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Research Article

Preharvest Application with Oxalic Acid and Calcium Nitrate Maintains the Quality of Cold-Stored 'Swelling' Peach Fruits

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Abstract:

Peach is a climacteric fruit suffering from rapid over-ripening and softening as well as quality deterioration after harvesting as a result having short storage period and shelf life. Therefore, the objective of this study was to investigate the effectiveness of preharvest spray applications of 5 mM oxalic acid (OA) and 2% calcium nitrate (CaNi) on quality attributes of peach fruit cv. Swelling during 30 days of cold storage at 0±1ºC and 90-95% RH. The results showed that preharvest treatments of fruit with 5 mM OA recorded the significantly highest marketable percentage and visual appearance score, restricted the increase in total soluble solids/titratable acidity ratio and was more effective in maintaining the maximum content of ascorbic acid followed by 2% CaNi as compared to control. Therefore, it could be recommended to use OA at 5 mM and CaNi at 2% as safe preharvest treatments to maintain quality attributes of 'Swelling' peach fruits during cold storage.

1. Introduction

Peach (*Prunus persica L.*) belongs to family Rosaceae. It is an important stone fruit crop of the world that originated in China or north-west China. Peach is one of most deciduous fruits that grows successfully in the newly reclaimed areas in Egypt. Peach fruits show a climacteric behavior and deteriorate quickly after harvesting at ambient temperature, which results in quick postharvest decay and wastage during handling and transportation (Brummell et al., 2004). Peach cv. Swelling is one of the late season cultivars which suffer from accelerated-softened fruits, and therefore, the fruits exhibit a short handling period which limits its commercial potential. Storage at low temperature of harvested peach is indispensable to decrease the quality loss and excessive softening and to prolong the time for marketing by lowering the incidence of decay and slowing down the metabolic activities of fruits (Tareen et al., 2012).

Oxalic acid (OA) is an organic acid widely distributed in plants and acts as a natural antioxidant that induce an increase in membrane integrity and a delay in fruit ripening by controlling enzymes related to quality changes in peach fruits (Zheng and Tian, 2006). Recently, preharvest application of OA has received much attention mainly because it plays a crucial role in delaying fruit ripening (Zheng et al., 2007), acts as anti-senescence agent (Wu et al., 2011) and shows resistance against many fruit diseases (Wang et al., 2009). Preharvest and postharvest OA applications for prolonging shelf life and preserving fruit quality during storage have been reported in a variety of fruit species such as plums (Wu et al., 2011), mangoes (Razzaq et al., 2015), oranges (Mohamed et al., 2016), and apricots (Ahmed et al., 2021). Calcium nitrate (CaNi) is a source of calcium ion that is a constituent of the cell wall, plays a vital role in forming cross-bridges by interacting with pectin in the cell wall to form calcium pectate that affect cell wall strength and rigidity (Fry, 2004). Calcium treatment functions in various ways, such as delaying senescence of fruits by increasing calcium content in the epidermis or retarding hydrolysis by strengthening cell walls to prevent external invasion (Liu et al., 2017). Previously, preharvest and postharvest treatments of CaNi maintained ascorbic acid content, maintained acceptable sensory quality and marketable percentage of mango (Singh et al., 2017) and plum (Sinha et al., 2019). Peach fruits have a short life after harvesting due to the rapid ripening of the fruits, which reduces the quality of the fruits. Nowadays, the global challenges are how to use effective ways to control postharvest losses, extend the storage life and maintain the quality of peach fruits during cold storage. Therefore, the aim of this study was to evaluate the effect of preharvest applications with OA and CaNi study aims in maintaining the quality of 'Swelling' peach fruits during storage at 0±1ºC and 90-95% RH.

2. Materials and Methods

2.1. Plant materials

The present study was conducted during two successive seasons (2021 and 2022) on peach trees (*Prunus persica*) cv. Swelling. The trees are grown in a private orchard, El-Shaarawy village, El-Behera Governorate, Egypt (latitude, 30°70′ N; longitude, 30°27′ E). Trees were about 7 years old, planted in a sandy soil at 4×5 distance, irrigated by drip system and subjected to all ideal cultural practices adopted in the orchard.

