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EFFECT OF POSTHARVEST OXALIC ACID TREATMENT ON COLD STORAGE OF APRICOT CV. 'APRIKOZ'

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Abstract

In this study, effects of postharvest oxalic acid (OA) treatments on storage life and quality of apricot cv. 'Aprikoz' were investigated. Fruit were harvested at optimum stage (firm ripe stage) and transported to the postharvest physiology laboratory, immediately. Apricots were immersed in different doses (0, 1, 2, 4 and 8 mM) of OA solution+ Tween 20 for 10 minutes. After treatments, fruit were held at room conditions for drying during 30 minutes. Dried fruit were placed in modified atmosphere packages (MAP) and stored for 40 days at 0°C and 90±5% relative humidity. The weight loss, total soluble solids content, titratable acidity, fruit flesh firmness, fruit skin color, respiration rate and gas composition of MAP were determined at the beginning of the storage and 10-day intervals during the cold storage period. As a result, all doses of OA gave better results than control group in terms of some quality parameters. Especially, 1 mM dose of OA was the most effective treatment for decreasing weight loss and maintaining fruits firmness. The results suggest that OA has the potential to extend the storage life of apricot by delaying quality loss.

Key words*: apricot, oxalic acid, modified atmosphere, cold storage.*

INTRODUCTION

Apricots are one of the most popular fruit in both domestic and international markets owing to its delicious taste and aroma (Özdoğru et al., 2015). Apricots have sufficient amounts of sucrose, glucose, fructose and high antioxidant components (lycopene, β-carotene, vitamins A and E) and minerals (K, P, and Mg). Consumption of apricots plays an important role in preventing diseases and maintaining healthy life (Muradoğlu et al., 2011). Orchard conditions, developmental stage at harvest, and other postharvest factors such as chilling injury, high temperature and mechanical damage influence fruit quality. Fruit quality in apricot is an important factor that affects consumers' perception. Apricots as climacteric stone fruit have a limited postharvest life (Ezzat et al., 2017). The main factor limiting the postharvest life of apricot fruit are very rapid maturation process due to the high rate of respiration after harvest (Abd El Wahab, 2015; Jing et al., 2018). Oxalic acid (OA), as a final metabolite product in plants (Martinez-Espla et al., 2014), plays an important role in physiological functions such as regulating stress responses, resistance against disease (Wu et al., 2011). In addition, postharvest treatments with OA were effective in delaying some processes of climacteric fruit through an inhibition of ethylene biosynthesis (Martinez-Espla et al., 2014). Another beneficial effect of pre-storage OA applications is reduced chilling injury in pomegranate and mango in connection with an enhance in antioxidant capacity (Li et al., 2014). In previous studies, it was reported that both pre- and postharvest OA treatments extended storage life, and maintained fruit quality during the storage period. Zheng et al. (2007a; 2007b) stated that OA treatments in mango and peach fruit were effective in extending the postharvest life. Razavi and Hajilou (2016) treated sweet cherries with OA and stored them for 20 days under cold temperature, and reported that OA delayed the postharvest ripening. In literature, it can be found some researches related to OA but there are not enough studies about the effect of OA on the postharvest life and quality of apricot

during cold storage. The aim of this study was to investigate the effect of postharvest OA treatment on cold storage of apricot cv. 'Aprikoz'.

MATERIALS AND METHODS

Harvest and postharvest treatments

The fruit of apricot cv. 'Aprikoz' were harvested at commercial harvest stage (yellowish-green and firm ripe), and transported to the postharvest laboratory, immediately by a frigofric car. Fruit were selected for uniformity (color, size and shape) and any blemished/diseased fruit were discarded. Selected apricots were randomly divided into five groups. First group (control) apricots were dipped into distilled water + 0.01% Tween-20 (a surfactant) for 10 min. The other four group apricots were dipped into in different doses (1, 2, 4 and 8 mM) of OA solution + 0.01% Tween 20 for 10 minutes. After dipping treatments, fruit were held at room conditions for drying during 30 minutes. Dried fruit were placed in modified atmosphere packages (MAP) (25 µm low-density polyethylene) and stored for 40 days at 0°C and 90±5% relative humidity. All analyses were performed at harvest date and 10 days intervals during cold storage.

