Original article

Influence of in-package use of ethylene absorbents on shelf life and quality of nectarine during supermarket conditions

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Summary

Introduction – **Nectarine is a natural bud mutant of peach. Nowadays, consumers are being enticed to nectarine due to its attractive colour and smooth texture compared to its progenitor, peaches. Nutritionally, nectarines are on par with the functional fruit, peach. Hence in various parts, area under peach cultivation is getting replaced by nectarine at a swift footed rate. The shelf life of this climacteric fruit is limited due to its highly perishable nature attributed to high ethylene and respiration rate. But being a new crop, postharvest treatment to enhance its marketability is lacking. So as to tackle this problem, we conducted a study to enhance the marketability and shelf life of 'Silver Queen' nectarine by packing it with various ethylene absorbents.** *Materials and methods* – **After harvesting of fruits at climacteric stage, fruits were packed with different ethylene absorbent sachets such as $KMnO_4$, Bioconservacion, Al_2O_3, silica gel and $KMnO_4$ + silica gel and transported to IARI, New Delhi. Fruits were stored at supermarket condition (18 ± 2 °C) and evaluated for various physical and biochemical parameters. Observations were recorded at fixed interval of 4 days.** *Results and discussion* – **This study revealed that among the various ethylene absorbents used, $KMnO_4$ sachets was found to be better in reducing ethylene evolution rate and respiration. It extended the shelf life of fruits at super market condition by maintaining better firmness, low PLW, higher phenolics and antioxidant activity *etc.*** *Conclusion* – **In-package use of ethylene absorbents, especially $KMnO_4$ sachets, extended the shelf life of nectarines to 12 days under supermarket conditions.**

Keywords
antioxidant capacity, ethylene absorbents, in-package, nectarine, polyphenols

Significance of this study

What is already known on this subject?

- Nectarine is a climacteric fruit with a shelf life of about 3–4 days under ambient conditions. Various postharvest treatments have been experimented to extend the shelf life but in-package ethylene absorbents is a new approach.

What are the new findings?

- In-package ethylene absorbents extended the shelf life of nectarines stored under supermarket conditions for about 12 days without compromising in quality.

What is the expected impact on horticulture?

- This work would be useful to reduce the postharvest loss of nectarines at a lower cost and, most importantly, it is a farmer-friendly technology.

Introduction

Nectarine (*Prunus persica* var. *nucipersica*) is a smooth-skinned mutant of peach belonging to family *Rosaceae*, sub-family *Prunoidae* (Bal, 2006). It is a popular stone fruit growing in warmer temperate regions between latitudes 30° and 45°N and S of both the Northern and Southern hemispheres. North-western Himalayas cover the major area under nectarine production in India (Sharma and Krishna, 2016). Nutritionally, nectarines provide twice the vitamin A, slightly more vitamin C, and much more potassium and fiber than peaches and possess strong flavour and aroma. Moreover, nectarine fruits are smaller and sweeter in taste compared to peach fruits (Colaric *et al.*, 2005). Apart from that, fruits contain fairly good amount of antioxidants vitamins such as C, A, E and flavonoids, polyphenolic antioxidants like lutien, zeaxanthin and β-cryptoxanthin (Gil *et al.*, 2002) which makes it a preferable fruit for the health-conscious people round the world. Due to its smoothness and attractive colour, nectarine fruits are becoming popular among consumers and hence, peach orchards are being replaced by nectarine at a swift footed manner in different parts of India.

Nectarines have limited shelf life due to its highly perishable nature attributing to higher ethylene and respiration rate after harvest. The key physiological and biochemical changes associated with ripening in climacteric fruits including nectarines such as fruit softening, change in peel colour, respiration and ethylene evolution rates, sugar, organic acid metabolism are regulated by the endogenous ethylene level in fruits (Lelievre *et al.*, 1997; Valero *et al.*, 2005; Sharma *et al.*, 2011). Ethylene evolution rate in nectarines and peaches invariably increases with the increase in storage period and temperature (Aly *et al.*, 1981, Jayarajan and Sharma, 2018). As a result of increased activities of enzymes such as pectin methylesterase, polygalacturonase and other biochemical attributes the shelf life of fruits reduced drastically. Apart from that, rough handling and poor storage conditions further enhances the perishability of fruits. Furthermore, very short shelf life of fruit is also attributed to the shorter time between the commercial ripening to the degradative senescence phase (Egea *et al.*, 2007; Agar and Polate, 1995). According to the various sources, about 25–30% postharvest losses occur during transportation and marketing of nectar-

