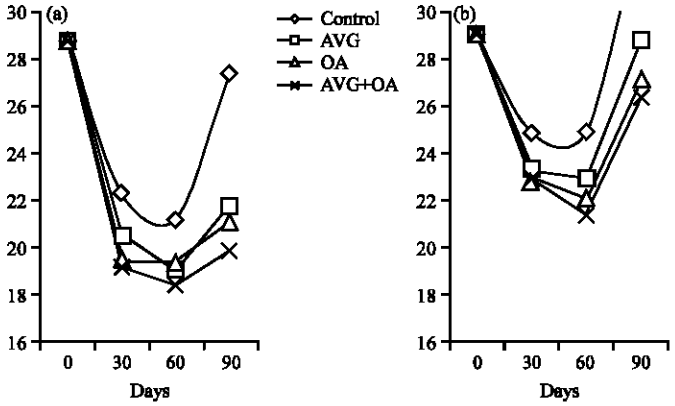

Fig. 1(a-b): Respiration rate percentage in Le Conte fruits after (a) 90 days of cold storage and (b) 5 days under marketing after each storage period as a mean of 2012-2013 seasons

Aminoethoxyvinylglycine (AVG) inhibits ethylene production during fruit ripening by blocking the conversion of S-adenosylmethionine (SAM) to 1-aminocyclopropane-1-carboxylic acid (ACC). This delay in fruit ripening was mainly due to an inhibition of ethylene biosynthesis, followed by reduced softening in flesh firmness.

In red delicious apple, Silverman *et al.* (2004) observed that AVG reduced ethylene production and starch degradation but had no significant effect on organic acids, color and sugar. It also reduced ethylene and protein biosynthesis and delayed fruit maturation in Cox's Orange Pippin apples (Johnson and Colgan, 2003).

Zheng *et al.* (2007) proved that mango fruits dipped in 5 mM OA solution for 10 min showed lower ethylene production, lower incidence of decay and slowed the respiration of fruits, while increased the activities of antioxidant enzymes, maintained membrane integrity and delayed the fruit ripening process.

Firmness (lb inch^{-2}): Fruit firmness testing is currently the main method used to determine pear maturity. Data from Table 2 and Fig. 2 show clearly that, fruit firmness was reduced as storage period advanced under cold storage or through shelf life at room temperature. The data also confirm that all treatments used significantly reduced changes in fruit firmness than the control at cold storage or during shelf life at room temperature through the two seasons. However, the reduction in fruit firmness was higher during shelf life at room temperature than under cold storage. Thus, fruit firmness for the control was 8.89 and 8.15 lb inch^{-2} after 90 days of cold storage, but it reached about 4.59 and 4.10 lb inch^{-2} through marketing in both seasons. Furthermore, treated fruits with AVG at 200 ppm alone maintained a higher fruit firmness (11.69 and 11.20 lb inch^{-2}) after 90 days of cold storage while, reached 7.75 and 7.99 lb inch^{-2} from fruits held 5 days at room temperature of two seasons, respectively.

Application of AVG to stark red gold nectarines fruits delayed flesh softening. The delay in flesh softening caused by AVG could be one of the consequences of reduced ethylene production (Torrigiani *et al.*, 2004). In 'Bartlett' pear, pre-harvest AVG treatments either 14 or 7 days before harvest did not affect ethylene production at harvest, but delayed changes in skin color, softening and starch content (Clayton *et al.*, 2000). Arctic snow nectarines also exhibited delayed ripening, lower ethylene production and extended firmness after treatment with AVG (McGlasson *et al.*, 2005). During fruit ripening, oxalate also plays important roles such as in the oxalate-soluble pectin which is related to firmness of banana (Emaga *et al.*, 2008).