Chemical and physical analysis

Weight loss of apricots was measured over 15 fruit in each replicate and expressed as the percentage of loss of weight with respect to the initial weight. Weight loss was determined by the formula; Weight loss = [(First weight - Last weight)/First weight] × 100. Fruit flesh firmness was measured over 15 fruit in each replicate. Fruit flesh firmness (a small slice of fruit skin was removed from each side of a fruit) was determined using a digital texture machine and measured via compression using a 50 N load cell and a stainless steel, 5.1 mm diameter. The results were expressed as Newton (N). Total soluble solid (TSS) content was measured using a digital refractometer (Atago Pocket PAL-1) and expressed as percentage. Titratable acidity (TA) was determined by a digital pH meter (Hanna Instruments HI 9231) and titrimeter (Digitrat, Isolab), and expressed as percentage. Fruit skin color was determined using a Minolta CR-300 colorimeter over 15 fruit in each replicate. The values were expressed by the CIE L^* (brightness-darkness), a^* ($+a^*$: red, $-a^*$: green) and b^* ($+b^*$: yellow, $-b^*$: blue) system. Respiration rate and ethylene production were measured in 600-700 g of fruit samples for each replicate. Fruit were weighed and placed in 2 L airtight jars for 2 h at 20ºC. Then gas sample was taken from jars and injected into gas chromatographs. Results were expressed as µL/kg.h for ethylene production and mL CO_2/kg h for respiration rate. Gas concentration (O_2 and CO_2) in the packages was measured by Gaspace 2 (Gas Headspace analyzer, Systech Instruments) and expressed as percentage. External appearance was rated on a hedonic scale of 1-9 (1-3: unmarketable, 5: marketable, 7: good, 9: very good), taste was rated on a hedonic scale of 1-5 (1: very bad, 2: bad, 3: medium, 4: good, 5: very good) and internal browning was rated on a hedonic scale of 0-4 (0: healthy, 1: 1-10%, 2: 11-33%, 3: 33-66%, 4: 66-100%). The experiment was set up according to the factorial randomized design with 3 replications (40 fruit per replication). Data were subjected to analysis of variance (ANOVA, JMP7), means were separated by means of Tukey test ($P<0.05$).

RESULTS AND DISCUSSIONS

Weight loss. Weight losses of apricots treated with different doses of OA, during the cold storage, was given in the Table 1. Weight loss, one of the most important factors limiting the storage life of the products, has increased continuously during storage. But this increase was found to be lower in OA treatments (except for 4 mM) than in control groups. The weight loss of the apricots treated with dose of 1 mM OA (1.36 %) was significantly delayed compared to control and other doses at the end of cold storage (Table 1.) Fruit lost their weight mainly due to respiration and transpiration through skin and various metabolic activities. The positive effects of OA on weight loss of fruit might be due to slowed metabolic process and decreased respiratory rate (Razzaq et al., 2015). According to some researches which are parallel to our results, OA-treated fruit exhibited reduced weight loss compared with control (Sayyari et al., 2010; Razzaq et al.,

2015). Sayyari et al., 2010 reported that pre-storage OA treatments reduced the weight loss in pomegranate fruit stored at 2°C for 84 days. Also, Razzaq et al. (2015) reported that OA treatments reduced weight loss in mango fruit.

Table 1. Weight loss (%) of 'Aprikoz' apricots treated with OA during MAP storage at 0°C

Treatment	10 d	20 d	30 d	40 d	Means
Control	0.55	1.34	1.94	2.58	1.59 ab*
1 mM	0.56	1.17	1.53	2.23	1.36 c
2 mM	0.64	1.43	1.55	2.53	1.53 ab
4 mM	0.60	1.50	1.93	2.60	1.65 a
8 mM	0.51	1.34	1.57	2.45	1.46 bc
Means	0.57 d	1.35 c	1.70 b	2.47 a	

*Means followed by the same letter in the same row and column are not statistically significant (P<0.05); d: days.

Fruit flesh firmness. The OA treatments had positive effects on fruit firmness. The flesh firmness in treated fruit was maintained compared with the control, thus fruit softening rate was delayed by OA during storage. The highest firmness value (34.43 N) was determined in 1 mM OA treatment, whereas the lowest (30.71 N) was from control fruit (Table 2). There are similar results obtained by other researchers. Studies on peach (Razavi and Hajilou, 2016; Zheng et al., 2007b), mango (Zheng et al., 2007a) and plum (Wu et al., 2011) showed that OA treatments maintained flesh firmness, delayed softening and extended the postharvest life of fruit. Correspondingly Wu et al. (2011) stated that the application of OA delayed softening of plum fruit. They suggested that the inhibition of softening was associated with decreased polygalacturonase (PG) and pectin methyl esterase (PME) activities; that is, the retardation of pectin solubilization/degradation (Razavi and Hajilou, 2016).

