Effect of Postharvest Aminoethoxyvinylglycine, 1-Methylcyclopropene and Jasmonic Acid Treatments on Storability and Quality Maintenance of Apricot Fruit Cv. "Canino"

Radwa F. Satuor, M.M. Attia, H.A. Kassem and Y.S. Mostafa
Pomology department, Faculty of Agriculture, Alexandria University, Alexandria, Egypt

ABSTRACT

The present study was performed on Canino apricots to study the effect of postharvest treatment with AVG 50, 100 mg/L, 500, 1000 µg/L 1-MCP and 50, 100 η mol JA on fruit physical, chemical and storability characteristics during cold storage at 1 ±1˚C and 90±5 % RH. All treatments significantly preserved fruit firmness, decreased fruit weight loss percent and slowed acidity decrement. 1-MCP and AVG delayed the color changes and reduced the decay percent. The most effective treatments to maintain fruit quality up to 30 days were 1- MCP at 1000 µg/L followed by AVG at 100 mg/L.

Keywords: Agrochemicals, fruit characteristics, browning index, storagability.

INTRODUCTION

Apricot (*Prunus armeniaca L.*) is one of the important stone fruits, planted in Egypt. According to FAO its total cultured area in Egypt is 6677 hectares in 2016 produced about 16.88 Tons/ hectare with total production of 102247 Tons (Faostat 2018).

Apricot is a climacteric fruit, characterized by a peak in ethylene production close to the ripening stage, leading to rapid ripening and deterioration after harvest and short shelf-life (Fan et al., 2018; Muñoz-Robredo et al., 2012). The maturity stage at harvest strongly affected the fruit quality, consumer acceptability and shelf-life. The too early harvested fruit do not reach the optimum quality, while, the overripe harvested fruit rapidly deteriorates (Davarynejad et al., 2013). Apricot fruit is highly susceptible to flesh softening and loss of flavor during postharvest storage and most of the dramatic ripening processes are highly regulated by ethylene.

Thereby, many postharvest management practices may be used to delay fruit ripening progress, and to maintain almost the related quality attributes. 1-MCP is an odorless, non-toxic ethylene action inhibitor, as it, blocks the ethylene active sites (Sisler and Serek, 1997). The irreversible binding of 1-MCP with the ethylene receptors leads to ethylene insensitivity and to delay or inhibit ethylene-mediated ripening and senescence processes of various fruits (Blankenship and Dole 2003; Watkins 2006). It is commonly used to delay ripening and maintain quality of many horticultural commodities (Palou and Crisosto, 2003), and slows down the softening of various climacteric fruits including; peach (Liguori et al., 2004), pomes (Watkins et al., 2000) and apricot (Dong et al., 2002 and Shi et al. 2013). Nevertheless, Liguori et al., (2004) showed that 1-MCP can extend shelf-life of rapidly soften and highly perishable fruits such as early season, melting flesh stone fruits.

In addition, aminoethoxyvinylglycine (AVG) inhibits the synthesis of ethylene at the level of the aminocyclopropane carboxylic acid synthase enzyme (ACS), responsible for the conversion of S-adenosylmetionine (SAM) to 1-aminocyclopropane carboxylic acid (ACC), which is an immediate precursor of ethylene, (Adams and Yang, 1979). AVG slows the softening rate and delay ripening of apricot, nectarines, peaches, and pears (Byres, 1997; Garner et al., 2001; Palou and Crisosto, 2003; Valdés et al., 2009; D'Aquino et al., 2010; Mu˜noz-Robredoa et al., 2012; and Tarabih, 2014).

Jasmonic acid (JA) is an endogenous plant hormone that activates an array of plant defense mechanisms. Jasmonates is the common name for JA and its volatiles derivative MeJA, (Mueller et al., 1993; Creelman and Mullet, 1997) which, are fatty acid derivative with a 12-carbon backbone that plays a role in plant development and plant defense against pests. MeJA has shown promising signs in preventing postharvest disease and disorders in horticultural crops, also to prolong shelf-life by postharvest application on some perishable commodities such as strawberry (Geransayeh et al., 2015) and maintain quality of mango fruit (Gonza´lez-Aguilar et al., 2001). Meng et al., (2009) reported that MeJA treatment regulated the degradation of cell wall and delay fruit softening of peach fruit flesh. Hence, the use of 1-MCP, AVG and JA are potentially of commercial value to manage postharvest disorders and storability of apricot fruit. So, the main objective of this study was to investigate the effect of postharvest treatments with 1-MCP, AVG and JA on storability and fruit quality of Canino apricot fruit during cold

storage at 1±1ºC and 90±5 % relative humidity (RH).

MATERIALS AND METHODS

1. Plant material treatments and statistical design:

' Canino' apricot fruits were harvested from 9-10 year-old trees from a private orchard in Nubaria district, Al Beheira governorate, Egypt, during 2016 and 2017 seasons. Fruits were manually harvested in the morning at early ripe stage (greenish-yellow skin color and firm flesh) and were directly transported to the postharvest laboratory, at the pomology department, Faculty of Agriculture, Alexandria University. The fruits were washed in chlorinated water at 100 ppm for 2 min., air dried, sorted to remove the mechanically injured and defected fruits. The selected fruits were divided into seven groups (32 kg per group). Each group was subjected to one of the following treatments in a randomized complete block design (RCBD); control (dipping in water only), 1-MCP (AgroFresh®) by incubating fruit in 0.685 m^3 sealed chamber with 500 or 1000 µg/L at 20±2ºC for 12h, AVG at 50 or 100 mg/L by dipping in the AVG solutions for 10 min according to Valdés et al., (2009) and JA at 50 or 100 η mol by dipping in JA solutions for 10 min according to Ezzat (2014). Fruits treated with AVG or JA were air dried to remove the excess solutions from the fruit surface before storage. All treated fruits were packed in plastic boxes (40 cm X 25 cm X 15cm), then stored in cold storage room at 1±1ºC and 90±5 % RH. Ten fruits per replicate were taken before storage to determine the initial fruit quality and at 4 days intervals to follow up the fruit quality changes.