2.2. Experimental design and procedures

In both seasons of the study, twenty-seven trees were selected as uniform as possible in growth, fruiting and free from any visual disease. The peach trees were arranged in a Randomized Complete Block Design (RCBD) with three replicates according to Snedecor and Cochran (1989) and subjected to three applications as follow:

1- Distilled water and used as a control.
2- Calcium nitrate [$Ca(NO_3)_2$] (CaNi) at 2%.
3- Oxalic acid [$C_2H_2O_4$] (OA) at 5 mM.

Each treatment consists of three replicated with a total of nine trees for each treatment. The peach trees were sprayed one time at the third week of June (2-weeks before harvest) by using a hand sprayer. Samples of fruits at maturity stage were picked after 2-weeks of applications (at the first week of July). The picked fruits were placed in plastic boxes (7 kg capacity) and transferred immediately after harvesting to Horticulture Research Institute (HRI), Giza, Egypt. Upon arrival, the fruits were cleaned, sorted and the defective fruits including wounded and damaged fruits were excluded.

A total of 180 sound clean fruits in each treatment with three replicates were selected and randomly divided into four storage periods (0, 10, 20 and 30 days) and each replicate consists of 15 fruits, after that the fruits in each treatment putted in foam plate and stored at (0±1ºC and 90-95% RH) for 30 days. Fruit quality attributes were measured at harvest time and then every ten days intervals of 30 days of cold storage in three replicates of each treatment.

2.3. Quality Assessments

2.3.1. Marketable percentage

Marketable fruit percentage was calculated by the following formula:-

Marketable (%) = [(Weight of sound fruits at specified storage period/Initial weight of stored fruits) x100].

2.3.2. Visual appearance score

Visual appearance of the peach fruits was rated for quality based on color, texture, and overall acceptability as described by Amerine et al. (1965).

2.3.3. Ascorbic acid content

Ascorbic acid content was determined according to AOAC (2005). The obtained data was expressed as mg/100 ml of juice.

2.3.4. TSS/Acid ratio

TSS/Acid ratio was calculated from the values recorded for fruit juice TSS and TA percentage.

2.4. Statistical analysis

The effects of preharvest treatments and cold storage period on different attributes were analyzed statistically by analysis of variance (ANOVA) using the MSTAT-C statistical package. Then means comparisons were compared using Tukey's honestly significant difference (HSD) test at probability ≤ 0.05 (Tukey, 1949).

3. Results and Discussion

3.1. Marketable fruits percentage

The results in Table 1 show that cold storage period significantly affected the marketable fruits in both seasons. marketable of peach fruits gradually and significantly decreased with the elongation of cold storage period. The minimum marketable percentage values (79.96 and 82.11%) were recorded after 30 days of cold storage in the 2021 and 2022 seasons, respectively. Moreover, marketable percentage was significantly affected by preharvest treatments and the highest marketable (93.25 and 93.78%) in the first and second seasons, respectively were obtained under the preharvest application with 5 mM OA in both seasons, respectively. On contrast, untreated fruits recorded the lowest marketable fruits (89.07 and 90.06%) in the first and second seasons, respectively.

