1-MCP Maintains Fruit Quality, Prevents Chilling Injury and Reduces POD and PPO Activities of Canino Apricots during Cold Storage and Subsequent Shelf Life Period

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ABSTRACT

The present investigation was carried out during 2010 and 2011 seasons on Canino apricots to characterize the physiological responses of fruits to 1-MCP treatment during cold storage and subsequent shelf life period. Fruit treatments included prestorage exposure to 0.5 ppm or 1 ppm 1-MCP at 20°C for 20 hours. The above treatments were compared to untreated fruits during the cold storage period at 0 ±1°C and 85-90±5 % relative humidity and during subsequent shelf life period for 2 days at 20°C. 1-MCP treatment effectively prevented chilling injury incidence, retarded ripening and senescence of Canino apricot fruits and significantly improved their storagability in both seasons by 8 and 12 days for 0.5 and 1 ppm concentrations, respectively, compared by the untreated fruits. 1-MCP treatment significantly decreased the loss of fruit weight, flesh firmness, malic acid and vitamin C contents. 1-MCP application delayed the changes in skin color as hue°, soluble solids and carotenoids contents. Polyphynol oxidase (PPO) and peroxidase (POD) enzymes activities were significantly reduced by 1-MCP.

Key words: 1-MCP, postharvest, storage, shelf life and apricot

INTRODUCTION

Ethylene has been shown to be involved in the ripening processes in fruits leading to limited shelf-life. Several approaches have been used to minimize the undesirable effects of ethylene on these fruits, including reducing the ethylene concentration in the holding environment. In the past, strategies such as the use of heat or anaerobiosis, which extend shelf life and reduce chilling injury symptoms, were based on the control of ethylene activity and maintenance of membrane integrity (Pesis *et al.*, 1994 and Woolf, 1997). Recently, the ethylene action inhibitor, 1-methylcyclopropene (1-MCP), a synthetic cyclopropene, was found to be effective in overcoming the effects of ethylene in a range of perishable fruits (Sisler and Serek, 1997) by the strong blocking of ethylene perception, preventing ethylene effects in plant tissues for extended periods. 1-MCP is nontoxic, odorless, and effective when plants are treated at concentrations as low as 0.5 nl/l and it acts by binding permanently to ethylene receptors in plant tissue (Sisler and Serek, 1997). 1-MCP at concentrations up to 1 ppm was approved by the US Environmental Protection Agency for use on apples, apricots, avocados, kiwifruit, mangoes, nectarines, papayas, peaches, pears, persimmons, plums and tomatoes (Kader, 2003). 1-MCP has been shown to delay ripening and improve storage quality of climacteric fruits (Watkins, 2006). Furthermore, application of 1-MCP has been reported to affect the trends in activities of cellular wall enzymes in avocado and plum fruit and to completely suppress the activities of PG and EGase enzymes during fruit ripening (Jeong *et al.*, 2002 and Khan and Singh, 2007). 1-MCP was reported to delay ripening, as expressed in changes in firmness, peel color, ethylene production and respiration rate. Depending on the timing of application relative to the climacteric development, the treatment can be more or less effective as, once triggered, the ripening process is hard to stop (Hershkovitz *et al.*, 2005). Positive effects of 1-MCP on delaying decay development and reducing internal physiological storage disorders were observed in strawberries (Jiang *et al.*, 2001), apricots (Dong *et al.*, 2002), pineapple (Selvarajah *et al.*, 2001) and plums (Menniti *et al.*, 2006). The present study was performed to characterize the physiological responses of Canino apricot fruits to 1-MCP treatment during cold storage and subsequent shelf life period

MATERIALS AND METHODS

The present investigation was carried out during 2010 and 2011 seasons on Canino apricot fruits harvested with straw color and residue of green color along the fruit suture from a private orchard in El-Khatatba Village, Sadat City, El-Monofeya Province and immediately transported to the Post-harvest Center of Horticulture Crops, Faculty of Agriculture (El-Shatby), Alexandria University. Initial quality of fruits at harvest (Fig 1) was determined using 25 fruits and the data are tabulated in Table (1).

Table 1: Initial quality of Canino apricot fruits in 2010 and 2011 seasons.

Parameters	2010 season	2011 season
Fruit weight (gm)	42.60	46.06
Fruit length (cm)	4.08	4.16
Fruit breadth (cm)	4.42	4.52
Seed weight (gm)	2.35	2.40
Flesh weight (gm)	40.25	43.66
Flesh thickness (cm)	1.26	1.24
Flesh firmness (lb/in^2)	6.30	6.53
SSC (%)	13.73	13.53
Acidity (%)	1.98	1.97

The fruits were sorted carefully to eliminate any fruits with obvious mechanical damage, browning or defect. Sound selected fruits were divided into three lots of 15 Kg each divided into 5 boxes of 3 kg. The first two lots were exposed to 0.5 and 1 ppm 1-methylcyclopropene (1-MCP), respectively for 20 hours at 20°C. 1-MCP treatment was carried out by putting 10 ml of the stock solution in a 100 ml glass beaker inside each box which was wrapped by polyethylene during treatment only. The third lot was untreated fruits as control. Fruits of each lot were packed into 5 closed carton boxes (3 Kg of each) then were stored at 0 ±1°C and 85-90±5 % relative humidity (RH). The physicochemical properties of the stored apricot fruits were followed up in 4 days intervals and after 2 days of subsequent storage at 20°C (shelf life fruits) throughout the storage period as follows.