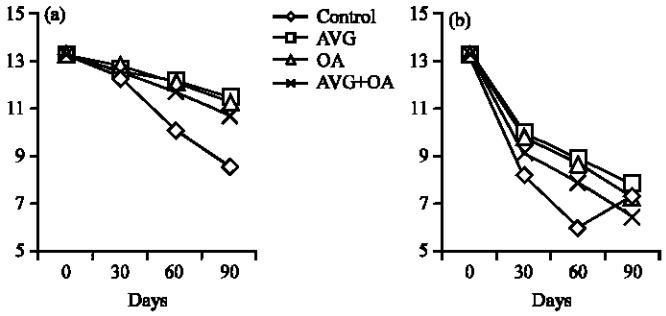

Fig. 2(a-b): Firmness (lb inch^{-2}) in Le Conte fruits after (a) 90 days of cold storage and (b) 5 days under marketing after each storage period as a mean of 2012-2013 seasons

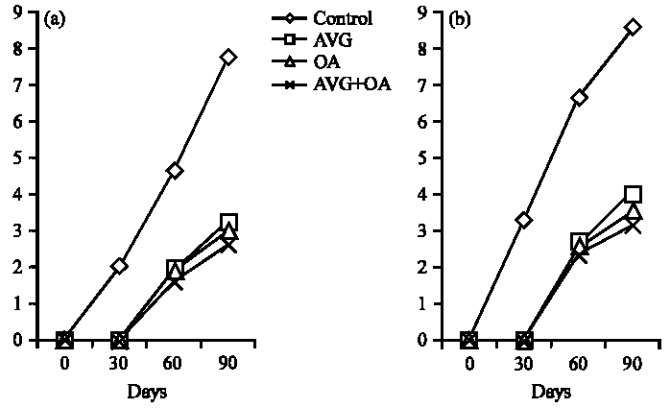

Fig. 3(a-b): Internal browning in Le Conte fruits after (a) 90 days of cold storage and (b) 5 days under marketing after each storage period as a mean of 2012-2013 seasons

Internal browning (%): The flesh browning index of all fruits increased after 3 months of storage plus 5 days of shelf life (Table 2 and Fig. 3). Pears treated by AVG+OA showed slight browning (2.90 and 2.30%) after 90 days of cold storage while, ranged 3.13 and 3.16% after 5 days at marketing in both seasons, respectively. On the other hand, the highest browning index was observed in control fruits, increasing to 7.60 and 7.90% at cold storage while ranged 8.53 and 8.56% after 5 days at marketing during both seasons, respectively.

Toal and Jones (1999) has reported that oxalic acid contributes to induced systemic resistance in plants and this may be due to both an increase in peroxidase (POD) activity and synthesis of new POD isoforms. Furthermore, oxahc acid is considered to be a natural anti-oxidant for artificial preservation of oxidized materials and under consideration to replace synthetic alternatives to minimize the risk of residues in bee products (Moosbeckhofer *et al.*, 2003).

We observed from Fig. 1, 2 and 3 great relationship among the rate of respiration, firmness and internal browning of Le Conte pear fruits during cold storage and through marketing at room temperature, as soon as increasing the fruit respiration rate resulting decreases in fruits firmness and raising the internal browning. So, this association may be due to the effect of aminoethoxyvinylglycine (AVG) to inhibit ethylene production during fruit ripening by blocking the conversion of S-adenosylmethionine (SAM) to 1-aminocyclopropane-1-carboxylic acid (ACC). Also, oxalic acid led to increase peroxidase (POD) activity and synthesis of new POD isoforms which aid to delay ripening.

Soluble solids content (SSC%): Data from Table 3 showed that, the percent of SSC in fruit juice was gradually increased as storage periods advanced either a cold storage or during marketing in both seasons. Since, all treatments gave somewhat lower values of SSC in fruit juice than the control fruit which ranged 14.93 and 15.92% after 90 days of cold storage and it were 14.70 and 15.35% after five days as marketing in both seasons under the study. The data also disclose that, OA at 5 mM gave a somewhat increment in SSC values in fruit juice compared with other treatments conducted averaged 14.75 and 15.64% after 90 days of cold storage and it were 14.51 and 15.17% after five days as marketing in both seasons, respectively.