Total soluble solid (TSS) content and titratable acidity (TA). The effects of OA treatments on TSS content and TA were statistically significant (P<0.05). The TSS and TA decreased in all treatments with increasing storage period. The TSS of fruit treated with 1.0 and 8.0 mM doses were significantly higher than those of control. The TSS contents varied between 10.50% and 9.57% at the end of 40 days (Table 3). The TA contents of fruit gradually decreased over the storage period regardless of treatments. The highest TA value was obtained from 1 mM dose of OA varying in the range of 1.10-0.92 throughout storage period. Zheng et al. (2007a) reported that OA treatments in mango, a climacteric fruit, increased TSS while TA was decreased. Adverse results of Zheng et al. (2007a; 2007b) related to TSS may be attributed to different species and storage condition.

Table 2. Firmness (N) of 'Aprikoz' apricots treated with OA during MAP storage at 0°C

Treatment	0 d	10 d	20 d	30 d	40 d	Means
Control	36.10	31.46	29.64	29.20	27.13	30.71 c*
1 mM	36.10	35.87	34.23	33.89	32.04	34.43 a
2 mM	36.10	35.00	33.65	32.55	30.31	33.52 ab
4 mM	36.10	33.24	32.30	29.55	28.96	32.03 bc
8 mM	36.10	31.96	31.71	29.34	29.30	31.68 c
Means	36.10 a	33.51 b	32.30 bc	30.91 cd	29.55 d	

*Means followed by the same letter in the same row and column are not statistically significant (P<0.05); d: days.

Table 3. TSS and TA of 'Aprikoz' apricots treated with OA during MAP storage at 0°C

	Treatment	0 d	10 d	20 d	30 d	40 d	Means
TSS	Control	11.53	11.63	11.00	10.80	9.97	10.99 bc*
	1 mM	11.53	11.70	11.47	11.20	10.50	11.28 a
	2 mM	11.53	10.93	10.87	10.63	10.47	10.89 bc
	4 mM	11.53	11.00	10.97	10.70	9.57	10.79 c
	8 mM	11.53	11.90	11.43	10.57	10.27	11.14 ab
	Means	11.53a	11.39ab	11.19b	10.78c	10.15d	
TA	Control	1.10	1.02	1.00	0.89	0.87	0.98 ab*
	1 mM	1.10	1.07	1.02	0.93	0.92	1.01 a
	2 mM	1.10	1.04	0.96	0.92	0.86	0.98 ab
	4 mM	1.10	0.95	0.94	0.90	0.81	0.94 b
	8 mM	1.10	0.94	0.91	0.90	0.77	0.92 b
	Means	1.10 a	1.00 a	0.97 a	0.91 b	0.85 b	

*Means followed by the same letter in the same row and column are not statistically significant (P<0.05); d: days.

Ethylene production and respiration rate. In the present study, the effect of the treatments on ethylene production (µL/kg h) and respiration rate (mL CO_2/kg h) was significant ($P<0.05$). The highest ethylene production (0.58 µL/kg h) was determined from untreated fruit, whereas the lowest ethylene production (0.46 µL/kg h) was detected in 8 mM OA-treated fruit. The OA treatments influenced the ethylene production of apricots depending on dose levels. The average ethylene production of fruit decreased with increasing doses of OA showing its obvious effect on ethylene biosynthesis (Table 4). Respiration rate is an important factor in maintaining quality during cold storage and shelf life of fruit. For this reason, it is important to reduce the respiration rate of the apricots during storage. It can be seen from data that the respiration rates of OA treated fruit are suppressed better than control group. The lowest respiration rate (44.64 mL CO_2/kg h) was detected in 4 mM OA-treated fruit. Similarly in a previous study, the decreased ethylene production by OA contributed to the delaying of ripening of plum fruit, and reported that reduced ethylene production in OA-treated fruit might be ascribed to the reduced 1-aminocyclopropane-1-carboxylic acid synthase (ACS) activity (Wu et al., 2011). In addition, it was reported that OA treatments reduced respiration rate of peach fruit, and inhibited the ethylene production rates in mango and plum (Huang et al., 2013).