Fifteen fruits of each treatment were labeled then weighed to calculate fruit weight loss percentage during the storage period in relation to its original weight. Weight loss percentages of shelf life fruits were calculate during the 2 days only and separately for each sample. External color of each fruit in the 4 days sample (25 fruits form each treatment) was estimated visually and measured with Minolta Chromameter CR-200-Japan on four points of each fruit in the sample. a* and b* values were used to calculate the hue angle (hue°) according to Sancho *et al.*, (2010) where hue° = Arctan (b*/a*). Hue° is a quantitative expression of color and represents the changes in fruit color (0 = red, 90 = yellow, 180 = green, and 270 = blue). Patches of skin were peeled from two opposite sides of each given fruit in the sample to measure the flesh firmness by using the Effegi pressure tester with an eight mm plunger (Effegi, 48011 Alfonsine, Italy). Three replicates of five fruits each were squeezed and the obtained juice was used to determine the percentage of the soluble solids content (SSC) by the use of a hand refractometer (Chen and Mellenthin, 1981). The titratable acidity (TA) was determined in three samples of the same above juice as g malic acid /100 ml of fruit juice (Chen and Mellenthin, 1981). The same above obtained juice was also used to determine vitamin C as mg ascorbic acid / 100 ml fruit juice (AOAC, 1990). Fruit total carotenoids content as ppm was determined according to the method described by AOAC (1990). Polyphenol oxidase (PPO) and peroxidase (POD) enzymes activity were determined in the crude extracts (Brenneman and Black, 1979) of three samples of fruit flesh in each treatment. The activity (as optical density or O.D.) of PPO was measured using the method of Matta and Dimond (1963) and the activity of POD was determined by the method of Chance and Maehly (1955).

The termination of the experiment was done by the loss of fruit quality and when the flesh firmness reached the average of less than 3 lb/inch^2 and with the appearance of chilling injury (CI) symptoms in shelf life fruits. All data obtained were statistically analyzed according to Snedecor and Cochran (1980). The individual comparisons were carried out by using the Least Significant Difference (LSD) according to SAS Institute (1997). Simple regression coefficient between storage period and studied properties was calculated using SAS Institute (1997).

RESULTS AND DISSCUSSION

Fruit Quality, Storagability and Chilling Injury Incidence:

1-MCP treatment effectively retarded ripening and senescence of Canino apricot fruits and significantly improved their storagability in both seasons by 8 and 12 days for 0.5 and 1 ppm concentrations, respectively, compared by the untreated fruits. After 12 days of cold storage, 35.24 and 33.69 % of the untreated fruits had external brown pits (Fig 2) which increased when the fruits were left to reach the room temperature and turned to dark brown after shelf life period of 2 days at 20°C (Fig 3). These symptoms were accompanied translucency or overripe as watery appearance from the skin toward the seed and with the beginning of flesh browning. 1-MCP treated fruits were free from any chilling injury symptoms with the maintaining of the external and internal fruit quality at the end of cold storage period (Fig 4) and subsequent shelf life period (Fig 5).

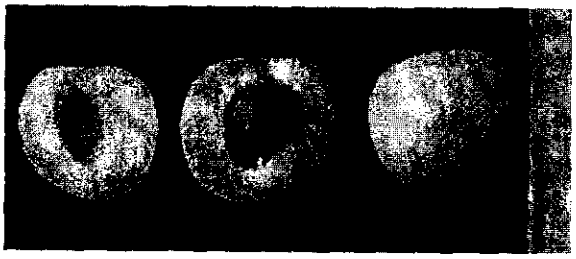

Fig. 1: Initial quality of Canino apricot fruits.

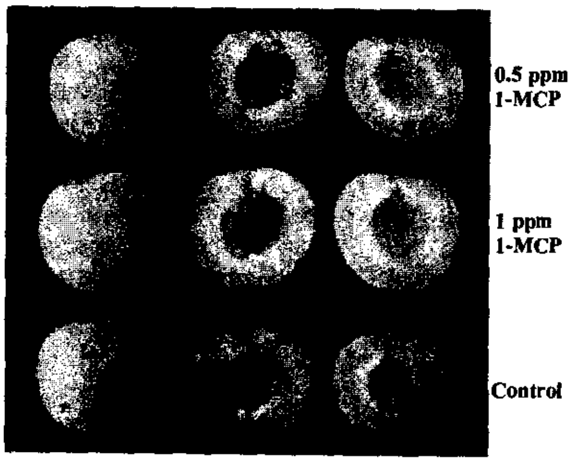

Fig. 2: Fruit quality of Canino apricots after 12 days of cold storage.

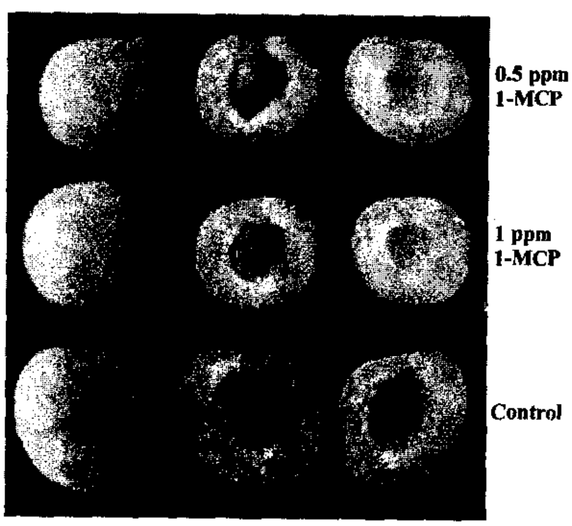

Fig. 3: Fruit quality of Canino apricots after 12 days of cold storage plus 2 days at 20°C.

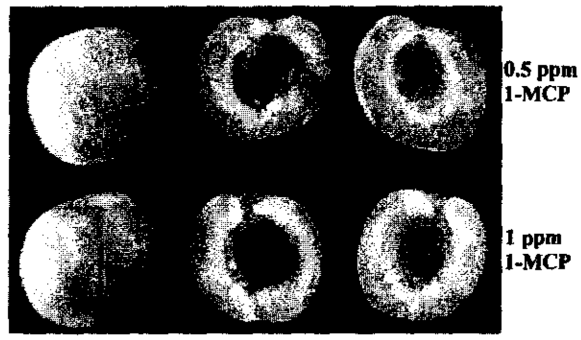

Fig. 4: Fruit quality of Canino apricots after 20 days of cold storage.