2. Fruit physical characteristics:

Fruit color was measured on the opposite pared cheeks of 10 fruits along their equatorial axes, using a Minolta Chromo meter, model CR-200 and expressed as lightness (L*), chroma (C*) and hue angle ($h°$) according to McGuire (1992). The fruit firmness was measured on the two opposite cheeks of each fruit after removal of small thin piece of peel using Effe-gi penetrometer, with an 8 mm (5/16 inches) plunger (Effe-gi, 48011 Alfonsine, Italy). The fruit firmness was measured as pounds-force (lbf) then converted into Newton (N) by multiply the values by (4.448), Mitcham et al. (1996).

a. Fruit chemical characteristics:

A representative sample of fruit flesh from each replicate were homogenized in the fruit juicer. The resulted juice was used to measure the soluble solids contents (SSC) by hand refrectometer (Atago, mod. N-1E, Japan) and expressed as percentage (%). Titratable acidity (TA) was determined by titration with NaOH 0.1N in the presence of ph.ph indicator and expressed as malic acid percentage (%) (Chen, et al., 2009).

The sugar extraction was carried out by using ten grams of well mixed fruit flesh tissues, using distilled water according to Loomis and Shull (1937). Reducing and total reducing sugars then determined by Fehling's test for reducing sugars and the inversion of the non-reducing sugars were done according to (AOAC, 2000). Non-reducing sugars were calculated by subtracting reducing sugars from total reducing sugars.

One gram of fruit flesh was homogenized in 25 ml of 95% ethanol for phenolic compounds extraction at 25 ºC for 15 min, then filtered. Total phenols (mg/100g) was extracted from fruit flesh sample with ethanol (80 %) and determined using Folin-Denis reagent according to Moyo et al., (2010).

b. Fruit storability:

Fruit storability was expressed as the percentage of fruit weight loss and decay incidence as well as fruit browning. Initial weight of 15 fruits was recoded for each replicate then fruit weight was recorded every 4 days throughout the experiment period and the percentage of fruit weight loss was calculated as follow: Weight loss (%) = $[(W_0-W_1)/W_0] \times 100$ (where W_0 is the initial weight and W_1 is the weight measured at sampling date).

The external browning index assessment of the fruit skin was based on five grades from 0 to 4 according to the browning area on the peel as follows: 0 = none (excellent quality); 1 = browning area <5%; 2 = browning area 5-25%; 3 = browning area 25-50%; 4 = browning area >50% (poor quality). The results were calculated from the following equation:

External browning index

$$= \sum \frac{(\text{browning rating}) \times (\text{number of fruit with the browning rating})}{4 \times \text{total number of fruit in the sample}}$$

The fruit was unacceptable if browning indices were 0.4 or higher (Wang et al., 2005). The decay incidence was determined by calculating the number of decayed fruits at the sampling date and expressed as a percentage of total fruit number.

$$\text{Decay incidence (\%)} = \frac{\text{Number of decayed fruits}}{\text{Total fruit number}} \times 100$$

Fruit decay was determined as percentage of decay incidence and transformed, using arcsine transformation to fit for analysis of variance.

c. Statistical analysis

The analysis of variance two way (ANOVA) was carried out according to Petersen (1985) using Statistical Package for the Social Sciences (SPSS) and differences among the means were determined for significance at $p<0.05$ using LSD_range test. Results were presented for the main effect of treatments only.

RESULTS AND DISSECTION

1. Fruit physical characteristics:

Concerning the external fruit color as lightness (L*), chroma (C*) and hue angel (h^o); the effect of the postharvest applied treatments on L* present in Fig. (1a), results showed that all applied chemicals with the two levels significantly maintained higher L* values than untreated fruit in both seasons. No significant differences were noticed among the two levels of each chemical substance used in both seasons except, between AVG treatments in the second season, where fruit treated with AVG at 100 mg/L had significant higher L* value than those treated with 50 mg/L.

Regarding the effect of the different treatments on C* of fruit skin results presented in Fig. (1b), the applied treatments significantly recorded lower yellow color intensity, where all treatments recorded lower significant C* values than control in both seasons and JA at 50 and 100 η mol in the first season only. The lowest significant C* value was found with 1-MCP at 1000 µg/L, but the differences were not big enough to be significant with 1-MCP at 500 µg/L and AVG at 100 mg/L in the first season only.

The results also indicated that all used treatments significantly maintained light yellow fruit color as indicated from the higher h^o than untreated fruit in both seasons Fig. (1c). Apricot fruits treated with the higher concentrations of 1-MCP and AVG recoded higher h^o than treated with lower concentrations, but the differences were significant in the second season only. Meanwhile, no significant differences were noticed among the two levels of JA in both seasons**.** The postharvest treatments with 1-MCP, AVG and JA significantly reduced apricot fruit softening Fig. (1d). The higher concentration of each applied substance was more effective for maintaining the fruit firmness than lower concentration in both seasons. But, the differences were significant between the two levels of JA in both seasons and the two levels of 1-MCP in the second season only. The highest significant fruit firmness was found with 1-MCP at 1000 µg/L in both seasons, followed by AVG at 100 mg/L in the second season. The results showed that 1-MCP treatments were the most effective for delaying fruit color development followed by AVG treatments in both seasons. These results might be due to the role of 1-MCP and AVG on retarding ethylene action and production, which subsequently delay ripening changes progress. Additionally, ethylene is playing an important role in the synthesis of chlorophyllase enzyme involved in the chlorophyll degradation and fruit coloration. In accordance, 1-MCP prevents or delays chlorophyll degradation and various types of color changes in a wide range of crop species by retarding the ethylene action (Yu and Yang, 1979; Palou and Crisosto, 2003 and Valdés *et al*., 2009).

Findings of the present study go along with, Valdés et al., (2009) who stated that 1-MCP and higher dose of AVG treatment on "Modesto" apricot showed a higher hue values, fruit color tended to be more green which means that 1-MCP delayed ripening process and coloration. Similar finding were reported by Tarabih, (2014) working on pears. However, Fan et al., (2002), stated that 1-MCP decreased the hue angle of treated peach fruit, and , Mahajan et al., (2010) reported that 1-MCP treated cherries presented a significantly lower L* value only after 6 days of storage at low temperature. Nevertheless, 1-MCP did not show any effect on apricot color in other studies (Botondi et al., 2003; and Mu˜noz-Robredoa et al., 2012). The results also conflict to those of Gonzalez-Aguilar et al. (2003) who mentioned that MeJA treatment enhanced yellowing of papaya fruit.