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ine fruit. There are several postharvest management strategies to improve the postharvest shelf life of these perishable fruits by slowing down the metabolic activity, cold storage, or lowering the storage temperature (Aly *et al.*, 1981; Sharma *et al.*, 2012), use of ethylene absorbents (Thakur *et al.*, 2005; Kaur and Singh, 2011).

Ethylene absorbents have been found invariably efficient in enhancing the postharvest life and quality of fruits. Potassium permanganate ($KMnO_4$) based commercial ethylene absorbents oxidizes ethylene (C_2H_4) into carbon dioxide (CO_2) and water (H_2O) (Wills and Warton, 2004). Due to absorption of ethylene by the absorbents, detrimental effects of ethylene on fruits such as enhanced fruit ripening, softening and quality degradation are reduced, which helps in enhancing postharvest shelf or storage life of fruits by delaying the natural process of senescence, thereby helping in extending the marketability of fruits (Kader *et al.*, 2002; Thakur *et al.*, 2005; Glahan *et al.,* 2006; Sharma *et al.*, 2012). Hence in this study, we attempted to prepare some ethylene absorbent sachets using cheap and locally available chemicals with an objective to see their impact by using them in the packing boxes maintained in super market conditions (18 ± 2 °C).

Materials and methods

Fruit materials, treatments and observation recorded

The studies were conducted in the Division of Food Science & Postharvest Technology, ICAR-IARI, New Delhi-110 012 during the fruiting season of 2015–16. Fruit of 'Silver Queen' nectarine variety was harvested at full maturity, *i.e.*, climacteric stage (ready-to-eat) on June 15, 2015 from the orchard of the Regional Horticultural Research Station, Dr Y.S. Parmar University of Horticulture and Forestry, Bajaura, H.P. The orchard is located at 77°7'48"N latitude, 31°58'56"E longitude, and at an elevation of 1,260 m a.s.l. In this study, five ethylene absorbents were attempted, of which, four sachets containing 5 g each of $KMnO_4$, silica gel, aluminium oxide, silica gel + $KMnO_4$, were prepared in the laboratory while a readymade ethylene removal sachet was supplied by Bioconservacion S.A., Avinguda Diagonal, Barcelona, Spain, free of cost for conducting the experiment. After sorting, two ethylene absorbent sachets were placed each at the bottom, centre and at the top of packing box (CFB) containing 5 kg nectarine fruit, replicated thrice. The packed nectarines were transported to the Division of Food Science & Postharvest Technology, IARI, New Delhi, and stored at supermarket conditions (18 ± 2 °C and 85–90% RH) for twelve days for further observations at 4-days interval.

Fruit characteristic measurements

Physical and physiological attributes

All physical (PLW and fruit firmness) and physiological (respiration and ethylene evolution rates) attributes of the 10 randomly selected 'Silver Queen' nectarine fruit were recorded at 4-days interval, replicated thrice. For the measurement of physiological loss in weight (PLW), fruit were weighed at regular intervals with the help of an electronic balance. The PLW was calculated by using the following formula and data were expressed in percentage.

$$\text{PLW (\%)} = \frac{\text{Initial weight} - \text{Weight after known storage period}}{\text{Initial weight}} \times 100$$

Fruit firmness was determined using a texture analyzer (model: TA+Di, Stable micro systems, UK) using compression test, and expressed as N (Newton). Ethylene production and respiration rates were measured using the static headspace technique. The respiration rate was determined by using auto gas analyzer (Model: Checkmate 9900 O_2/CO_2, PBI Dansensor, Denmark) and expressed as mL CO_2 kg^{-1} h^{-1} (Sharma *et al.*, 2011). The ethylene evolution rate was measured using Hewlett Packard (HP) gas chromatograph (model 5890 Series II) equipped with a flame ionization detector (FID), Porapack-N 80/100 mesh packed stainless steel column and a HP integrator and expressed as µL C_2H_4 kg^{-1} h^{-1} (Sharma *et al.*, 2011).