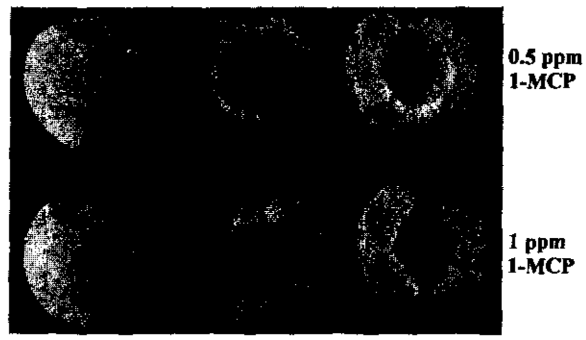

Fig. 5: Fruit quality of Canino apricots after 20 days of cold storage plus 2 days at 20°C.

The above obtained data of 1-MCP are associated with the results of Fan *et al.* (2000) on Perfection apricots, Selvarajah *et al.* (2001) on pineapple, Pesis *et al.*, (2002) on avocado, Salvador *et al.*, (2004) on persimmons and Candan *et al.* (2006) on plums. However, Dong *et al.* (2002) found that 1-MCP increased internal browning of Canino apricots significantly when fruits were treated prior to storage. In contrast, when fruits were treated after storage and ripened directly, 1-MCP decreased the internal browning by almost 50%. On the other hand, Palou and Crisosto (2003) reported that 1-MCP did not prevent chilling symptoms of Patterson and Castlebrite apricots. Biochemical mechanisms of browning involve the oxidation of phenolic substrates by polyphenol oxidase (PPO) to brown pigments (Mayer, 1987). Low temperatures increase the permeability of the cellular reservoir, allowing ions to leak out during exposure to chilling (Pesis *et al.*, 1994; Saltveit, 2002). Hershkovitz *et al* (2005) showed that PPO and POD activities were significantly suppressed by 1-MCP treatment as a result of inhibiting the ethylene action. 1-MCP probably reduced the disruption of the cell membranes and maintained the cell compartments intact, so that the PPO enzyme could not interact with its phenolic substrates, and there was less pulp browning.

In the present study, it was observed that 1 ppm 1-MCP treatment prevented the ripening of some fruits (maximum 1 or 2 fruits from the sample of 25 fruits) during shelf life period at 20°C. These fruits did not soften and still had the residue of green color along the suture with the shrinkage appearance on the rose end. Since 1-MCP inhibits ethylene perception by binding to the ethylene receptors to block the effects of endogenous and exogenous ethylene (Sisler *et al.*, 1997), this compound can impair the normal ripening in a wide range of fruit species (Lurie and Crisosto, 2005 and Larrigaudière *et al.*, 2009) by blocking the normal feedback regulation of ethylene production (Golding *et al.*, 1998). 1-MCP effect on disrupt the peel degreening may be due to the irreversibly disruption of chlorophyllase biosynthesis (Golding *et al.*, 1998).

Weight loss (%):

1-MCP significantly affected apricot fruit weight loss during cold storage and subsequent shelf life period. The presented data in Table (2) cleared that after 12 days of cold storage, both of 0.5 and 1 ppm 1-MCP treatments respectively declined the fruit weight loss by 29.66 and 30.86 % in the first season and by 33.21 and 36.98 % in the second season compared to the untreated fruits. In shelf life period, the untreated fruits lost nearly three folds of the treated fruits weight loss. The concentration of 1 ppm 1-MCP gave lower weight loss percentages than 0.5 ppm but the differences were insignificant. All apricot weight loss percentages significantly increased with the increasing of the cold storage period (r^2 values were highly significant).

The obtained results agree with those of Manganaris *et al.* (2007) on Harrow Sun plums and Mortazavi *et al.* (2010) on Barhee dates. However, Salvador *et al.* (2004) found slightly higher weight loss for 1-MCP treated persimmon fruits while Fan *et al.* (2000) and Salvador *et al.* (2003) reported that 1-MCP did not affect apricot and plum fruits weight loss. Fruit weight loss is mainly associated with respiration and moisture evaporation through the skin (Ghasemnezad *et al.*, 2010). 1-MCP reduced fruit weight loss of apricot fruits as a result of reducing the respiration rate which was reported by Fan *et al.* (2000) and Palou and Crisosto (2003).

Skin color (hue°):

1-MCP application delayed the skin color changes of Canino fruits especially the concentration of 1 ppm where it had the highest hue° values in both seasons with insignificant differences compared by 0.5 ppm one (Table 3). The lowest significant hue° values of untreated fruits reflected the highest rate to change their peel color to deep yellow during cold storage and subsequent 2 days storage at 20°C. Fan *et al.* (2000) reported that the effect of 1-MCP on ethylene action inhibition in apricot fruits delays the onset of the climacteric increase in ethylene production and respiration rate and as a result delays the fruit color changes associated with ripening. The above results and associated discussion agree with Menniti *et al.* (2006) and Candan *et al.* (2006) on plums. However, Dong *et al.* (2002) reported that 1-MCP did not affect color of Canino apricots.

Table 2: Effects of 1-MCP treatment on weight loss (%) of cold stored Canino apricot fruits in 2010 and 2011 seasons.