The results also revealed that 1-MCP and AVG treatments effectively maintain apricot fruit firmness in both seasons, these may be due to the role of these substances on the reduction of ethylene related reactions, through the suppress of softening related genes, which strongly retard the degradation of cell wall components (cellulose, hemicellulose and pectin) according to Fan et al., (2018). Fruit softening commonly attributes to the deterioration of cell wall, which is related to the degradation of pectin (Bennett and Labavitch, 2008). Thus, Asgharia and Aghdam, 2010 stated that, inhibiting cell wall and membrane degrading enzymes such as, pectin methyl esterase, poly-galacturonase, lipoxygenase, and cellulase, leading to decreased fruit softening rate.

Obtained results of 1-MCP goes on line with those of Valdés *et al*., (2009) and Mu˜noz-Robredoa *et al*., (2012) in treated apricot and peaches ,Yu *et al.,* (2017) in nectarines and Ozkaya *et al.*, (2014) in fig. Also, the previous studies reported that AVG significantly slowed the softening rate for apricot (Palou and Crisosto, 2003; Valdés *et al*., 2009 and Mu˜noz-Robredoa *et al*., 2012), and pears (Tarabih, 2014 and D'Aquino *et al*., 2010). Also, with Meng *e t al*., (2009) reported similar results found of MeJA-treatment, reduced loss of firmness to be in agreement with Gonza´lez-Aguilar *et al*., (2001) results in mango. However, it do contradict with Perez *et al.*, (1997) who demonstrated that, MeJA treatments slightly decreased the firmness of strawberry and with Gonza´lez-Aguilar *et al*., (2000) who reported that MeJA did not affect the firmness of mango 'Tommy Atkins' during cold storage and shelf-life. So, it appears that response of fruit to MeJA treatment in the reduction of firmness loss may be related to the cultivars and the MeJA concentrations used.

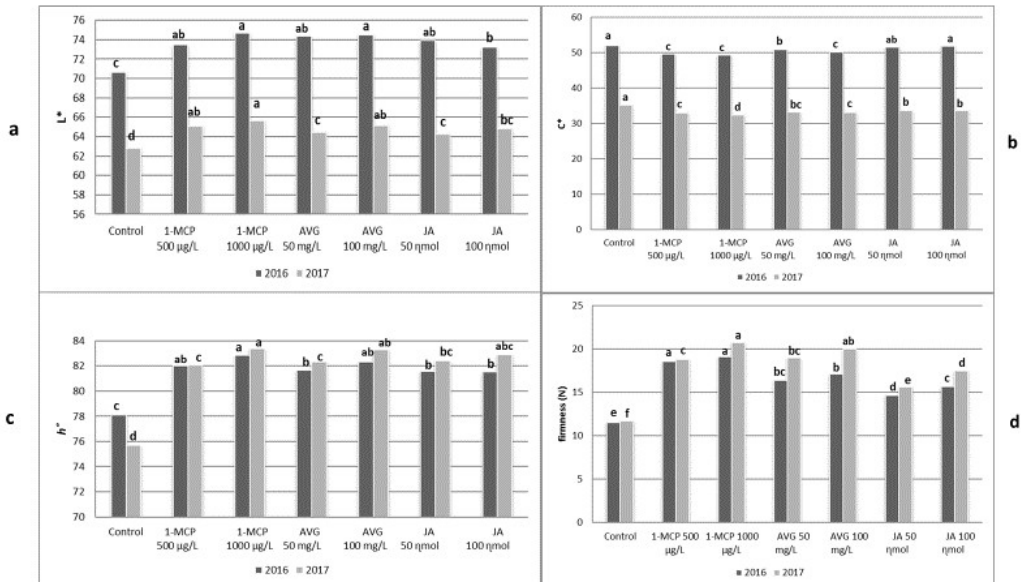

Figure 1: Effect of postharvest treatments on L* (a), C* (b), h°(c) and firmness (d), of 'Canino'

2. Fruit chemical characteristics:

The highest significant SSC percent occurred in control fruit, but the differences with JA 50 ηmol was not significant in both seasons Fig. (2a). No significant differences were noticed among the two concentrations of each substance in both seasons, except between the two concentrations of 1-MCP and JA in the second season only, whereas, the higher concentration was significantly lower in SSC percent. In the first season, the lowest significant SSC percent was noticed with 1-MCP treatments, followed by AVG without significant differences among them. Meanwhile, in the second season treatments of 1-MCP at 1000 µg/L, AVG at 50, 100 mg/L and JA at 100 η mol recorded the lowest significant SSC percent.

Results in Fig. (2b) revealed that the lowest significant fruit TA percentage was noticed with control fruits in both seasons. However, the highest significant fruit TA percentage was occurred with the higher concentrations of both 1-MCP and AVG in the two experimental seasons. No significant differences were found among the rest treatments in the second season, and between treatments of 1-MCP at 500 µg/L and JA at 100 η mol and between AVG at 50 mg/L and JA at 50 η mol in the first season only. Higher concentration of 1-MCP, AVG and JA significantly maintained higher TA percentage than those of lower concentration in both seasons, except between JA levels in the second season only.

Regarding to the effect of the postharvest treatments on total sugars results in Fig. (3a) showed that, the differences among untreated and treated fruits were not significant in both seasons, except those treated with 1-MCP 1000 µg/L and AVG treatments in the first season only which were significantly lower compared to the control, 1-MCP at 500 µg/L and JA at 100 ηmol. However, in the second season 1-MCP at 500 and 1000 µg/L treatments recorded higher significant total sugars percentage than JA at 50 and 100 ηmol. With regard to reducing sugars; data presented in Fig. (3b) revealed that the highest significant reducing sugars percentage was found with the control in both seasons. Moreover, there were no significant deference between the two applied levels of each substance. 1-MCP at 500 µg/L was significantly higher in reducing sugars percentage compared to AVG at 50 and 100 mg/L in the first season. As for the second season, 1-MCP at 500 and 1000 µg/L treatments were significantly higher in reducing sugars than AVG at 100 mg/L and JA at 50 and 100 ηmol. Concerning non- reducing sugars the lowest percent was found with control in both seasons, without markedly differences among the applied substance Fig. (3c).