Pears is a climacteric fruits that tend to have increased SSC until maximum is reached at the fully ripe stage, followed by a decreasing trend when the fruits reaches full senescence (Xiao *et al.*, 2011).

Zheng *et al.* (2007) found that mango fruits dipped in 5 mM oxalic acid L^{-1} for 10 min and stored at controlled atmospheres (6% CO_2, 2% O_2 and 14±1°C) were more firm and had lower total soluble solid contents, disease index and decay incidence compared with control. It was suggested that the effects of exogenous oxalic acid on the enhancement of antioxidant capacity helps to retardation of the ripening process and decrease in decay incidence during storage and that oxalic acid treatment is an alternative method for prolonging the storage life of mango fruits.

Titratable acidity (TA): From Table 3, it's clear that the content of total acidity in fruit juice was decreased with the progress in storage period from harvest till 90 days at cold storage or during shelf life at room temperature, which may be attributed to the use of acids as substrate for respiration. The values of total acidity in fruit juice were almost lower during shelf life than those obtained at cold storage.

Significant differences began to appear at the end of cold storage. The highest value was obtained with AVG at 200 ppm in the first season (0.240) while untreated ones gave higher values of total acidity in the second season (0.260%) after 90 days of cold storage. Moreover, control treatment produced higher acidity after 5 days as marketing in the two seasons ranged 0.233 and 0.255%, respectively.

On the other hand, AVG treatment at 200 ppm gave lower acidity after 5 days as marketing in the two seasons ranged 0.229 and 248% respectively, but the reduction was unpronounced. Acidity is an important component of fruit flavor and in combination with SSC, contributes to overall quality. Total organic acid content declines in fruit as they mature, ripen and storage. However, fruit acidity should be considered in conjunction with other quality parameters, especially firmness and SSC as consumer studies show a strong relationship between the three (Harker *et al.*, 2008). In addition, reduction in acidity during ripening may be due to their conversion into sugars and further utilization in the metabolic process of the fruit respiration (Abbasi *et al.*, 2009). Softening of flesh, decreased acidity, increased carotenoid pigments among the recognized parameters of maturity and ripening in mango.

SSC/acid ratio: Considering to the effect on SSC/acid ratio, data in Table 3 reveal that the values of SSC/acid ratio were progressively increased by the storage period advanced from harvest till 90 days either at cold storage or during marketing at room temperature.

With regard to the effect of these treatments on SSC/acid ratio the data reveal that, control treatment produced a higher value of SSC/acid ratio at cold storage in the first season since the values averaged about 64.08 while, in the second one AVG at 200 ppm treatment presented higher value 62.04%.

Table 3: Effect of AVG and oxalic acid on SSC (%), acidity (%) and SSC/acid ratio (%) of Le Cont pear fruits during cold storage and under market conditions during 2012 and 2013 seasons