Season	Treatment	Storage Period (days)							r^2
		0	4	8	12	16	20	24	
2010	**Cold stored fruits**								
	0.5 ppm 1-MCP	0.00a	2.43b	4.99b	7.02b	9.26a	11.92a		0.999**
	1 ppm 1-MCP	0.00a	2.07b	4.71b	6.90b	8.90a	11.48a	14.79	0.995**
	Control	0.00a	3.56a	7.50a	9.98a				0.992**
	Shelf life fruits								
	0.5 ppm 1-MCP	4.023b	1.67b	2.25b	2.21b	2.65a	3.67a		
	1 ppm 1-MCP	3.76b	2.60b	2.25b	1.99b	2.27a	3.13a	3.27	
	Control	10.53a	6.34a	6.63a	6.38a				
2011	**Cold stored fruits**								
	0.5 ppm 1-MCP	0.00a	2.56b	5.28b	7.08b	9.31a	12.13a		0.997**
	1 ppm 1-MCP	0.00a	1.89c	4.64b	6.68b	9.03a	11.97a	13.99	0.998**
	Control	0.00a	3.61a	7.79a	10.60a				0.995**
	Shelf life fruits								
	0.5 ppm 1-MCP	4.71b	1.06b	2.63b	2.26b	2.32a	3.68a		
	1 ppm 1-MCP	4.46b	2.05b	1.79c	1.68b	1.73a	3.17a	3.23	
	Control	11.04a	4.05a	6.42a	5.85a				

Means within a column (in same season) having a common letter are not significantly different.

r^2=Determination coefficient.

Table 3: Effects of 1-MCP treatment on peel color (hue°) of cold stored Canino apricot fruits in 2010 and 2011 seasons.

	Treatment	Storage Period (days)							r^2
		0	4	8	12	16	20	24	
2010	**Cold stored fruits**								
	0.5 ppm 1-MCP	92.25a	87.96a	84.30b	74.72a	71.44a	69.35ab		0.965**
	1 ppm 1-MCP	92.52a	90.02a	87.95a	75.29a	71.52a	69.95a	66.97a	0.891**
	Control	92.34a	79.69b	73.65d	65.90b				0.975**
	Shelf life fruits								
	0.5 ppm 1-MCP	79.64b	80.40b	78.47c	71.14a	67.05b	65.29bc		
	1 ppm 1-MCP	80.58b	81.04b	79.64c	72.32a	68.27b	63.81c	61.79a	
	Control	79.21b	72.93c	68.91e	62.81b				
2011	**Cold stored fruits**								
	0.5 ppm 1-MCP	92.35a	88.17a	84.06a	75.87a	72.01a	69.47ab		0.979**
	1 ppm 1-MCP	92.59a	90.09a	84.69a	77.45a	74.91a	72.00a	67.78a	0.983**
	Control	91.11a	81.54b	74.59b	64.64c				0.996**
	Shelf life fruits								
	0.5 ppm 1-MCP	80.18bc	80.05b	75.86b	70.06b	66.63b	63.15c		
	1 ppm 1-MCP	82.10b	81.24b	76.05b	72.23b	67.11b	65.55bc	61.24b	
	Control	77.34c	72.30c	60.95c	62.29c				

Means within a column (in same season) having a common letter are not significantly different.
r^2=Determination coefficient.

All hue° values decreased significantly by the increasing of cold storage period where all r^2 values were highly significant in both seasons. The hue° values decrease reflected the change of fruit color to deep yellow. These results are consistent with Fan *et al.* (2000) on Perfection apricots.

Total Carotenoids (ppm):

At harvest, Canino apricot fruits contained 5.86 and 4.34 ppm as total carotenoids in the first and the second seasons, respectively (Table 4). These initial contents were not affected by 1-MCP directly after treatment (storage period of 0 days) but increased after 2 days at 20°C and the untreated fruits had highest significant contents of carotenoids. 1-MCP effect on fruit carotenoids was also clear during cold storage period where the treated fruits contained lower significant values than untreated ones and there were insignificant differences between the two concentrations in both seasons, but generally the 1ppm concentration had lower values.

Table 4: Effects of 1-MCP treatment on total carotenoids (ppm) of cold stored Canino apricot fruits in 2010 and 2011 seasons.

	Treatment	Storage Period (days)							r^2
		0	4	8	12	16	20	24	
2010	**Cold stored fruits**								
	0.5 ppm 1-MCP	5.84b	5.96b	6.45c	7.23cd	8.27ab	8.77a		0.954**
	1 ppm 1-MCP	5.73b	5.93b	6.16c	6.82d	7.48b	8.68a	9.31a	0.941**
	Control	5.86b	7.01b	8.53b	10.11ab				0.995**
	Shelf life fruits								
	0.5 ppm 1-MCP	6.07b	6.83b	7.28bc	8.70bc	9.77a	9.95a		
	1 ppm 1-MCP	5.93b	6.20b	6.83c	7.77cd	8.51ab	9.53a	10.47a	
	Control	7.54a	9.67a	10.93a	11.53a				
2011	**Cold stored fruits**								
	0.5 ppm 1-MCP	4.26b	4.95d	5.58c	6.33b	7.24bc	8.30b		0.990**
	1 ppm 1-MCP	4.41b	5.00cd	5.54c	6.10b	6.96c	7.73b	8.37a	0.994**
	Control	4.34b	6.87b	8.90b	10.57a				0.991**
	Shelf life fruits								
	0.5 ppm 1-MCP	5.50b	6.17bc	6.87c	7.41b	9.74a	10.30a		
	1 ppm 1-MCP	5.27b	5.35cd	6.60c	7.06b	8.04b	9.62a	10.00a	
	Control	7.26a	9.20a	11.40a	12.13a				

Means within a column (in same season) having a common letter are not significantly different.
r^2=Determination coefficient.