Table 1. Effect of preharvest applications of oxalic acid (OA) and calcium nitrate (CaNi) on marketable percentage of 'Swelling' peaches during cold storage (0±1ºC and 90-95% RH)

Treatments	Storage period (days)				Means
	0	10	20	30	
Season 2021					
Control	100.00 a	94.54 c	84.96 e	76.77 g	89.07 C
CaNi at 2%	100.00 a	96.80 bc	88.21 d	80.13 f	91.29 B
OA at 5 mM	100.00 a	99.20 ab	90.82 d	82.98 e	93.25 A
Means	100.00 A	96.85 B	87.99 C	79.96 D	
Season 2022					
Control	100.00 a	92.22 c	89.15 c	78.86 e	90.06 C
CaNi at 2%	100.00 a	94.54 b	90.27 c	82.43 d	91.81 B
OA at 5 mM	100.00 a	99.45 a	90.61 c	85.06 d	93.78 A
Means	100.00 A	95.40 B	90.01 C	82.11 D	

Means followed by the same uppercase letters in the treatments or storage periods and lowercase letters in interaction during 2021 or 2022 seasons, respectively are not significantly different at level *P*≤0.05 according to Tukey's HSD test.

In general, decay and over ripening might be the main causes for loss of marketability of fruits of the untreated fruits. On the other side, the better appearance along with lower decay incidence due to slow metabolic rates could be the reason for higher percentage of marketable in fruits treated with 5 mM OA. The higher percentage of marketable fruits due to OA treatment goes in parallel with those previously mentioned by Mohamed et al. (2016) on 'Valencia' oranges and Zheng et al. (2007) on mangoes. They stated that OA treatment maintained higher percentage of marketable of fruits as compared to control during cold storage period. The maintained percentage of marketable in fruits treated with calcium nitrate might be due to increase in concentration of calcium of middle lamella that provided physical strength to cell wall and improved their appearance (Cheour et al., 1990). Our results in this line were in conformity with those investigated by Al Eryani-Raqeeb et al. (2009) who noticed that 2.5 % calcium combined with chitosan coating extended the percentage of marketable and the storage life of papaya fruits.

3.2. Visual appearance score

The results in Table 2 show a gradual reduction in the visual appearance score of 'Swelling' peach fruits with the advancement of cold storage at (0±1ºC and 90-95% RH) in the two seasons. The lowest visual appearance score (5.11 and 5.44) in 2021 and 2022 seasons, respectively were observed after 30 days of cold storage. Additionally, peach fruits significantly affected by preharvest treatments and fruits sprayed with 5 mM OA treatment recorded the highest visual appearance score (7.92 and 8.08) in 2021 and 2022 seasons, respectively while, the lowest visual appearance score (6.83 and 7.08) in the first and second seasons, respectively were observed in the untreated peach fruits.

The visual appearance of fruits is extremely important quality attribute in overall produce acceptance by the consumers. The low visual appearance score in the untreated peach fruits could be attributed to the increased decay, the rapid loss of its firmness, pathogen infections, internal browning and chilling injuries during cold storage. Oxalic acid was an effective treatment in maintaining visual appearance score that might be attributed to its antioxidant activity that retain the quality of fruits for long period during storage as well as its effectiveness in maintaining firmness and reducing decay incidence (Mohamed et al., 2016). Our results in this line are in similar trend with the research made by Koyuncu et al. (2018) on apricot fruits cv. Aprikoz. They mentioned that applications of OA on fruits were effective in retarding the reduction in fruit visual appearance score. Calcium nitrate also reserved good visual appearance score through maintaining cell wall integrity and firmness as well as reducing decay and spoilage incidence of fruits. Similar results were observed previously by Sinha et al. (2019) on plum fruits. They reported that fruits treated with CaNi (1%, 1.5%, and 2%) maintained the acceptable sensory quality (color, appearance, texture and taste) up to 28 days of storage period.

Table 2. Effect of preharvest applications of oxalic acid (OA) and calcium nitrate (CaNi) on visual appearance score of 'Swelling' peaches during cold storage (0±1ºC and 90-95% RH)

Treatments	Storage period (days)				Means
	0	10	20	30	
	Season 2021				
Control	9.00 a	8.33 b	6.33 d	3.67 f	6.83 C
CaNi at 2%	9.00 a	8.67 ab	7.33 c	5.67 e	7.67 B
OA at 5 mM	9.00 a	9.00 a	7.76 c	6.00 de	7.92 A
Means	9.00 A	8.67 B	7.11 C	5.11 D	
	Season 2022				
Control	9.00 a	8.67 a	6.67 c	4.00 e	7.08 B
CaNi at 2%	9.00 a	9.00 a	7.67 b	6.00 d	7.92 A
OA at 5 mM	9.00 a	9.00 a	8.00 b	6.33 cd	8.08 A
Means	9.00 A	8.89 A	7.44 B	5.44 C	