Biochemical attributes

The biochemical attributes such as total anthocyanin content, total phenolics and total antioxidant capacity were determined in 10 randomly selected nectarine fruit at 4 days interval, replicated thrice. The total monomeric anthocyanin content was determined by using the pH-differential method (Wrolstad *et al.*, 2005) using two buffer systems- potassium chloride buffer, pH 1 (0.025 M) and sodium acetate buffer, pH 4.5 (0.4 M). The pigment content was calculated and expressed as cyanidin-3,5-diglucoside kg^{-1} fresh weight (FW), using an extinction coefficient (ε) of 795 L cm^{-1} mol^{-1} and a molecular weight of 465.2 g mol^{-1}.

$$\text{Monomeric anthocyanin content (mg L}^{-1}) = A \times MW \times DF \times 1000/(\varepsilon \times 1)$$

where A = absorbance; MW = molecular weight (465.2); DF = dilution factor; ε = molar absorptivity (795). The final concentration of anthocyanins was calculated based on total volume of extract and weight of sample.

The total phenolic content of the fruit extracts were determined by the Singleton *et al.* (1999) method with some modifications. Two g of fruit sample was properly grinded in 10 mL of 80% ethanol and then was centrifuged at 10,000 rpm for 20 min at 4 °C and supernatant was used for assay of total phenols using Folin-Ciocalteu reagent. The absorbance was measured at 750 nm in spectrophotometer. The total phenol content was expressed in mg of Gallic acid equivalents (GAE) per 100 g of extract.

Antioxidant capacity in the nectarines was determined by using CUPRAC (Cupric Reducing Antioxidant Capacity) method (Apak *et al.*, 2004). For determining antioxidant activity, copper (II) chloride solution, a neocuproine alcoholic solution, and an ammonium aqueous buffer (pH 7) was mixed**.** The measurements of the developed colour were taken after 30 min in a spectrophotometer at absorbance at 450 nm and expressed as µmol Trolox g^{-1} fresh weight (FW).

Eating quality attributes

The eating quality attributes such as total soluble solids (TSS), titratable acidity (TA) and ascorbic acid content (AAC) were determined in 10 randomly selected nectarine fruit at 4-days interval, replicated thrice. The total soluble solids of nectarine fruit samples were estimated using Fisher hand-refractometer (0–50) and was expressed as °Brix (Ranganna, 1999). Titratable acidity in the nectarines was determined by using 0.1 N NaOH as described by Ranganna (1999), and expressed as mg 100 g^{-1} FW.

Statistical analysis

The experiments were laid out in factorial CRD design with each treatment consisting of five kg boxes with 3 replications. However, observations on different attributes were recorded in 10 randomly selected fruit at 4-days interval, which was replicated three times. The data obtained from the experiments were analysed as per design and the results were compared from ANOVA by calculating the LSD (Least Significance Difference) (Panse and Sukhatme, 1984). The data were analyzed using the SAS (Statistical Analysis System).

Results and discussion

Effects on physical and physiological attributes

Physiological loss in weight (%)

The results revealed that there was a significant influence of treatments, storage period and their interaction on PLW of 'Silver Queen' nectarine (Table 1). Irrespective of storage period, treatments (ethylene absorbents) have shown significant effect on PLW. For instance, the PLW was lowest in $KMnO_4$ (5.484%) and highest in control fruits (7.643%) (Table 1). The PLW increased with the increase in storage period, the lowest being on 4th day of storage (2.19%) and highest on 12th day of storage (11.05%). Interestingly, nectarine fruits placed with $KMnO_4$ sachets exhibited only 9.302% PLW on 12th day of storage, which meets our international acceptance standards of less than 10% (Table 1), making it fit for consumption after storage.

The lower PLW in $KMnO_4$ treated fruits may be due to higher ethylene oxidizing capacity and less moisture loss or transpiration rate than other absorbents. Similarly, higher PLW in control fruits may be due to higher water loss through transpiration. Ethylene absorbents are most effective in reducing physiological loss in weight and thereby increasing the postharvest life of fruits and vegetables. Similarly, when fig fruits were treated with $KMnO_4$ as ethylene absorbent, shelf life was extended up to 10 days of storage by minimizing the physiological loss in weight (Paramesha *et al*., 2017).