The main carotenoids in apricots are ß-carotene, ß-cryptoxanthin, γ- carotene, lycopene, and lutein (Sass-Kiss *et al.*, 2005 and Ruiz *et al.*, 2005). Akin *et al.*, (2008) found that total carotenoid contents in Bursa, Alyanak, Hasanbey, Tokalog˘lu and Kabaas apricot varieties were 10.87, 11.52, 9.73, 9.02 and 8.80 mg/100g of fresh weights, respectively. Ruiz *et al.* (2005) reported that the carotenoid content of Spanish apricot varieties varies from 1.36 to 38.52 mg/100g of fresh weights. Fan *et al.* (2000) revealed that 1-MCP treated apricot fruits were greener and exhibited less color change than untreated controls. However, Dong *et al.* (2002) found that apricot and plum color changes were not affected by 1-MCP.

With the progress of cold storage and during the subsequent shelf life periods, the fruit carotenoids contents increased and the highest rate was for untreated fruits with the highest r^2 values. These results agree with Marty *et al.* (2005) and Uzelac *et al.* (2007) both on apricots.

Flesh Firmness (lb/in^2):

There was clear significant effect of 1-MCP application on decreasing the apricot fruit softening rate during both cold storage and shelf life periods (Table 5). After 12 days of cold storage, the untreated fruits lost 69.84 and 70.03 % of its initial flesh firmness in both seasons, respectively. The corresponding percentages respectively were 30.02 and 29.72 % for 0.5 ppm 1-MCP treated fruits and 16.02 and 17.65 % for 1 ppm 1-MCP treated ones. The differences were significant between the 1-MCP two concentrations where 1 ppm concentration reduced the flesh firmness loss by 15.09 and 15.19 % less than the 0.5 ppm one after 20 days of cold storage.

Regarding to shelf life fruits, 1-MCP treatment significantly maintained the flesh firmness of apricot fruits during the subsequent period at 20°C. Treated fruits had flesh firmness more than 2.50 lb/in^2 during the first three intervals in both seasons while the untreated ones had less than 1 lb/in^2. The 1 ppm concentration gave the highest firmness values.

The above results are consistent with Fan *et al.* (2000) and Palou and Crisosto (2003) on apricots. Fan *et al.* (2000) reported that inhibition of ethylene action in Perfection apricot fruit following treatment with 1-MCP delayed the onset of the climacteric increase in ethylene production and respiration rate. This delay is sufficient to delay loss of firmness associated with ripening. Also, 1-MCP was reported to reduce fruit softening enzymes activities of polygalacturonase, cellulose (Feng *et al.*, 2000), pectinmethylesterase (Jeong *et al.*, 2002) and *endo*-glucanase (Dong *et al.*, 2001).

With cold storage duration, all flesh firmness values decreased with highly significant r^2 values in both seasons. These data agree with Fan *et al.* (2000) on Perfection apricots and Aubert *et al.* (2010) on Bergeron apricots.

Table 5: Effects of 1-MCP treatment on flesh firmness (lb/in^2) of cold stored Canino apricot fruits in 2010 and 2011 seasons.

	Treatment	Storage Period (days)							r^2
		0	4	8	12	16	20	24	
2010	**Cold stored fruits**								
	0.5 ppm 1-MCP	6.33a	6.03ab	5.23b	4.43b	4.07b	3.77b		0.971**
	1 ppm 1-MCP	6.43a	6.27a	5.93a	5.40a	5.07a	4.80a	2.90a	0.853**
	Control	6.30a	5.17b	4.00c	1.90d				0.974*
	Shelf life fruits								
	0.5 ppm 1-MCP	2.77b	2.80c	2.50d	2.37d	2.00d	1.60d		
	1 ppm 1-MCP	3.20b	3.07c	2.80d	3.00c	2.53c	2.20c	1.23b	
	Control	0.73c	0.90d	0.60e	0.37e				
2011	**Cold stored fruits**								
	0.5 ppm 1-MCP	6.73a	6.00a	5.47b	4.73b	4.28b	3.60b		0.970**
	1 ppm 1-MCP	6.80a	6.53a	6.20a	5.60a	5.20a	4.67a	2.67a	0.861**
	Control	6.53a	4.85b	3.53c	1.63d				0.996**
	Shelf life fruits								
	0.5 ppm 1-MCP	2.57b	2.87c	2.73d	2.57c	2.27c	1.67c		
	1 ppm 1-MCP	3.07b	3.03c	2.87cd	2.80c	2.47c	2.67c	1.13b	
	Control	0.50c	0.77d	0.63e	0.53e				

Means within a column (in same season) having a common letter are not significantly different.
r^2=Determination coefficient.

Soluble solids content (SSC %):

Treatment by 1-MCP slowed the increase of SSC of Canino apricot fruits during both seasons (Table 6). At harvest, apricot fruits contained SSC values of 13.73 and 13.53 % in the first and the second seasons, respectively. These values did not change significantly directly after treatment (storage period of 0 days), but after 2 days at 20°C, these values increased and the highest SSC percentages were obtained by untreated fruits. During cold storage period, 1-MCP treated fruits contained lower significant values of SSC than untreated ones and there were insignificant differences between the two concentrations of 1-MCP. The same above results were obtained by shelf life fruits. It is concluded that 1-MCP inhibition to the ripening process such as SSC changes is a result of delaying climacteric ethylene production and respiration rate (Dong *et al.*, 2002 on plums). On the other hand, 1-MCP did not affect SSC of Canino apricots (Dong *et al.*, 2002), Patterson apricots (Palou and Crisosto, 2003), Marietta apricots (Martino *et al.*, 2006) and Blackamber plums (Candan *et al.*, 2006).

All fruits showed a significant increase in SSC values with the advancing of cold storage period (r^2 values were highly significant in both seasons). These results are consistent with Fan *et al.* (2000) on Perfection apricots and Aubert *et al.*, (2010) on Bergeron apricots. However, Ghasemnezad *et al.* (2010) reported that SSC decreased with storage of Darashti apricots. SSC in apricots slightly increases after harvest when fruits were early harvested; in contrast, at the advanced ripening stage, SSC tends to decrease after harvest (Botondi *et al.*, 2000) may be due to the respiration rate and conversion of sugars to carbon dioxide and H_2O (Saira *et al.*, 2009).