Visual appearance of fruit was measured by a rating system, fruit scored: very good = 9, good = 7, acceptable = 5, unacceptable = 3 and poor = 1. Means followed by the same uppercase letters in the treatments or storage periods and lowercase letters in interaction during 2021 or 2022 seasons, respectively are not significantly different at level $P \leq 0.05$ according to Tukey's HSD test.

3.3. Ascorbic acid (AsA) content

As shown in Table 3, a gradual decline in the AsA of 'Swelling' peach fruits was detected with prolonging of cold storage period at (0±1ºC and 90-95% RH) in both seasons. The results reveal that the lowest AsA content (2.70 and 2.80 mg/100 ml juice) in 2021 and 2022 seasons, respectively were recorded after 30 days of cold storage. The preharvest treatments also had a significant effect on AsA content and the highest values (5.14 and5.24 mg/100ml juice) in the first and second seasons, respectively were observed in fruits treated with 5 mM OA. On contrary, the untreated fruits recorded the lowest AsA values (4.19 and 4.26 mg/100 ml juice) in 2021 and 2022 seasons, respectively.

Table 3. Effect of preharvest applications of oxalic acid (OA) and calcium nitrate (CaNi) on ascorbic acid content (mg/100ml juice) of 'Swelling' peaches during cold storage (0±1ºC and 90-95% RH)

Treatments	Storage period (days)				Means
	0	10	20	30	
	Season 2021				
Control	6.05 c	5.15 f	3.58 i	1.97 l	4.19 C
CaNi at 2%	6.33 b	5.63 e	4.24 h	2.78 k	4.74 B
OA at 5 mM	6.55 a	5.95 d	4.71 g	3.35 j	5.14 A
Means	6.31 A	5.58 B	4.18 C	2.70 D	
	Season 2022				
Control	6.14 c	5.20 e	3.64 h	2.07 k	4.26 C
CaNi at 2%	6.41 b	5.71 d	4.36 g	2.86 j	4.84 B
OA at 5 mM	6.63 a	6.04 c	4.83 f	3.46 i	5.24 A
Means	6.39 A	5.65 B	4.27 C	2.80 D	

Means followed by the same uppercase letters in the treatments or storage periods and lowercase letters in interaction during 2021 or 2022 seasons, respectively are not significantly different at level $P \leq 0.05$ according to Tukey's HSD test.

Ascorbic acid is an important antioxidant bioactive compound that retards the deterioration of fruit during storage because of oxidation and limits the detrimental effects of free radicals (Davey et al., 2000). The highest loss in AsA content in Untreated peach fruits might be due to a fast transformation of L-ascorbic acid into dehydroascorbic acid by oxidizing enzymes such as ascorbic acid oxidase and ascorbate peroxidase (Davey et al., 2000). On contrary, treated fruits with preharvest applications of OA or CaNi maintained the AsA content of peach and this due to associated to the fact that OA and CaNi are antioxidant that reducing ascorbic acid oxidation (Kayashima and Katayama, 2002, Goutam et al., 2010 and Koyuncu et al., 2018). Thus, these applications retained higher ascorbic acid content during storage than control.

In this line, our findings agree with those of Razzaq et al. (2015) on 'Samar Bahisht Chaunsa' mangoes, Mohamed et al. (2016) on 'Valencia' oranges and Ahmed et al. (2021) on apricot fruits. They investigated that OA-treated fruits held more quantity of ascorbic acid content during cold storage as compared with control. The higher retention of ascorbic acid by calcium compound treatment has been reported by Azam et al. (2021) on guava fruits.