Fruit firmness (N)

Our results revealed that ethylene absorbent treatments have influenced the firmness of 'Silver Queen' nectarines. Fruit firmness decreased considerably from 0th day to 12th day of storage. However, the rate of decline was higher and faster in the untreated fruits than those packed with different ethylene absorbents (Figure 1). Among different ethylene absorbents, the minimum firmness was recorded in untreated (control) fruits (2.36 N) and maximum in $KMnO_4$ sachets (3.77 N) at the end of storage period (Figure 1).

Firmness is one among those parameters by which consumer's acceptability is evaluated in the market and distribution chain. So to have a good marketability, fruits should be firm and sound enough. The in-package ethylene sachet treatments have influenced the firmness of 'Silver Queen' nectarines. Among different ethylene absorbents, the minimum firmness was recorded in untreated (control) fruits (1.36 N) and maximum in $KMnO_4$ (3.26 N) at the end of storage period. Improvement in fruit firmness by the use of ethylene absorbents have also been reported in apple (Thakur *et al*., 2005), grapes (Jang *et al*., 2006) and plum (Sharma *et al*., 2011), which supports our present findings.

Respiration and ethylene evolution rate

As a general trend, the respiratory rate of treated as well as non-treated nectarine fruits increased considerably and reached the climacteric peak and thereafter it declined. Irrespective of treatments, all fruits showed respiratory peak on 8th day of storage but the amount of CO_2 evolution differed, the highest being in untreated fruits (29.84 mL CO_2 kg^{-1} h^{-1}) and the lowest in silica gel and $KMnO_4$ (20.07 mL CO_2 kg^{-1} h^{-1}) (Figure 2). The pattern of ethylene evolution was similar to respiration rate as different ethylene absorbents have significantly influenced the ethylene evolution rate of 'Silver Queen' nectarine (Figure 3). However, in general, ethylene evolution rates of treated and untreated fruits increased from 0th to 14th day and thereafter it declined. The rate of ethylene evolution was higher in case of untreated fruits (106.63 µL C_2H_4 kg^{-1} h^{-1}) on 14th day of storage and lowest in fruits packed with $KMnO_4$ (81.52 µL C_2H_4 kg^{-1} h^{-1}) (Figure 3).

Climacteric fruits shows a distinguishable upsurge in ethylene and respiration rate, which is directly correlated with its perishability nature. Being a climacteric fruit, respiration and ethylene evolution are major metabolic changes associated with postharvest life which decide the marketability of nectarine fruits. Perishability of the fruit is determined by its respiration and ethylene evolution rate after harvest. So it is very important to keep respiration and ethylene evolution at the lowest level to enhance the shelf life, and making it available for larger period of the year. In this study, we observed that the ethylene absorbents have considerably influenced the respiration and ethylene evolution rates of 'Silver Queen' nectarine fruit during storage. These rates increased considerably and reached the climacteric peak on 14th day of storage, and thereafter declined sharply. In a similar study, Pekmezci *et al*. (2004) observed lower respiration and ethylene evolution rates in 'Hayward' kiwifruit when stored in

Table 1. Effect of in-package use of ethylene absorbents on physiological loss in weight (%) of 'Silver Queen' nectarine during storage under supermarket conditions.

Ethylene absorbent	Storage period (day)			
	4th	8th	12th	Mean
Control	2.537	7.987	12.406	7.643
$KMnO_4$	1.830	5.320	9.302	5.484
Silica gel	1.960	5.865	10.115	5.980
Al_2O_3	2.250	6.842	11.898	6.997
$KMnO_4$ + Silica gel	2.168	5.900	10.000	6.148
Bioconservacion	2.406	7.678	12.210	7.431
Mean	2.192	6.599	11.051	

LSD (0.05) for Treatment (T) = 0.156; Storage period (S) = 0.110 and Treatment (T) × Storage period (S) = 0.290.

modified atmosphere along with ethylene absorbents than control kiwifruits. Similarly, Sharma *et al.* (2011) reported significantly lower rates of ethylene evolution and respiration in 'Santa Rosa' plums when packed with ethylene absorbents. The decline after 14th day may be due to progressive decline in carbohydrates.