Titratable acidity (TA %):

The initial TA percentages of Canino apricot fruits at harvest were 1.98 and 1.97 % in both seasons, respectively (Table 7). These values did not change directly after 1-MCP treatment (storage period of 0 days) but declined significantly after 2 days at 20°C. The 1-MCP concentration of 1ppm had the highest significant values of TA during cold storage and subsequent shelf life periods. After 12 days of cold storage, TA of 1 ppm 1-MCP treated fruits declined by 19.29 and 9.60 % in both seasons, respectively, compared by 33.84 and 36.04 % for untreated fruits. The inhibition of ethylene action in apricot fruits by 1-MCP treatment delayed the decreasing in TA associated with ripening (Fan *et al.*, 2000 and Martino *et al.*, 2006). The above results and associated discussion are in agreement with Fan *et al.* (2000) on Perfection apricots, Martino *et al.* (2006) on Marietta apricot and Candan *et al.* (2006) on plums. However, 1-MCP did not affect TA of Canino apricots (Dong *et al.*, 2002) and Patterson apricots (Palou and Crisosto, 2003).

With the progress of cold storage period, all TA percentages decreased significantly where r^2 values were significant in both seasons. These results agree with Fan *et al.* (2000) on Perfection apricots, Martino *et al.* (2006) on Marietta apricots and Ghasemnezad *et al.* (2010) on Darashti apricots. The decreasing acidity at the end of storage might be due to the metabolic changes in fruits or due to the use of organic acid in respiratory process (Ghasemnezad *et al.*, 2010).

Table 6: Effects of 1-MCP treatment on soluble solids content (%) of cold stored Canino apricot fruits in 2010 and 2011 seasons.

	Treatment	Storage Period (days)							r^2
		0	4	8	12	16	20	24	
2010	**Cold stored fruits**								
	0.5 ppm 1-MCP	13.73b	13.87bc	13.80cd	14.00c	14.67b	15.00b		0.900**
	1 ppm 1-MCP	13.67b	13.40c	13.60d	14.07c	14.33b	14.73b	15.20a	0.884**
	Control	13.73b	14.53b	15.13ab	15.80ab				0.997**
	Shelf life fruits								
	0.5 ppm 1-MCP	14.20b	14.53b	14.80ab	15.00bc	15.40a	16.00a		
	1 ppm 1-MCP	14.20b	14.07bc	14.47bc	14.73c	15.33a	15.73a	16.13a	
	Control	14.93a	15.33a	15.60a	16.20a				
2011	**Cold stored fruits**								
	0.5 ppm 1-MCP	13.47c	13.33d	13.87d	14.40d	14.90b	15.53bc		0.937**
	1 ppm 1-MCP	13.40c	13.53cd	13.93dc	14.27d	14.87b	15.20c	15.40a	0.980**
	Control	13.53bc	14.33b	15.20ab	15.93ab				0.999**
	Shelf life fruits								
	0.5 ppm 1-MCP	14.07abc	14.60ab	15.00ab	15.40bc	15.80a	16.13a		
	1 ppm 1-MCP	14.33ab	14.20bc	14.67bc	14.93dc	15.47a	15.80ab	16.27a	
	Control	14.87a	15.20a	15.53a	16.47a				

Means within a column (in same season) having a common letter are not significantly different.

r^2=Determination coefficient.

Table 7: Effects of 1-MCP treatment on titratable acidity (g malic acid /100 ml of fruit juice) of cold stored Canino apricot fruits in 2010 and 2011 seasons.

	Treatment	Storage Period (days)							r^2
		0	4	8	12	16	20	24	
2010	**Cold stored fruits**								
	0.5 ppm 1-MCP	1.97a	1.89b	1.63b	1.28b	1.42ab	1.31ab		0.833*
	1 ppm 1-MCP	1.97a	2.05a	1.82a	1.59a	1.47a	1.40a	1.23a	0.945**
	Control	1.98a	1.74c	1.61b	1.31b				0.979**
	Shelf life fruits								
	0.5 ppm 1-MCP	1.63b	1.27d	1.17d	1.11cd	1.24c	1.19b		
	1 ppm 1-MCP	1.54b	1.73c	1.43c	1.22bc	1.28bc	1.23b	1.03b	
	Control	1.37c	1.20d	1.03e	1.01d				
2011	**Cold stored fruits**								
	0.5 ppm 1-MCP	2.00a	1.84a	1.69ab	1.55b	1.44b	1.21a		0.992**
	1 ppm 1-MCP	1.98a	1.89a	1.76a	1.79a	1.68a	1.26a	1.15a	0.872**
	Control	1.97a	1.74a	1.60b	1.26c				0.973*
	Shelf life fruits								
	0.5 ppm 1-MCP	1.50b	1.21c	1.14c	1.08d	1.15c	1.16a		
	1 ppm 1-MCP	1.47b	1.48b	1.24c	1.11d	1.34b	1.17a	0.93b	
	Control	1.36b	1.19c	1.00d	0.91e				

Means within a column (in same season) having a common letter are not significantly different.
r^2=Determination coefficient.