As for total phenols content, the higher significant percentages were occurred in fruit treated with 1-MCP at 500 and 1000 µg/L, while the differences among 1-MCP at 500 µg/L and AVG at 100 mg/L not big enough to be significant in both seasons Fig. (3d). On the other hand, the lowest significant phenolic content was found with control and JA at 50 ηmol in both seasons in addition to JA at 100 ηmol in the second season.

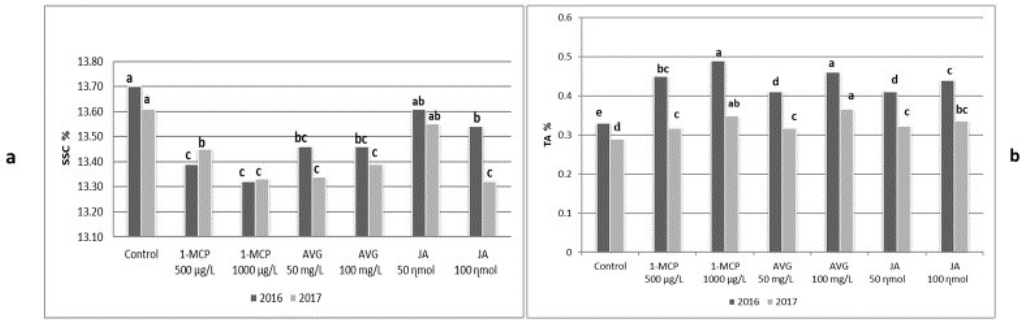

Figure 2: Effect of postharvest treatments on soluble solid content SSC (a) and titratable acidity (b) of 'Canino' apricot fruit.

The results showed that the highest SSC percentage was found with untreated fruits (control) in both seasons, and all used substances were lower in their SSC percentage, these may be due to the effect of 1-MCP, AVG and JA on maintaining cell wall integrity and delay degradation. Cell walls contain large amounts of polysaccharides, mainly pectins and cellulose. The activation of cell wall degrading enzymes during the ripening progress solubilize the cell wall components which leading to a significant increase in SSC content (Asgharia and Aghdam, 2010, and Ezzat 2014). 1-MCP application might indirectly affect SSC levels, by influencing the maturity stage of the stored fruits (Ozkaya et al. 2014). The increment of SSC on the first storage periods could be due to the increasing in fruit weight loss (Ezzat, 2014).

Higher levels of 1-MCP and AVG showed high acid concentration, which may be a result of reduction of the metabolic changes and respiration in treated fruit. These findings agree with those of Shi *et al*., (2013) and Valdés et al., 2009 who stated that 1-MCP maintained a high content titratable acidity in Japanese and "Patterson" apricot. Also, Geransayeh *et al*. (2015) mentioned that MeJA treatment increased acidity in Strawberry. Also, Tarabih (2014) found that fruit treated with AVG had a higher value of acidity in pears. Also, it is partially agreeing with Geransayeh *et al*. (2015) who mentioned that MeJA treatment decreased TSS content in strawberries compared to controls.

Furthermore, 1-MCP and AVG treatments reduced the total phenol decrement, this result could be due to the reduction of oxidative stress enhanced during the fruit ripening and senescence. These results associated with Mirdehghan and Ghotbi (2015) demonstrated that, total phenolic compounds were not influenced by MeJA treatments which been in agreement with results by Gonza´lez - Aguilar et al. (2004). However, it do not go along with Meng et al. (2009) who stated that MeJA treatment could limit increase of total phenolic content, also with Candir et al. (2017) who reported that the AVG treatment had no effect on total phenolic content during storage.

Concerning sugars; obtained results are along with those of Yu et al., (2017) who found that ,Glucose and fructose content of two peach varieties was decreased after 28 days of storage when treating with 1-MCP which, increased the sucrose content, and significantly slowed the sucrose loss. However, Fan et al. (2018) and Ozkaya et al., (2014) stated no influence of 1-MCPon fruit sugars content of apricot and fig respectively.

3. Fruit storability characteristics:

Respecting fruit weight loss; results in Fig. (4a) indicated a reduction in fruit weight loss by all treatments. Meanwhile, the lowest significant weight loss percent was found with 1-MCP at 500 and 1000 µg/L and AVG at 50 and 100 mg/L.

These results could be due to the delay of fruit ripening and senescence and maintaining cell integrity as well as to the reduction of respiration rate. Ozkaya et al. (2014) explained that decrement in weight loss might be due to, 1-MCP action in inhibit ethylene evolution and decreasing fruit respiration rate.

Similar reduction in fruit weight loss was recorded in 1-MCP treated fig (Ozkaya et al. 2014), pears (Mahajan et al., 2010), and sweet cherry (Piazzolla et al., 2015), in addition to AVG treated pears (Tarabih, 2014) and in MeJA treated strawberries (Geransayeh et al., 2015), pomegranate (Zolfagharinasab and Hadian 2007). Meanwhile, Fan et al. (2000) and Salvador et al. (2003) reported that 1-MCP did not affect apricot and plum fruits weight loss.

Appearance quality of apricot fruit significantly maintained by the postharvest treatment with 1-MCP, AVG and JA as presented from the results in Fig. (4b), the applied treatments reducing the development of external browning than those of control in both seasons.