Effects on biochemical attributes

Total anthocyanin content

It is clearly evident from Table 2 that treatment, storage alone and in combination, have significantly influenced the anthocyanin content present in 'Silver Queen' nectarine. Regardless of storage, treatments have considerably influenced

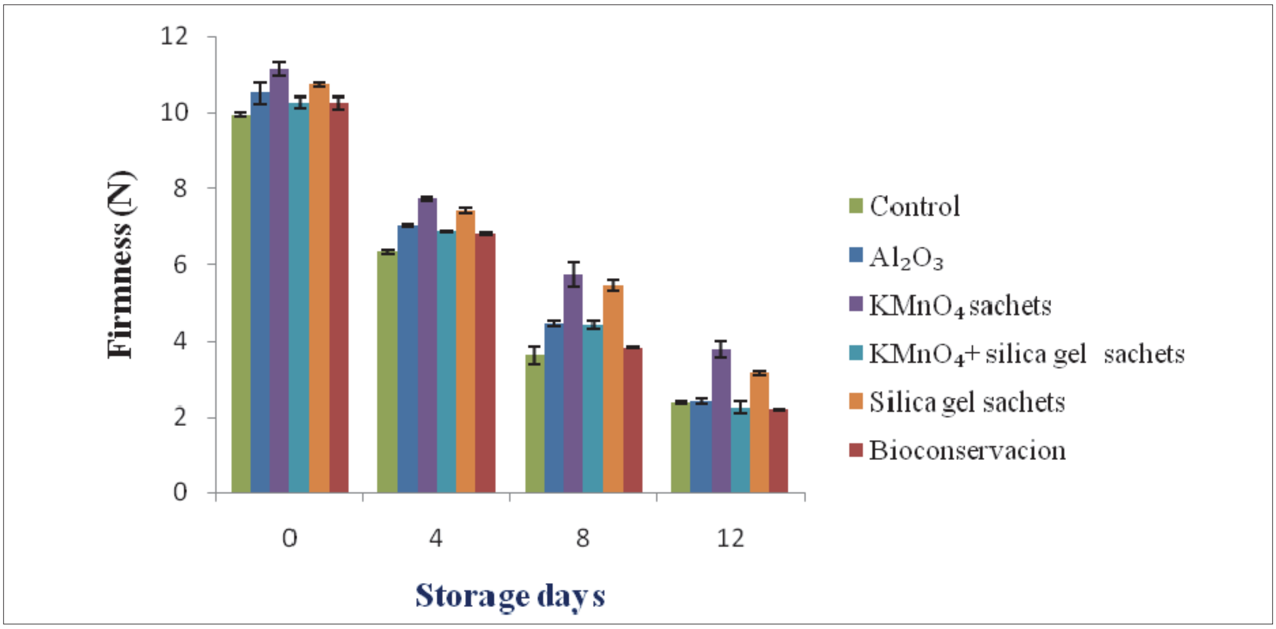

FIGURE 1. Influence of various ethylene absorbents on fruit firmness (N) of 'Silver Queen' nectarine under supermarket storage conditions.

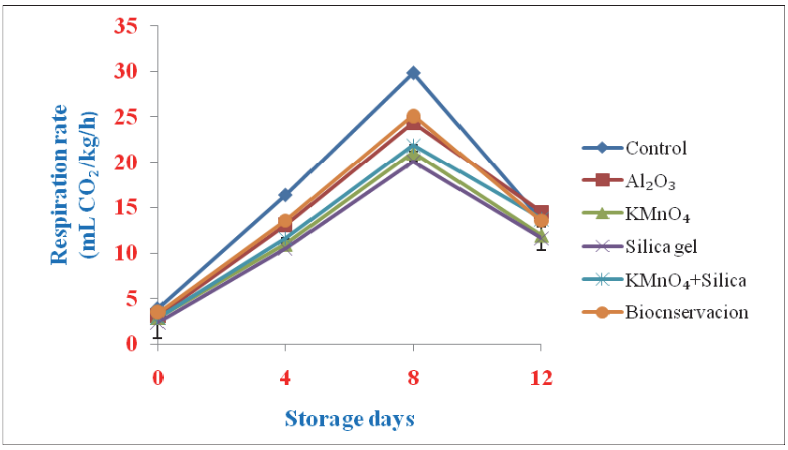

FIGURE 2. Effect of ethylene absorbents on respiration rate (mL CO_2 kg^{-1} h^{-1}) of 'Silver Queen' nectarine under supermarket conditions.