Vitamin C (mg ascorbic acid / 100 ml fruit juice):

At harvest, Canino apricot fruits contained 15.93 and 14.60 mg ascorbic acid/ 100 ml fruit juice in the first and the second seasons, respectively (Table 8). These contents were not affected by 1-MCP directly after treatment but with the duration of cold storage, 1-MCP had significant effect on maintaining ascorbic acid content and on delaying its loss with insignificant differences between concentrations. When the fruits were kept directly after treatment at 20°C, the treated fruits (an average of both concentrations) lost 27.47 and 17.74 % of vitamin C compared by 38.48 and 30.34 % for untreated fruits in both seasons, respectively. After 12 days of cold storage and in both seasons respectively, 1 ppm 1-MCP treated fruits lost the least percentages of vitamin C of 15.25 and 21.63 % compared by 24.88 and 26.72 % for 0.5 ppm 1-MCP treated fruits and 66.10 and 64.93 % for the untreated fruits. The above effect of 1-MCP treatment was obtained also in shelf life fruits where the untreated fruits contained the lowest significant values of ascorbic acid. All ascorbic acid contents declined with the increasing of cold storage period (r^2 values were significant in both seasons).

The positive effect of 1-MCP on the retention of vitamin C contents agree with the results of Selvarajah *et al.* (2001) on pineapple and both Bassetto *et al.* (2005) and Singh and Pal (2008) on gauava. However, Larrigaudière *et al.* (2004) reported that 1-MCP treatment decreased vitamin C of pear fruits. Ascorbic acid plays an important role in detoxification of activated oxygen (Foyer *et al.*, 1991). Ascorbate levels generally increase in plants under stress conditions (Allen, 1995). The presence of high levels of ascorbate in fruit favours stress compensation. A decrease in ascorbate is often considered a symptom of fruit senescence (Borracino *et al.*, 1994) and is directly associated with the incidence of physiological disorders during storage (Veltman *et al.*, 1999 and Pint *et al.*, 2001). The preservation of higher vitamin C contents may result from the 1-MCP-induced retarded ripening of fruit (Singh and Pal, 2008). 1-MCP treatment has been proposed to reduce the accumulation of active oxygen species (AOS) in fruit (Larrigaudi'ere *et al.*, 2004) which in turn may help to prevent loss of vitamin C in order to scavenge AOS. 1-MCP-induced ethylene inhibition indicated that ethylene might be playing a detrimental role through its involvement in oxidative injury to the loss of vitamin C content of fruit (Singh and Pal, 2008).

Table 8: Effects of 1-MCP treatment on V.C (mg ascorbic acid / 100 ml fruit juice) of cold stored Canino apricot fruits in 2010 and 2011 seasons.

	Treatment	Storage Period (days)							r^2
		0	4	8	12	16	20	24	
2010	**Cold stored fruits**								
	0.5 ppm 1-MCP	16.20a	15.73a	14.10a	12.17a	10.80ab	8.33ab		0.973**
	1 ppm 1-MCP	16.20a	15.87a	15.07a	13.73a	12.27a	9.87a	7.70a	0.940**
	Control	15.93a	14.00ab	9.38b	5.40c				0.976*
	Shelf life fruits								
	0.5 ppm 1-MCP	12.03b	10.80c	10.10b	10.03b	8.83b	6.70b		
	1 ppm 1-MCP	11.47b	11.63bc	10.47b	12.17a	10.60ab	7.77ab	5.07b	
	Control	9.80b	6.90c	6.68c	4.17c				
2011	**Cold stored fruits**								
	0.5 ppm 1-MCP	14.37ab	13.97a	11.60b	10.53ab	9.17ab	6.97ab		0.976**
	1 ppm 1-MCP	14.93a	14.07a	13.30a	11.77a	10.40a	8.63a	5.67a	0.954**
	Control	14.60ab	10.93b	8.48cd	5.12c				0.995**
	Shelf life fruits								
	0.5 ppm 1-MCP	11.90bc	10.93b	9.18c	9.50b	7.50b	5.70b		
	1 ppm 1-MCP	12.20abc	11.67b	10.07bc	10.53ab	8.87ab	6.80ab	3.80b	
	Control	10.17c	7.10c	6.81d	3.70c				

Means within a column (in same season) having a common letter are not significantly different.
r^2=Determination coefficient

POD enzyme activity (O.D.):

Directly after 1-MCP treatment, POD enzyme activity decreased compared by the initial activity at harvest (Table 9). When the fruits kept after treatment for 2 days at 20°C, the treated fruits had lower POD activity than the untreated ones. After 4 days of cold storage, 1 ppm 1-MCP gave the lowest significant POD activity in both seasons compared by 0.5 ppm 1-MCP treated and untreated fruits. During cold storage, 1-MCP applications slowed the POD activity and after 12 days the treated fruits by both concentrations had lower POD activities compared by untreated fruits. There were insignificant differences between the two 1-MCP concentrations during the rest of cold storage period in both seasons. That effect of 1-MCP continued when the fruits were transported to 20°C for 2 days where the highest significant activity was obtained by the untreated fruits. With the duration of cold storage period, POD activity increased significantly and the highest r^2 values were recorded for untreated fruits.

The results of 1-MCP on suppression POD activity were showed by Blankenship and Dole (2003) on apples, Hershkovitz *et al.* (2005) on avocado and Win *et al.* (2006) on limes.

PPO enzyme activity (O.D.):

At harvest, Canino apricot fruits had the initial PPO activity of 0.070 in the first season and 0.075 in the second one (Table 10). These values declined directly after 1-MCP treatment. When the fruits were kept directly after treatment at 20°C, the treated fruits had lower significant activity than the untreated ones. 1-MCP treatment had significant effect on delaying the increase in PPO activity during cold storage and subsequent shelf life period. The untreated fruits showed the highest significant PPO activity and generally the 1ppm 1-MCP treatment had lower PPO activity compared by 0.5 one. The same trend was recorded for shelf life fruits where the untreated fruits had the highest significant PPO activity in both seasons.

The results of 1-MCP on suppression POD activity were recorded by Cai *et al.* (2006) on loquat fruits, Pesis *et al.* (2002) on avocado and Hershkovitz *et al.* (2005) on avocado.

Table 9: Effects of 1-MCP treatment on POD activity (O.D.) of cold stored Canino apricot fruits in 2010 and 2011 seasons.