Treatments	Storage period (days)	Cold storage (%)			Marketing 5 days after each storage period (%)		
		SSC	Acidity	SSC/Acid ratio	SSC	Acidity	SSC/Acid ratio
Season 2012							
Control	0	13.10h	0.274a	47.81h	13.10k	0.274a	47.81f
	30	13.98e	0.260b	53.77fg	13.74g	0.261b	52.64d
	60	14.49c	0.243d	59.63d	14.29d	0.254cd	56.26b
	90	14.93a	0.233f	64.08a	14.70a	0.233g	63.09a
AVG at 200 ppm	0	13.10h	0.274a	47.81h	13.10k	0.274a	47.81f
	30	13.73f	0.258b	53.22g	13.40j	0.264b	50.75e
	60	14.16d	0.249c	56.87e	14.13e	0.249e	56.75b
	90	14.70b	0.240de	61.25c	14.27d	0.229h	62.31a
OA at 5 mM	0	13.10h	0.274a	47.81h	13.10k	0.274a	47.81f
	30	13.76f	0.253c	54.39f	13.60h	0.253d	53.75c
	60	14.20d	0.242d	58.67d	14.07ef	0.247ef	56.96b
	90	14.75b	0.236ef	62.51b	14.51b	0.230gh	63.09a
AVG 200 ppm+OA at 5 mM	0	13.10h	0.274a	47.81h	13.10k	0.274a	47.81f
	30	13.63g	0.250c	54.52f	13.50i	0.257c	52.53d
	60	14.12d	0.240de	58.83d	14.00f	0.245f	57.14b
	90	14.45c	0.234f	61.75bc	14.40c	0.231gh	63.23a
Season 2013							
Control	0	13.95h	0.297a	46.97h	13.95h	0.297a	46.97f
	30	15.10ef	0.286b	52.98g	14.93d	0.288bc	51.83d
	60	14.65g	0.269d	54.46ef	15.10bc	0.271f	55.71b
	90	15.92a	0.260e	61.23a	15.35a	0.255g	60.20a
AVG at 200 ppm	0	13.95h	0.297a	46.97h	13.95h	0.297a	46.97f
	30	15.00f	0.280c	53.57fg	14.33g	0.284cd	50.45e
	60	15.28cd	0.271d	56.38cd	14.50f	0.275ef	52.72d
	90	15.57b	0.251fg	62.04a	14.97d	0.248h	60.35a
OA at 5 mM	0	13.95h	0.297a	46.97h	13.95h	0.297a	46.97f
	30	15.00f	0.282bc	53.19g	14.54f	0.289b	50.31e
	60	15.33c	0.270d	56.78c	15.00cd	0.276e	54.34c
	90	15.64b	0.255ef	61.33a	15.17b	0.250h	60.69a
AVG 200 ppm+OA at 5 mM	0	13.95h	0.297a	46.97h	13.95h	0.297a	46.97f
	30	15.59b	0.281bc	55.48de	14.65e	0.282d	51.95d
	60	15.93a	0.271d	58.78b	15.00cd	0.274ef	54.74c
	90	15.20de	0.249g	61.04a	15.13b	0.250h	60.52a

Means followed by the same letters are not significantly different by Duncan's multiple range test at 0.05 levels

Moreover, in the first season after 5 days during marketing AVG 200 ppm+OA at 5 mM treatment gave a higher value of SSC/acid ratio (63.23%) while, oxalic acid application alone produced higher value of this trend ranged 60.69% in the second seasons.

In the ripening fruits, the alcohol dehydrogenase (ADH), a main enzyme responsible for catalyzing the reduction of acetaldehyde to ethanol during the fermentation of sugars (glycolysis) plays an important role in the development of sugar compounds (Speirs *et al*., 2002). Exogenous OA application decreased ADH activity in jujube fruit during storage periods at 20°C (Wang *et al*., 2009).

Skin hue color (h°): From Table 4 data presented that all applied treatments delayed the development of fruits skin color when compared with the untreated fruit. The loss of the green color in pear skin was expressed as lower hue angle (h°). In control fruit, hue angle decreased rapidly during storage indicating a losing green color, either at cold storage (83.00 and 89.00 h°) or during shelf life (72.00 and 75.00 h°). Furthermore, green color in pear fruits decreased with storage period advanced during cold storage or under room temperature. Whereas, the values of green color during shelf life were almost lower than those obtained at cold storage during the both seasons of study. Moreover, AVG at 200 ppm maintained a higher green color than all treatments or the

Table 4: Effect of AVG and oxalic acid on sugar (%) and hue angle (h°) of pear fruits during cold storage and under market conditions during 2012 and 2013 seasons