3.4. Total soluble solids/titratable acidity (TSS/TA) ratio

Results in Table 4 illustrate that the changes in the TSS/Acid ratio in 'Swelling' peach fruits during 30 days of cold storage at (0±1ºC and 90-95% RH). It was shown that TSS/Acid ratio of peach fruits gradually and significantly increased with the extension of cold storage time in both seasons. It is clear from results that, the highest TSS/Acid ratios (76.12 and 76.29) were obtained after 30 days of cold storage period in 2021 and 2022 seasons, respectively. Also, preharvest treatments with OA and CaNi retarded the increase in the TSS/Acid ratio of peach fruits as compared to control. The fruit treated with OA was found to have the lowest TSS/Acid ratios (42.80 and 43.58) after 30 days of cold storage in first and second seasons, respectively. On the other hand, untreated fruits recorded the highest TSS/Acid ratios (55.08 and 56.86) in 2021 and the 2022 seasons, respectively.

TSS/Acid ratio is considered a good index for the assessment of fruit ripening, and it is important for fruit flavor. A lower ratio of TSS/Acid makes fruits more desirable (Ding et al., 2006 and Petriccione et al., 2015).

Our study investigated that TSS/Acid ratio increased more in the control fruits that was attributed to a decrease in the TA, with an increase in the total soluble solid content. OA treatment may limit the senescence process of peach fruits as a result retard the increase in TSS/TA ratio.

Table 4. Effect of preharvest applications of oxalic acid (OA) and calcium nitrate (CaNi) on total soluble solids/titratable acidity (TSS/TA) ratio of 'Swelling' peaches during cold storage (0±1ºC and 90-95% RH)

Treatments	Storage period (days) 0	10	20	30	Means
Season 2021					
Control	29.52 f	34.84 e	65.45 c	90.50 a	55.08 A
CaNi at 2%	28.48 f	33.31 e	45.93 d	71.04 b	44.69 B
OA at 5 mM	27.78 f	32.67 e	43.93 d	66.83 c	42.80 C
Means	28.59 D	33.61 C	51.77 B	76.12 A	
Season 2022					
Control	29.87 h	37.20 f	65.75 c	94.62 a	56.86 A
CaNi at 2%	29.13 h	34.84 g	49.39 d	69.42 b	45.69 B
OA at 5 mM	28.67 h	33.93 g	46.90 e	64.84 c	43.58 C
Means	29.22 D	35.32 C	54.01 B	76.29 A	

Means followed by the same uppercase letters in the treatments or storage periods and lowercase letters in interaction during 2021 or 2022 seasons, respectively are not significantly different at level $P \leq 0.05$ according to Tukey's HSD test.

In this aspect, our results are in harmony with the investigations of Razzaq et al. (2015) on mangoes, Mohamed et al. (2016) on 'Valencia' oranges and Ahmed et al. (2021) on apricots. They stated that TSS/Acid ratio of fruits is lower in fruits treated with OA as compared with the untreated ones. Our results with respect to CaNi agree with those mentioned by Azam et al. (2021) on 'Golla' guava fruits, where they stated that the lowest TSS/Acid ratio was found in calcium nitrate-treated fruits as compared to untreated fruits during storage period.

Conclusion

In conclusion, this study revealed that the preharvest applications of 5 mM oxalic acid (OA) and 2% calcium nitrate (CaNi) 2-weeks before harvest improved the quality attributes of cold-stored 'Swelling' peaches. Amongst treatments, 5 mM OA was the most effective one in delaying ripening and senescence of peach fruits through its effectiveness in reducing the deterioration in fruit marketable percentage, visual appearance score and AsA content along with delaying the increase in TSS/Acid ratio during cold storage at 0±1ºC and 90-95% RH. Based on the results of this experiment, 5 mM OA might be a promising treatment suitable for large-scale application to improve the postharvest quality of this highly perishable fresh product and should be tested on different peach cultivars and other fruits.

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