Fruit skin color. The results of the effects of OA treatments on the change of fruit skin color are given in Table 5. The effects of storage period and treatments on L^*, a^* and b^* value of fruit skin were statistically significant, ($P<0.05$). L^* value, which shows fruit brightness of fruit skin, decreased during the storage period. The highest L^* value was 72.93 with OA 8 mM treatment. The a^* and b^* values of the fruit generally showed an increase during storage. All treatments showed similar characteristics of the a^* value when compared to the control group. The highest a^* (-6.80) and lowest b^* (44.68) values were obtained from 4 mM OA treated fruit. The skin color of apricots is one of the symbols of fruit senescence. In general, the color of the skin changes from yellow-green (at harvest) to orange-yellow (at the end of storage). OA-treated fruit turned to orange-yellow slowly compared to control fruit during storage. Turning color to dark-orange has been associated with ripening of apricot. OA delayed the ripening process of climacteric fruit such as mango (Zheng et al., 2007a) and peach (Zheng et al., 2007b), due to the inhibition of ethylene production.

Sensory analyses. Storage period and treatments affected significantly the external appearance, taste scores and internal browning of apricots during storage ($p<0.05$).

OA treated apricots preserved their external appearance and taste values better than control fruit (Table 6).

The average highest external appearance (8.79) and taste (4.83) scores were obtained from 1 mM OA treatment during storage.

Table 4. Ethylene production (µL/kg h) and respiration rate (mL CO_2/kg h) of 'Aprikoz' apricots treated with OA during MAP storage at 0°C

	Treatment	0 d	10 d	20 d	30 d	40 d	Means
Ethylene Production	Control	0.54	0.54	0.63	0.73	0.48	0.58 a*
	1 mM	0.36	0.56	0.52	0.67	0.57	0.54 ab
	2 mM	0.37	0.42	0.42	0.80	0.65	0.53 ab
	4 mM	0.40	0.50	0.40	0.50	0.67	0.50 ab
	8 mM	0.43	0.58	0.42	0.45	0.45	0.46 b
	Means	0.42 c	0.52 abc	0.48 bc	0.63 a	0.56 ab	
Respiration Rate	Control	95.97	67.46	48.90	32.77	34.74	55.97 a*
	1 mM	75.52	42.99	48.01	41.14	34.79	48.49 bc
	2 mM	86.28	59.50	50.39	36.55	33.80	53.31 ab
	4 mM	80.01	35.38	33.33	43.25	31.25	44.64 c
	8 mM	84.71	52.83	35.70	39.77	34.35	49.47 abc
	Means	51.63 a	43.27 b	38.70 c	33.79 cd	34.50 d	

*Means followed by the same letter in the same row and column are not statistically significant ($P<0.05$); d: days.

Table 5. Change color (L^*, a^*, b^*) of 'Aprikoz' apricots treated with OA during MAP storage at 0°C

	Treatment	0 d	10 d	20 d	30 d	40 d	Means
L^*	Control	74.07	72.32	73.65	71.90	70.81	72.55 ab*
	1 mM	74.07	73.47	72.75	71.54	70.51	72.47ab
	2 mM	74.07	73.14	73.35	72.26	68.24	72.21 b
	4 mM	74.07	72.65	73.30	71.84	68.13	71.99 b
	8 mM	74.07	74.28	74.22	73.43	68.65	72.93a
	Means	74.07 a	73.17 c	73.45 b	72.19 c	69.26 d	
a^*	Control	-11.79	-9.75	-4.32	-6.02	-4.85	-7.34ab*
	1 mM	-11.79	-8.37	-4.56	-5.60	-7.69	-7.60b
	2 mM	-11.79	-7.53	-5.10	-4.95	-6.51	-7.17ab
	4 mM	-11.79	-7.11	-5.04	-4.54	-5.53	-6.80a
	8 mM	-11.79	-6.87	-5.39	-7.10	-6.41	-7.51ab
	Means	-11.78 d	-7.92 c	-4.88 a	-5.63 ab	-6.19 b	
b^*	Control	43.99	45.18	47.64	46.84	45.16	45.76a*
	1 mM	43.99	47.47	45.71	46.89	44.46	45.70a
	2 mM	43.99	45.20	46.96	45.53	43.00	44.93b
	4 mM	43.99	43.85	45.38	46.94	43.27	44.68b
	8 mM	43.99	47.01	47.34	46.19	43.89	45.68a
	Means	43.99 c	45.74 b	46.60 a	46.47 a	43.95 c	

*Means followed by the same letter in the same row and column are not statistically significant (P<0.05); d: days.