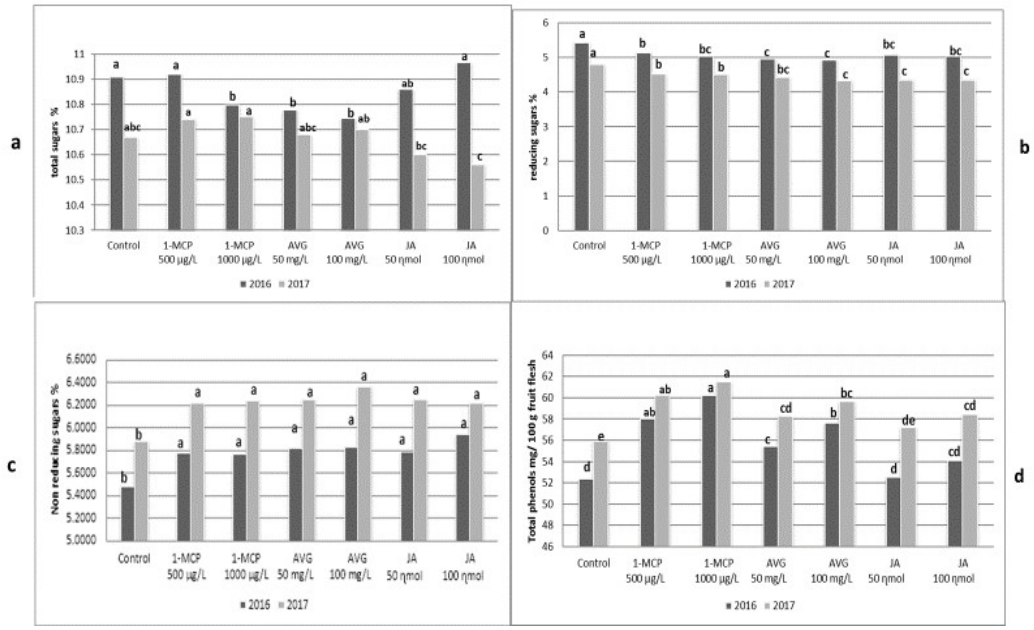

Figure 3: Effect of postharvest treatments on total sugars (a), reducing sugars (b), non-reducing sugars(c) and Total phenols (d) of 'Canino' apricot fruit.

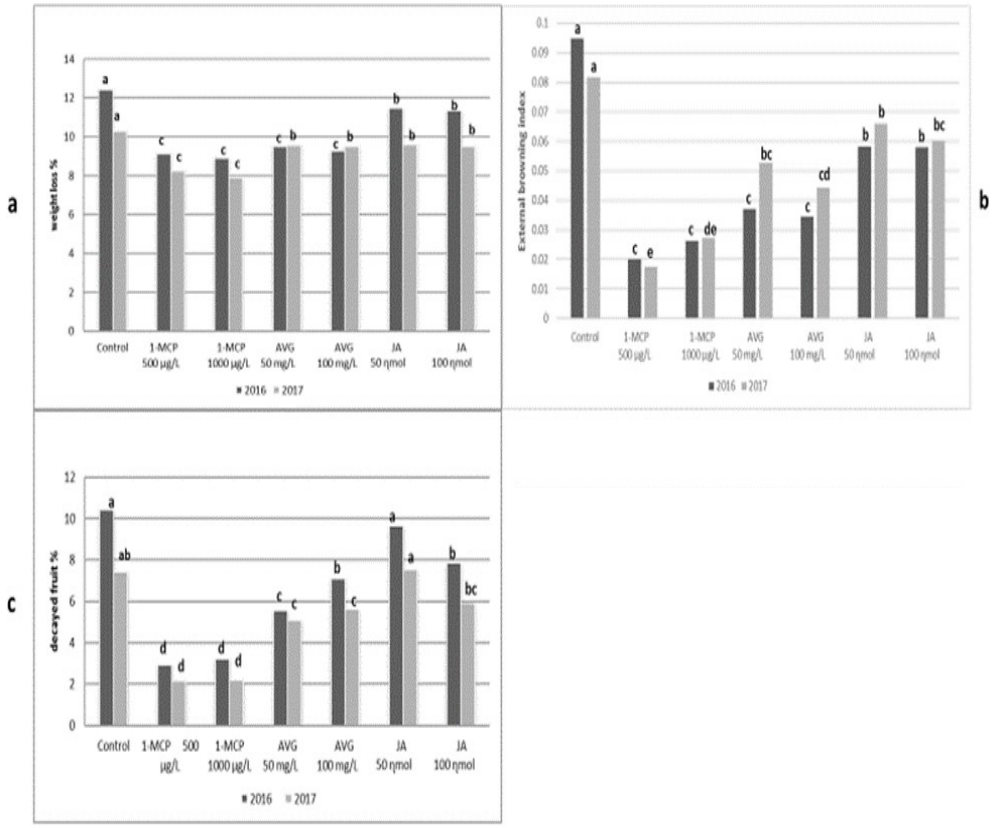

Figure 4: Effect of postharvest treatments on weight loss (a), external browning index (b) and decay percentage (c) of 'Canino' apricot fruit

Moreover, the lower EBI values among the treatments in both seasons was found with 1-MCP treatments, no significant different was noticed between AVG and 1-MCP treatments in the first season.

Regarding to decay incidence percentage; the results in Fig. (4c) showed a marked significant reduction in decay incidence of apricot fruits treated with 1-MCP and AVG at the two concentrations of each in 2016 and 2017. 1-MCP treatments at both levels were the most effective treatments for reducing fruit decay incidence in both seasons. However, JA at 50 ηmol was less efficient for reduction of fruit decay in the two experimental seasons.

The reduction effect of 1-MCP and AVG treatments on the decayed fruit percentage might be ascribed to one or more of the followed probabilities: increase of enzymes activity involved in phenolics metabolism which participate in fruit resistance against pathogens (Zhang et al., 2012). Fruit tissues could be induced to raise its resistance and activate its defenses system by obtained high phenol content which accompanied with high activities of some phenol's biosynthesis enzymes such as POD which has essential role to reinforcement of cell walls against pathogens infection as it produces the oxidative power for cross linking proteins and phenylpropanoid radicals (Huckelhoven et al., 1999 and Kristensen et al., 1999). Moreover, studies clarified that the tissues resistance against decay might increase through improving their antioxidant capacity (Chanjirakul et al., 2008, Wang et al., 2008 and Ezzat 2014). Moreover, it might be attributed to their effect on obstructing ethylene action and delaying the development of ripening characteristics which led to more resistance to decay, since, cell wall disassembly and tissue softening during postharvest ripening submit fruit more susceptible to pathogen infection and, hence, higher decay incidence (Lacerna et al., 2018 ; Fan et al., 2018). The obtained data are associated with the decay percent reduction reported in 1-MCP treated apricot (Dong et al. 2002), avocado (Pesis et al. 2002), peach (Liu et al., 2005) and strawberries (Jiang et al. 2001). In addition to those reported by Tarabih (2014) that there was a decreasing in decayed fruit percentage for AVG treated pear.