		Cold storage (%)		Marketing 5 days after each storage period	
Treatments	Storage period (days)	Sngar	Hue angle	Sugar	Hue angle
Season 2012					
Control	0	8.36i	125.00a	8.36j	125.00a
	30	9.65f	119.33b	9.06g	111.00de
	60	10.54c	104.33f	9.74d	93.66j
	90	11.34a	83.00g	10.44a	72.00k
AVG at 200 ppm	0	8.36i	125.00a	8.36j	125.00a
	30	9.30g	121.00b	8.67i	119.33b
	60	10.16e	114.66cd	9.05g	112.66cd
	90	11.07b	109.66e	10.04c	103.00gh
OA at 5 mM	0	8.36i	125.00a	8.36j	125.00a
	30	9.26g	116.00c	8.84h	114.33cd
	60	10.37d	109.66e	9.33e	106.00fg
	90	11.10b	104.00f	10.12b	99.00i
AVG 200 ppm+OA at 5 mM	0	8.36i	125.00a	8.36j	125.00a
	30	9.13h	119.33b	8.74i	115.66c
	60	9.60f	111.66de	8.89h	109.00ef
	90	10.15e	106.00f	9.17f	100.66hi
Season 2013					
Control	0	8.90j	131.66a	8.90g	131.66a
	30	9.67g	120.00bc	9.37e	115.00bc
	60	10.94d	100.66f	10.24c	96.66h
	90	11.80a	89.00g	10.83a	75.00i
AVG at 200 ppm	0	8.90j	131.66a	8.90g	131.66a
	30	9.20i	121.66b	9.00fg	119.66b
	60	10.40e	119.66bc	9.56de	113.00cd
	90	11.30c	111.00d	10.13c	106.66ef
OA at 5 mM	0	8.90j	131.66a	8.90g	131.66a
	30	9.45h	120.00bc	9.12f	115.66bc
	60	10.50e	113.00d	10.05c	108.00de
	90	11.64b	107.00e	10.55b	100.66gh
AVG 200 ppm+OA at 5 mM	0	8.90j	131.66a	8.90g	131.66a
	30	9.54h	120.00bc	9.05fg	114.66bc
	60	10.10f	117.33c	9.14f	112.66cd
	90	10.84d	105.00e	9.66d	102.33fg

Means followed by the same letters are not significantly different by Duncan's multiple range test at 0.05 levels

control after 90 days of cold storage and 5 days during shelf life in both season, because the hue angle decreased slowly during all of the storage period.

The increment due using these treatment reached about 109.66 and 111.00 h° after 90 days of cold storage, respectively during both seasons. While, after 5 days during shelf life in the same period the values averaged 103.00 and 106.66 h° in both seasons, respectively. Maintaining the coloring of fruits increase its market values so, AVG generally delays ripening and undesirable color formation on fruit (Greene and Schupp, 2004; Rath and Prentice, 2004).

Total sugar: Concerning to the effect on total sugar, Data from Table 4 showed that total sugar content in fruit juice of "Le Conte" pear was gradually increased as storage period prolonged either after cold storage or during shelf life at room temperature.

Since, the untreated fruits produced higher significant values of total sugar in pear fruits than all treatments which ranged 11.34 and 11.80% after 90 days of cold storage and it were 10.44 and 10.83% after five days as marketing in both seasons under the study. The data also disclose that, application of AVG 200 ppm+OA at 5 mM presented lower values of total sugars compare to the applied treatments averaged 10.15 and 10.84% after 90 days of cold storage and it were 9.17 and 9.66% after five days as marketing in both seasons, respectively. Sugars are the most important constituent of fruit product and are essential factor for the flavor of the food product and also act as a natural food preservative.

In red delicious apple, Silverman *et al.* (2004) observed that AVG reduced ethylene production and starch degradation but had no significant effect on organic acids, color and sugar.

Guimaraes and Stotz (2004) investigated the mechanism by which OA affects host cells and tissues and found that guard cells treated with OA accumulated potassium and broke down starch, both of which are known to contribute to stomatal opening.

CONCLUSION

This study reveals that AVG and/or OA materials were relatively more effective in delaying respiration rate and ripening, since it play an integrated role in many of the biochemical changes occur during ripening such as, firmness, sugar, color and internal browning. Besides, AVG+OA were more effective on reduced respiration rate, showed slight browning and produced a lower fruit sugar. AVG considered a material with promising future in prolonging the storability of Le Conte pear fruits and maintaining the highest possible quality during marketing.

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