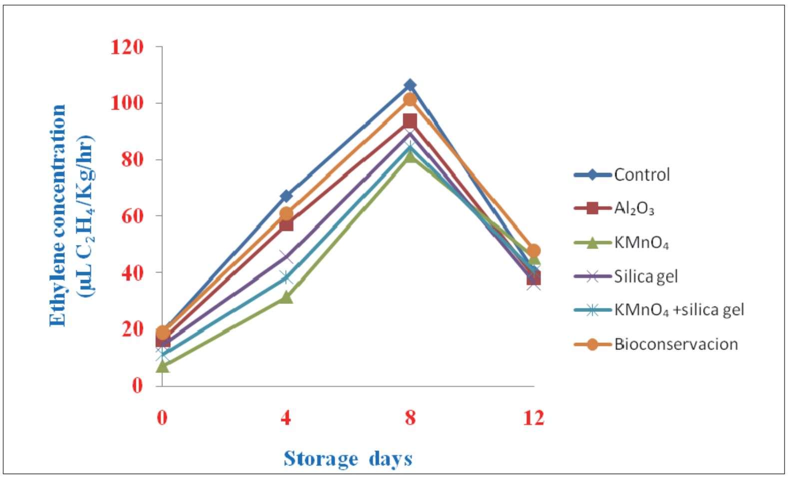

FIGURE 3. Influence of various ethylene absorbents on ethylene evolution rate (µL C_2H_4 kg^{-1} h^{-1}) of 'Silver Queen' nectarine under supermarket storage conditions.

Table 2. Impact of in-package use of ethylene absorbents on anthocyanin content (mg kg^{-1} FW) of 'Silver Queen' nectarine during storage under supermarket conditions.

Ethylene absorbent	Storage period (day)				
	0^{th}	4^{th}	8^{th}	12^{th}	Mean
Control	172.73	181.78	185.29	202.18	185.50
$KMnO_4$	174.99	184.52	194.66	224.68	194.71
Silica gel	167.24	177.30	188.42	226.20	187.67
Al_2O_3	163.54	174.18	179.83	187.54	176.27
$KMnO_4$ + Silica gel	179.58	196.61	208.12	211.63	198.98
Bioconservacion	160.81	169.89	174.57	184.04	172.33
Mean	169.81	180.71	188.48	204.63	

LSD (0.05) for Treatment (T) = 1.83; Storage period (S) = 1.49 and Treatment (T) × Storage period (S) = 3.68.

the anthocyanin content. The highest anthocyanin content was found in fruits being packed with silica gel (226.20 mg kg^{-1} FW) and $KMnO_4$ (224.68 mg kg^{-1} FW) and lowest in fruits packed with Bioconservacion (184.04 mg kg^{-1} FW). The amount of anthocyanin in 'Silver Queen' nectarine significantly increased with increase in storage (Table 2). The lowest anthocyanin content was recorded on initial day (169.81 mg kg^{-1} FW) and the highest on 12^{th} day of storage (204.63 mg kg^{-1} FW).

Total phenol content

The ethylene absorbents, storage period alone or in combination have significantly influenced the total phenol and total antioxidant content in 'Silver Queen' nectarine fruit. The maximum phenol content was retained by the fruits packed with $KMnO_4$ (16.06 mg GAE 100 g^{-1} FW) and minimum in fruits without ethylene absorbents (14.03 mg GAE 100 g^{-1} FW). The interaction of treatment × storage has also significantly influenced the phenol content of 'Silver Queen' nectarine cultivar. The highest phenol content (17.75 mg GAE 100 g^{-1} FW) was observed on the initial day of storage in fruits packed with $KMnO_4$ based ethylene absorbent sachets, and lowest in fruits without absorbents (control) (14.03 mg GAE 100 g^{-1} FW) during the final storage day (Table 3).