	Treatment	Storage Period (days)							r^2
		0	4	8	12	16	20	24	
2010	**Cold stored fruits**								
	0.5 ppm 1-MCP	0.050c	0.057cd	0.077b	0.078d	0.090ab	0.076a		0.682*
	1 ppm 1-MCP	0.049c	0.044d	0.064b	0.077d	0.065b	0.071a	0.081b	0.720*
	Control	0.054c	0.058c	0.080b	0.099c				0.940*
	Shelf life fruits								
	0.5 ppm 1-MCP	0.069b	0.078ab	0.091ab	0.108b	0.109a	0.099a		
	1 ppm 1-MCP	0.057c	0.068bc	0.087ab	0.101bc	0.098ab	0.093a	0.117a	
	Control	0.087a	0.082a	0.110a	0.131a				
2011	**Cold stored fruits**								
	0.5 ppm 1-MCP	0.054c	0.064b	0.082bc	0.082c	0.098ab	0.078a		0.593
	1 ppm 1-MCP	0.051c	0.048c	0.072c	0.081c	0.071b	0.078a	0.088b	0.760*
	Control	0.058c	0.064b	0.086bc	0.108b				0.951*
	Shelf life fruits								
	0.5 ppm 1-MCP	0.074b	0.082a	0.098ab	0.110b	0.119a	0.108a		
	1 ppm 1-MCP	0.063bc	0.077ab	0.094abc	0.110b	0.112a	0.102a	0.125a	
	Control	0.091a	0.087a	0.118a	0.141a				

Means within a column (in same season) having a common letter are not significantly different.
r^2=Determination coefficient.

Table 10: Effects of 1-MCP treatment on PPO activity (O.D.) of cold stored Canino apricot fruits in 2010 and 2011 seasons.

	Treatment	Storage Period (days)							r^2
		0	4	8	12	16	20	24	
2010	**Cold stored fruits**								
	0.5 ppm 1-MCP	0.066bc	0.058cd	0.042b	0.031d	0.032b	0.045b		0.548
	1 ppm 1-MCP	0.063c	0.046d	0.042b	0.029d	0.026b	0.028c	0.040a	0.510
	Control	0.070bc	0.066bc	0.052b	0.048c				0.941*
	Shelf life fruits								
	0.5 ppm 1-MCP	0.074b	0.076ab	0.101a	0.088b	0.079a	0.065a		
	1 ppm 1-MCP	0.071bc	0.067bc	0.056b	0.048c	0.075a	0.059a	0.046a	
	Control	0.097a	0.087a	0.117a	0.108a				
2011	**Cold stored fruits**								
	0.5 ppm 1-MCP	0.072bc	0.061c	0.046b	0.033d	0.035b	0.046b		0.611
	1 ppm 1-MCP	0.068c	0.052d	0.046b	0.032d	0.030b	0.037b	0.044b	0.481
	Control	0.075bc	0.074b	0.112a	0.052c				0.729
	Shelf life fruits								
	0.5 ppm 1-MCP	0.078b	0.077b	0.060b	0.087b	0.085a	0.070a		
	1 ppm 1-MCP	0.079b	0.074b	0.053b	0.054c	0.079a	0.062a	0.053a	
	Control	0.102a	0.094a	0.128a	0.103a				

Means within a column (in same season) having a common letter are not significantly different.
r^2=Determination coefficient.

CONCLUSION

1-MCP application effectively prevented chilling injury incidence, retarded ripening and senescence of Canino apricot fruits and significantly improved their storagability. That reflected on decreasing loss of fruit weight, flesh firmness, malic acid and vitamin C contents. 1-MCP delayed the changes in skin color, soluble solids and carotenoids contents and declined PPO and POD enzymes activities.

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الملخص العربي

المعاملة ١- ميثيل سيكلوبروبين تحافظ على جودة الثمار، تمنع أضرار التبريد وتقلل نشاط إنزيمي البيروكسيديز والبولي فينول أوكسيديز لثمار المشمش كانينو خلال التخزين المبرد وفترة التسويق

رجاء موسى علي الصعيدى

معهد بحوث البساتين ، مركز البحوث الزراعية ، الجيزة ، مصر

أجريت هذه الدراسة خلال موسمى ٢٠١٠ و ٢٠١١ لتحديد استجابة ثمار المشمش صنف كانينو للتركيزات المختلفة من ١- ميثيل سيكلوبروبين خلال فترة التخزين المبرد وفترة التسويق. تضمنت المعاملات تعريض الثمار قبل التخزين لأحد التركيزيين ٠,٥ أو ١ جزء في المليون من ١- ميثيل سيكلوبروبين لمدة ٢٠ ساعة على درجة حرارة ٢٠ °م. تم مقارنة هذه المعاملات بالثمار غير المعاملة خلال فترة التخزين المبرد على درجة صفر±١°م ورطوبة نسبية ٨٥-٩٠±٥ % وخلال فترة التسويق لمدة يومين على درجة حرارة ٢٠ °م. أخرت معاملة ١- ميثيل سيكلوبروبين معنويا من نضج وتدهور ثمار المشمش كانينو وحسنت معنويا من إمكانية تخزينها المبرد في كلا الموسمين بمدة ٨ و ١٢ يوم للتركيزات ٠,٥ و ١ جزء في المليون، على التوالي بالمقارنة بالثمار غير المعاملة. قللت معاملة ١- ميثيل سيكلوبروبين من فقد كل من وزن الثمار، صلابة اللحم، حامض الماليك وفيتامين ج. أخرت معاملة ١- ميثيل سيكلوبروبين معنويا من تغيرات لون الثمار ومحتواها من المواد الصلبة الذائبة والكاروتين الكلي. قل نشاط إنزيمي البيروكسديز والبولي فينول أوكسيديز معنويا بالمعاملة ١- ميثيل سيكلوبروبين.