The reduction of the external browning index (EBI) might be due to retardation effect on fruit senescence, and hence delaying the process of fruit browning. Furthermore, high peroxidase (POD) activity resulted in lower browning incidence in peach fruits (Wills et al. 1998) thus, 1-MCP and AVG might have reduced such enzymes activity and reduced EBI. Similar results were stated by Shi et al., (2013) and Yu et al., (2017).

CONCLUSION

In accordance to the obtain results and previous discussion it might be concluded that 1-MCP at 1000 µg/L and AVG at 100 mg/L could be used postharvest for decrease of apricot fruit deterioration during storage and enhancing the keeping quality.

ACKNOWLEDGEMENTS

The authors would like to thank Valent BioSciences Corporation, Libertyville, IL, USA for supporting the ReTain® and AgroFresh Inc. for supplying with 1-MCP.

REFERENCES

Adams, D.O. and S.F. Yang. **1979**. Ethylene biosynthesis: identification of 1-aminocyclopropane-1-carboxylic acid as an intermediate in the conversion of methionine to ethylene. Proc. Natl. Acad. Sci., **76**: 170-174.

A.O.A.C. **2000**. Official Methods of Analysis of the Association of Official Analytical Chemists.17th ed. Washington, DC, USA., pp 578.

Badejo, A.A.; Y. Fujikawa and M. Esaka. **2009**. Gene expression of ascorbic acid biosynthesis related enzymes of the Smirnoff-Wheeler pathway in acerola (Malpighia glabra). J. Plant Physiol., **166**: 652–660.

Blankenship, S.M. and J.M. Dole. **2003**. 1-Methylcyclopropene: a review. Postharv. Biol. Technol., **28**: 1-25.

Botondi, R.; D. DeSantis; A. Bellicontro; K. Vizovitis; and F. Mencarelli. **2003**. Influence of ethylene inhibition by 1-methylcyclopropene on apricot quality, volatile production, and glycosidase activity of low -and high aroma varieties of apricots. J. Agric. Food Chem., **51**: 1189-1200.

Buta, I.T.and H.E. Moilne .**1998**. Methyl jasmonate extends shelf life and reduces microbial contamination of fresh-cut celery and peppers. J Agric Food Chem., **46**: 1253-1256.

Chahine, H.; B. Gouble; J.M. Audergon; M. Souty; G.Albagnac and G. Jacquemin. **1999**. Effect of ethyleneon certain quality parameters of apricot fruit (Prunus armeniaca L.) during maturation and postharvest evolution. Acta Hort. (ISHS), **488**: 577-584.

Chanjirakul, K.; S.Y. Wang; C.Y. Wang and J. Siriphanich. **2008**. Effect of natural volatile compounds on antioxidant capacity and antioxidant enzymes in raspberries. Postharvest Biol and Technol., **40**: 106–115.

Chen, F.X.; X.H. Liu and L.S. Chen. **2009**. Developmental changes in pulp organic acid concentration and activities of acid-metabolising enzymes during the fruit development of two loquat (*Eriobotrya jabonica* Lindl.) cultivars differing in fruit acidity. Food Chem., **114**: 657-664.

Creelman, R. A. and J. E. Mullet. **1997**. Biosynthesis and action of jasmonate in plants. Annu. Rev. Plant Physiol., **48**: 355–381.

D'Aquino, S.; M. Schirra; M.G. Molinu; M. Tedde and A.Palma. **2010**. Preharvest aminoethoxyvinylglicine treatments reduce internal browning and prolong the Shelf-life of early ripening pears. Sci. Hortic., **125**: 353-360.

Davarynejad, G.; M. Zarei,; E. Ardakani and M. E. Nasrabadi. **2013**. Influence of Putrescine Application on Storability, Postharvest quality and antioxidant activity of two Iranian apricot (*Prunus armeniaca L.*) cultivars. Not Sci Biol., **5(2)**: 212-219.

De Martino, G.; K. Vizovitis; R. Botondi; A. Bellincontro and F. Mencarelli. **2006**. 1-MCP controls ripening induced by impact injury on apricots by affecting SOD and POX activities. Postharvest Biol. Technol., **39**: 38-47.

Dong, L.; Susan Lurie and H.W. Zhou. **2002**. Effect of 1-methylcyclopropene on ripening of 'Canino' apricotsand 'Royal Zee' plums. Postharvest Biol. Technol., **24**:135-145.

Ezzat, A. G. K. **2014**. Pomological evaluation of apricot cultivars and roles of postharvest application of salicylic acid and methyl jasmonate on stress resistance. PhD Thesis, Institute of Horticulture, Debrecen Univ., Hungary.

Fan, X.; L. Argenta and J.P. Mattheis. **2000**. Inhibition of ethylene action by 1-methylcyclopropene prolongs storage life of apricots. Postharvest Biol. Technol., **20**: 135-142.

Fan, X.; L. Argenta and J.P. Mattheis. **2002**. Interactive effects of 1-MCP and temperature on 'Elberta' peach quality. Hort. Sci., **37**: 134-138.

Fan, X.; C. Shu; K. Zhao; X. Wang; J. Cao and W. Jiang. **2018**. Regulation of apricot ripening and softening process during shelf life by post-storage treatments of exogenous ethylene and 1-methylcyclopropene. Scientia Horticulturae, **232**: 63–70.

Fao: http://faostat3.fao.org.

Feng, X.; A. Apelbaum; E.C. Sisler and R. Goren. **2000**. Control of ethylene responses in avocado fruit with 1-methylcyclopropene. Postharvest Biol. Technol., **20**: 143-150.

Garner, D.; C.H. Crisosto and E. Otieza. **2001**. Controlled atmosphere storage and aminoethoxyvinylglycine postharvest dip delay post cold storage softening of 'Snow King' peach. Hort. Technol., **11**: 598-601.

Geransayeh, M.; S. Sepahvand; V. Abdossic and V. Zarrinniad. **2015**. Effect of methyl jasmonate treatment on decay, post-harvest life and quality of Strawberry (*Fragaria ananassa* L. cv. Gaviota) fruit. Int. J. Curr. Sci., **15**: 123-131.