Total antioxidant capacity

The results have revealed that both treatments and storage period, alone and in combination, have significantly affected the antioxidant capacity of 'Silver Queen' nectarine fruit (Table 4). As people are becoming more health-conscious, it is important to include the fruits rich in phytochemicals such as AOX, phenols, anthocyanins, *etc.* in the diet. Nectarine, being a phytochemical rich fruit, is most preferred by consumers. Regardless of storage period, treatment has

Table 3. Total phenol content (mg GAE 100 g^{-1} FW) as influenced by in-package use of ethylene absorbents in 'Silver Queen' nectarine during storage under supermarket conditions.

Ethylene absorbent	Storage period (day)				
	0^{th}	4^{th}	8^{th}	12^{th}	Mean
Control	16.10	15.23	14.60	14.03	14.99
$KMnO_4$	17.75	16.98	16.87	16.06	16.91
Silica gel	17.50	16.80	16.30	15.80	16.60
Al_2O_3	17.09	16.50	16.00	15.22	16.20
$KMnO_4$ + Silica gel	16.78	15.75	15.20	14.67	15.60
Bioconservacion	16.39	15.23	14.76	14.20	15.15
Mean	16.94	16.08	15.62	14.99	

LSD (0.05) for Treatment (T) = 0.12; Storage period (S) = 0.10 and Treatment (T) × Storage period (S) = 0.25.

Table 4. Influence of in-package use of ethylene absorbents on antioxidant activity (μmol TE g^{-1} FW) of 'Silver Queen' nectarine variety during storage under supermarket conditions.

Ethylene absorbent	Storage period (day)				
	0^{th}	4^{th}	8^{th}	12^{th}	Mean
Control	21.60	20.36	18.28	17.21	19.36
$KMnO_4$	24.72	23.27	21.73	19.09	22.20
Silica gel	24.09	22.90	20.68	18.87	21.63
Al_2O_3	23.54	21.33	19.51	18.06	20.61
$KMnO_4$ + Silica gel	23.01	20.95	20.95	17.94	20.28
Bioconservacion	21.80	20.17	18.20	17.33	19.37
Mean	23.12	21.50	19.60	18.08	

LSD (0.05) for Treatment (T) = 0.21; Storage period (S) = 0.17 and Treatment (T) × Storage period (S) = 0.42.

Table 5. Effect of ethylene absorbents on TSS (°B) of 'Silver Queen' nectarine fruits stored under supermarket conditions.

Ethylene absorbent	Storage period (day)				
	0th	4th	8th	12th	Mean
Control	5.16	8.80	12.10	11.70	9.44
$KMnO_4$	5.03	7.40	11.33	10.30	8.51
Silica gel	4.53	6.30	8.87	8.10	6.95
Al_2O_3	4.80	6.76	9.90	9.30	7.69
$KMnO_4$ + Silica gel	4.80	7.10	9.70	9.13	7.68
Bioconservacion	5.83	7.16	10.56	10.13	8.42
Mean	5.02	7.25	10.41	9.78	

LSD (0.05) for Treatment (T) = 0.07; Storage period (S) = 0.06 and Treatment (T) × Storage period (S) = 1.08.

Table 6. Influence of ethylene absorbents on titratable acidity (%) of 'Silver Queen' nectarine fruit during supermarket conditions storage.

Ethylene absorbent	Storage period (day)				
	0th	4th	8th	12th	Mean
Control	0.32	0.29	0.27	0.25	0.28
$KMnO_4$	0.41	0.39	0.38	0.36	0.38
Silica gel	0.31	0.27	0.25	0.22	0.26
Al_2O_3	0.33	0.31	0.29	0.26	0.29
$KMnO_4$ + Silica gel	0.31	0.28	0.26	0.25	0.28
Bioconservacion	0.37	0.32	0.29	0.28	0.32
Mean	0.34	0.31	0.29	0.27	

LSD (0.05) for Treatment (T) = 0.034; Storage period (S) = 0.027 and Treatment (T) × Storage period (S) = NS.

considerably affected antioxidant activity, being highest in fruits in which $KMnO_4$ (22.60 µmol TE g^{-1} FW) were used as in-package ethylene absorbent and lowest in fruits packed without any absorbents (19.36 µmol TE g^{-1} FW). There is a decreasing trend in antioxidant capacity with the increase in storage days. The highest antioxidant activity in 'Silver Queen' nectarine was observed on initial day of storage (24.72 µmol TE g^{-1} FW) and lowest during the last (12^{th} day) (17.21 µmol TE g^{-1} FW) (Table 4).