Table 6. The external appearance, taste and internal browning scores of fruit during MAP storage at 0°C

	Treatment	0 d	10 d	20 d	30 d	40 d	Means
External Appearance	Control	9.00	9.00	9.00	7.45	8.33	8.12 d*
	1 mM	9.00	9.00	9.00	8.60	8.05	8.79 a
	2 mM	9.00	9.00	9.00	8.50	7.96	8.71 b
	4 mM	9.00	9.00	9.00	8.20	7.80	8.63 c
	8 mM	9.00	9.00	9.00	8.14	6.15	8.59 c
	Means	9.00 a	9.00 a	9.00 a	8.18 b	7.66 c	
Taste	Control	5.00	5.00	5.00	4.20	3.20	4.42 c*
	1 mM	5.00	5.00	5.00	4.86	4.30	4.83 a
	2 mM	5.00	5.00	5.00	4.25	4.00	4.65 b
	4 mM	5.00	5.00	5.00	4.10	4.00	4.62 b
	8 mM	5.00	5.00	4.70	4.05	3.80	4.57 b
	Means	5.00 a	5.00 a	4.94 a	4.29 b	3.86 c	
Internal browning	Control	0.00	0.00	0.60	1.50	1.90	0.84 a*
	1 mM	0.00	0.00	0.00	1.10	1.40	0.50 c
	2 mM	0.00	0.00	0.00	1.20	1.60	0.56 bc
	4 mM	0.00	0.00	0.00	1.40	1.80	0.64 bc
	8 mM	0.00	0.00	0.00	1.60	1.70	0.66 c
	Means	0.00 c	0.00 c	0.12 c	1.36 b	1.68 a	

*Means followed by the same letter in the same row and column are not statistically significant (P<0.05); d: days.
External appearance: 1-3: unmarketable, 5: marketable, 7: good, 9: very good; Taste: 1: very bad, 2: bad, 3: medium, 4: good, 5: very good; Internal browning: 0: healthy, 1: 1-10%, 2: 11-33%, 3: 33-66%, 4: 66-100%.

Control fruit gave the lowest external appearance (8.12) and taste (4.42) scores. Internal browning of fruit increased compared to the initial values at the end of cold storage regardless of treatment, but the lowest value was determined in 1 mM OA treatment. The OA treatments limited internal browning incidence of apricots (Table 6). It can be said that internal browning is the important and limiting factor for marketable quality of apricots (Koyuncu et al., 2010).

Gas composition. The CO_2 concentration in the packages increased, while a decreasing was found in O_2 concentration compared to initial levels during storage period (Table 7). The effects of storage period and treatments on O_2 and CO_2 values in MAP were significant (P<0.05). The highest average O_2 (15.06%) and

the lowest CO_2 (5.65%) concentrations were measured in packages of 1 mM OA treatment. This means that the 1 mM dose of OA suppressed respiration rate of apricots better than the other treatments. Generally, OA treatments decreased respiration rate of apricots compared to control group according to gas compositions in MAP. Our findings related to respiration rate (Table 4), which indicates suppressing effect of OA on respiration, support present results.

Table 7. The O_2 (%) and CO_2 (%) composition of MAP during storage at 0°C

Treatment		10 d	20 d	30 d	40 d	Means
O_2	Control	15.55	14.55	14.15	11.60	13.96ab*
	1 mM	15.85	15.90	15.25	13.23	15.06 a
	2 mM	15.95	14.35	14.11	12.96	14.34 ab
	4 mM	15.80	15.45	13.90	13.63	14.70 ab
	8 mM	15.85	13.15	12.65	10.90	13.14 b
Means		15.80a	14.68ab	14.01bc	12.46c	
CO_2	Control	5.88	6.30	7.10	8.65	6.98 a*
	1 mM	4.15	4.90	6.30	7.25	5.65 b
	2 mM	5.70	5.95	7.40	8.20	6.81 a
	4 mM	5.85	6.15	7.30	7.90	6.80 a
	8 mM	4.82	6.15	7.30	8.35	6.66 a
Means		5.28 c	5.89 c	7.08 b	8.07a	

*Means followed by the same letter in the same row and column are not statistically significant (P<0.05); d: days.

CONCLUSIONS

In conclusion, all doses of OA gave better results than control group in terms of some quality parameters. Especially, 1 mM dose of OA was the most effective treatment for decreasing weight loss and maintaining fruit flesh firmness, TA and sensory quality. The results suggest that OA has the potential to extend the storage life of apricot by delaying quality loss. Based on our results, it can be indicated that OA could maintain fruit firmness and delayed quality loss of apricot by suppression of ethylene production and respiration rate.

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