Ghasemnezhad, M.; M.A. Shiri and M. Sanavi. **2010**. Effect of chitosan coatings on some quality indices of apricot (*Prunus armeniaca* L.) during cold storage. Caspian J. Env. Sci., **8**: 25-33.

Gonza´lez-Aguilar G.A.; J. Fortiz; R. Cruz; R. Baez and Y. Wang. **2000**. Methyl jasmonate reduces chilling injury and maintains postharvest quality of mango fruit. J. Agri. Food Chem., **48**: 515-519.

Gonza´lez-Aguilar G.A.; J.G. Buta and C.Y. Wang. **2001**. Methyl jasmonate reduces chilling injury symptoms and enhances color development of 'Kent' mangoes. J. Sci. Food Agri., **81**: 1244-1249.

Gonza´lez-Aguilar, G.A.; J.G. Buta and C.Y. Wang. **2003**. Methyl jasmonate and modified atmosphere packaging (MAP) reduce decay and maintain postharvest quality of papaya 'Sunrise'. Postharvest Biol. Technol., **28**: 361-370.

Gonza´lez-Aguilar, G.A.; M.E. Tiznado-Hernandez; R. Zavaleta-Gatica and M.A. Martinez-Tellez. **2004**. Methyl Jasmonate Treatments Reduce Chilling Injury and Activate the Defense Response of Guava Fruits. Biochem. Biophysiol. Res. Commun., **313**: 694-701.

Huckelhoven, R.; J. Fodor; C. Preis and K.H. Kogel. **1999**. Hypersensitive cell death and papilla formation in barley attacked by the powdery mildew fungus are associated with hydrogen peroxide but not with salicylic acid accumulation Plant Physiol., **119**: 1251-1260.

Infante, R.; C. Meneses, and B.G. Defilippi. **2008**. Effect of harvest maturity stage on the sensory quality of `Palsteyn` apricot (*Prunus armeniaca* L.) after cold storage. J. Horti. Sci. Biotechnol., **83**: 828-832.

Jiang, Y.; D.C. Joyce and L.A. Terry. **2001**. 1-Methylcyclopropene treatment affects strawberry fruit decay. Postharvest Biol. Technol., **23**: 227-232.

Kristensen B.K.; H. Bloch and S.K. Rasmussen. **1999**. Barley coleoptile peroxidases. Purification, molecular cloning, and induction by pathogens Plant Physiol., **120**: 501–512.

Lacerna, M.M.; E.V. Bayogan and L.B. Secretaria. **2018**. Rind color change and granulation in pummelo [*Citrus maxima* (Burm. ex Rumph.) Merr.] fruit as influenced by 1-methylcyclopropene. Int. Food Res. J., **25**: 1483-1488.

Liguori, G.; A. Weksler; Y. Zutahi; S. Lurie and I. Kosto. **2004**. Effect of 1-methylcyclopropene on ripening of melting flesh peaches and nectarines Postharvest Biol. Technol., **31**: 263-268.

Loomis, W.E. and C.A. Shull. **1937**. Methods in plant physiology. MC. Grow. Hill Book Co. Inc. New York.

Macheix, J.J.; A. Fleuriet and J. Billot. **1990**. Fruit phenolics. Florida: CRC Press, Inc.

Mahajan, B.V.C.; K. Singh and W.S. Dhillon. 2010. Effect of 1-methylcyclopropene (1-MCP) on storage life and quality of pear fruits. J. Food Sci. Technol., **47**: 351-354.

Manolopoulou, H. and C. Mallidis. **1999**. Storage and processing of apricots. Acta Hort., **488**: 567-576.

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

McGuire, R.G., **1992**. Reporting of objective color measurements. HortSci., **27**: 1254–1255.

Meng, X.; J. Han; Q. Wang and S. Tian. **2009**. Changes in physiology and quality of peach fruit treated by Methyl Jasmonate under low temperature stress. Food Chem., **114**: 1028-1035.

Mirdehghan,S.H. and F. Ghotbi. **2014**. Effect of salicylic acid, jasmonic acid and calcium chloride on reducing chilling injury of pomegranate (Punica granatum L.) fruit. J. Agr. Sci. Technol., **16**: 163-173.

Mitcham, B.; M. Cantwell. And A. Kader. **1996**. Methods for determining quality of fresh commodities. Perishables Handling Newsletter, **85**: 1-5.

Moyo, M.; A.R. Ndhlala; J.F. Finnie and J. Van Staden. **2010**. Phenolic composition, antioxidant and acetylcholinesterase inhibitory activities of *Sclerocarya birrea* and *Harpephyllum caffrum* (Anacardiaceae) extracts. Food Chem.,**123**, 69–76.

Mueller, M.E.J.A.; W. Brodshelm; E. Spannagl and M.H. Zcnk. **1993**. Signaling in the elicitation process is mediated through the octadecanoid pathway leading to jasmonic acid. Proc. Nation. Acad. Sci., **90**: 7490-7494.

Mu˜noz –Robredoa, P.; P. Rubiob; R. Infanteb; R. Campos-Vargasc; D. Manríqueza; M. González-Agüeroa and B.G. Defilippia. **2012**. Ethylene biosynthesis in apricot: Identification of a ripening-related aminocyclopropane-1-carboxylic acid synthase (ACS) gene. J. Agri. Food Chem., **57**: 5809-5815.

Ozkaya, O.; S. Çomlekcioglu and H. Demircioglu. **2014**. Assessment of the Potential of 1-Methylcyclopropene treatments to maintain fruit quality of the common fig (*Ficus carica* L cv. 'Bursa Siyahi') during refrigerated storage. Not. Bot. Hort. Agro., **42**: 516-522.

Palou, L. and C.H. Crisosto. **2003**. Postharvest treatments to reduc e the harmful effects of ethylene on apricots. Acta Hort., **599**: 31-38.

Perez, A.G.; C. Sanz; D.G. Richardson and J.M. Olias. **1997**. Effect of methyl jamonate on in vitro strawberries ripening. J. Agri. Food Chem., **24**: 3733-3737.