Biochemical attributes such as anthocyanin content, total phenols and total antioxidant capacity were significantly influenced by the storage period and various treatments. With the increase in storage period, increase in total anthocyanin content may be due to intensification of colour but decline in phenolic compounds and AOX activity may be due to utilization of metabolites, primarily during the processes of respiration and ethylene evolution. Since ethylene absorbents have delayed these activities significantly, it is likely to have higher phenolics or AOX activity in such fruits. Sharma *et al*. (2011) have also reported significantly higher levels of anthocyanin and phenolics or AOX activity in 'Santa Rosa' plums when packed with ethylene absorbents. The interaction between treatment and storage period was significant for anthocyanin content, total phenols and antioxidant activity of 'Silver Queen' nectarine, which may be due to synergistic influence of genotypic influences of a variety and storage time on these variables.

Effects on eating quality attributes

Total soluble solids

The data presented in Table 5 elucidated that total soluble solids present in the 'Silver Queen' nectarine was significantly affected by different ethylene absorbent treatments, storage period alone, and the interaction of both. Irrespective of storage period, TSS was significantly influenced by the different ethylene absorbents. Among these, the highest TSS was recorded in fruits packed without any treatment (9.44 °B) and the lowest in fruits packed with silica gel sachets (6.95 °B) (Table 5). Regardless of treatment, storage period influenced the TSS present in the 'Silver Queen' nectarine fruit. The maximum amount of TSS was found on 8^{th} day of storage (12.10 °B) and minimum on initial day of storage (4.53 °B) (Table 5).

Titratable acidity

The titratable acidity (TA) in 'Silver Queen' nectarine fruits was significantly influenced by treatment and storage period individually and their interaction as well (Table 6). Irrespective of storage period, treatment significantly influenced the titratable acid present in fruit. The highest percentage of titratable acidity was observed in fruits packed with $KMnO_4$ (0.38%) and the lowest in fruits packed without any absorbents (0.28%). Not only the storage period and treatment alone but their interactions have shown significant influence on titratable acid content of 'Silver Queen' nectarine fruit.

Eating quality of fruit is mainly determined by its organoleptic properties. Taste is one of the major organoleptic components. Consumers prefer the fruit by its sweetness, flavor and/or extent of acidity, *etc*. In this study, we found that titratable acidity, total soluble solids in the 'Silver Queen' nectarine were significantly affected by different ethylene absorbents, storage period alone, and the interaction of both. Thakur *et al*. (2005) have also reported slower increase in TSS in 'Starking Delicious' apples, with ethylene absorbents.

With respect to titratable acidity, our findings are in line with that of Shorter *et al.* (1992) who had reported that 'Granny Smith' apples in polyethylene bags with ethylene absorbents had higher acidity than untreated ones. Similarly, Thakur *et al.* (2005) reported that 'Starking Delicious' apples showed slower decrease in TA during transportation when ethylene absorbents were placed in CFB boxes.

Conclusion

From this study, we could find that all treatments were very effective in controlling the ethylene evolution and respiratory rate. Apart from that, all the treatments effectively influenced the biochemical attributes such as anthocyanin content, total phenol content and AOX activity, and thereby maintained the quality. Hence, in-package use of ethylene absorbents, especially $KMnO_4$ sachets, can be recommended to enhance the shelf life of nectarine up to 12 days under supermarket conditions without compromising the quality attributes such as PLW (9.3%), higher anthocyanin content (224.68 mg kg^{-1} FW), and higher AOX (19.09 µmol TE g^{-1} FW).

Acknowledgments

We gratefully acknowledge Dr. Jayant, Associate Director, Regional Horticulture Research Station, Dr. Y.S. Parmar University of Horticulture and Forestry, Bajaura (H.P.) for providing fruit material of nectarine for conducting the present study.

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Received: Feb. 15, 2018
Accepted: Apr. 21, 2019