Pesis, E.; M.Ackerman and R. Ben-Arie. **2002**. Ethylene involvements in chilling injury symptoms of avocado during cold storage. Postharvest Biol. and Technol., **24**: 171–181.

Petersen, R.G. **1985**. Design and analysis of experiments. Marcel Dekker, Inc. New York, 253-301 .

Piazzolla, F.; M.L. Amodio; F. Colantuono and G. Colelli. **2015**. Effects of 1-methylcyclopropene (1-MCP) on quality of sweet cherry (*Prunus avium* L., cv. Ferrovia) during storage. Acta Hort., **2**: 551-557.

Pint´o, E; I. Lentheric; M. Vendrell and C. Larrigaudière **2001**. Role of fermentative and antioxidants metabolisms in the induction of core-browning in controlled-atmosphere stored pears. J. Sci. Food Agric., **81**: 364-370.

Salvador, A.; J. Cuquerella and J.M. Martínez-Jávega. **2003**. 1-MCP treatment prolongs postharvest life of Santa Rosa plums. J. Food Sci., **68**: 1504-1510.

Shi, T.; Z. Li; Z. Zhang; C. Zhang and G. Zhihong. **2013**. Effect of 1-methylcyclopropene (1-MCP) treatment on antioxidant enzymes of postharvest Japanese apricot. African J. Biotechnol., **12**: 689-694.

Sisler, E.C. and M. Serek. **1997**. Inhibitors of ethylene responses in plants at the receptor level: recent developments. Physiol. Plant, **100**: 577-582.

Tarabih, M.E. **2014**. Improving storability of Lecont pear fruit using aminoethoxyvinylglycine (AVG) and oxalic acid (OA) under cold storage. Asian J. crop sci., **6**: 320-333.

Tian, M.S.; S. Prakash; H.J. Elgar ; H. Young; D.M. Burmeister and G.S. Ross. 2000. Responses of strawberry fruit to 1-methylcyclo-propene (1-MCP) and ethylene. Plant Growth Reg., **32**: 83-90.

Valdés, H.; M. Pizarro; R. Campos-Vargas; R. Infante and B.G. Defilippi. **2009**. Effect of ethylene inhibitors on quality attributes of apricot cv. Modesto and Patterson during storage. Chilean J. Agric. Res. **69**: 134-144.

Veltman R; M. Sanders; S. Persijn; H. Peppelenbos and J. Oosterhaven. **1999**. Decreased ascorbic acid levels and brown core development in pears. Physiol. Plant ,**107**: 39-45.

Wang, Y.S.; S.P. Tian and Y. Xu. **2005**. Effects of high oxygen concentration on pro- and anti-oxidant enzymes in peach fruits during postharvest periods.Food Chem., **91**: 99-104.

Wang, S.Y.; L. Bowman and M. Ding. **2008**. Methyl jasmonate enhances antioxidant activity and flavonoid content in blackberries (*Rubus* sp.) and promotes antiproliferation of human cancer cells. Food Chem., **107**: 1261-1269.

Wang, K.; P. Jin; S. Cao; H. Shang; Z. Yang and Y. Zheng. **2009**. Methyl jasmonate reduces decay and enhances antioxidant capacity in chinese bayberries J. Agri. Food Chem., **57**: 5809-5815.

Watkins,C.B.; J.F. Nock; and B.D. Whitaker. **2000**. Responses of early, mid and late season apple cultivars to postharvest application of 1-methylcyclopropene (1-MCP) under air and controlled atmosphere storage conditions. Postharvest Biol. Technol., **19**: 17-32.

Watkins, CB. **2006**. The use of 1-methylcyclopropene (1-MCP) on fruits and vegetables. Biotechnol. Adv., **24**:389-409.

Wills, R.; B. Mcglasson; D. Graham and D. Joyce. **1998**. Postharvest an introduction to the physiology and handling of fruit and vegetables and ornamentals (4th Edn). Sydney 2052, Australia, University of New South Wales Press Ltd., 125-156.

Yu, L.; X. Shao; Y. Wei; F. Xu and H. Wang. **2017**. Sucrose degradation is regulated by 1-methycyclopropene treatment and is related to chilling tolerance in two peach cultivars. Postharvest Biol. Technol., **124**: 25-34.

Zhang, Z.; S. Tian; Z. Zhu; Y. Xu, and G. Qin. **2012**. Effects of 1-methylcyclopropene (1-MCP) on ripening and resistance of jujube (*Zizyphus jujuba* cv. Huping) fruit against postharvest disease. Food Sci. Technol., **45**:13-19.

الملخص العربى

تأثير معاملات ما بعد الحصاد بالأمينوايسوكسي فينيل جليسين و١- ميثيل سيكلو بروبان وحامض الجاسمونيك على القدرة التخزينية والحفاظ على جودة ثمار المشمش صنف "كانينو

رضوى فاروق ساطور، محمد محمد عطية، حسن على قاسم ويحيى صلاح مصطفى.

قسم الفاكهة، كلية الزراعة، جامعة الأسكندرية، الأسكندرية، مصر

تم اجراء الدراسة الحالية على المشمش صنف الكانينو لتقدير استجابته للامينوايسوكسي فينيل جليسين (٥٠،١٠٠ ميللي جرام/ لتر) و١- ميثيل سيكلو بروبان (٥٠٠، ١٠٠٠ ميكرو جرام/ لتر) وحامض الجاسمونيك (٥٠،١٠٠ نانومول) مقارنة بالثمار غير المعاملة خلال التخزين المبرد على ١± ٥١ م وعلى رطوبة نسبية ٥±٩٠ %. أدت كل المعاملات إلى تأخير انخفاض محتوى الثمار من الحموضة كما حافظت على صلابة الثمار وقللت من الفقد في الوزن. أخرت المعاملة بكل من الأمينوايسوكسي فينيل جليسين و١- ميثيل سيكلو بروبان من التغير في اللون و قللت من النسبة المئوية لتلف الثمار. وكانت المعاملة بـ ١- ميثيل سيكلو بروبان عند تركيز ١٠٠٠ ميكرو جرام/ لتر هي الاكثر تأثيرا للحفاظ على جودة الثمار يليها الأمينوايسوكسي فينيل جليسين عند تركيز ١٠٠ ميللي جرام/ لتر.