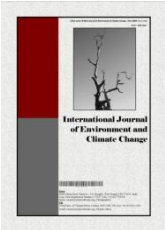

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Storability and Quality Attributes of Pear (*Pyrus communis* L.) cv. Carmen Fruits at Ambient Storage Conditions as Influenced by Foliar Application of Salicylic Acid and Calcium Chloride

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Authors' contributions

This work was carried out in collaboration among all authors. Authors MH and AA designed the study. Authors MH, AA, AK and ASS managed the experiment. Authors MH and AA managed the literature searches. Author MH wrote the first draft of the manuscript. Authors SM and SA contributed to final draft manuscript. All authors read and approved the final manuscript.

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ABSTRACT

An investigation was carried out to examine the storage behaviour and biochemical quality of pear (*Pyrus communis* L.) fruits cv. Carmen raised on Quince C rootstock as affected by pre-harvest foliar application of salicylic acid and calcium chloride treatments. The treatments consisted of four levels each of salicylic acid (0, 100, 150 and 200 ppm) and Calcium chloride (0, 0.20, 0.25 and 0.30 %). The experiment was laid out in Randomized Complete Block Design in factorial arrangements with three replications. The treatments were applied as a foliar spray at 3, 6 and 9 weeks after the petal fall. Control plants were sprayed with water. After harvest, fruits were stored under ambient conditions for 7, 14 and 21 days. Postharvest physiological loss in weight (PLW), rotting percentage, total soluble solids, total sugars and reducing sugars in fruits was increased. In contrast, fruit firmness, titratable acidity and ascorbic acid content decreased with an increase over storage periods. Salicylic acid @ 200 ppm and calcium chloride @ 0.30 % resulted minimum

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physiological loss in weight and rotting percentage. Also, salicylic acid @ 200 ppm and calcium chloride @ 0.30 % were effective in minimizing the loss of fruit firmness, titrable acidity and ascorbic acid content. In conclusion, the salicylic acid @ 200 ppm and calcium chloride @ 0.30 % were found to be effective in improving pear cv. Carmen fruits storability by reducing physiological loss in weight and fruit rotting; and maintaining the biochemical quality.

Keywords: Biochemical quality; calcium chloride; pear; pre-harvest; postharvest; salicylic acid; storability.

1. INTRODUCTION

Pears belongs to the genus *Pyrus* of the sub-family Maloidae in the the Family Rosaceae [1], native to Europe and Asia [2] and widely cultivated in the temperate regions of the world [3]. Pears broadly grouped in two major types, the 'European' pears; *P. communis,* and the 'Asian' pears; *P. pyrifolia* [4]. Pears have wide range of agro-climatic adaptation, hence plantations can be found from subtropical plains to temperate highland regions of India [5]. In India, it is grown in more than eleven states, primarily in the temperate zones of Jammu and Kashmir, Himachal Pradesh, and Uttarakhand, and even in the subtropical area of Punjab, Haryana, Jharkhand, the North Eastern region (Manipur, Mizoram, and Nagaland), and Tamil Nadu [6]. The agro-climatic conditions of Kashmir valley are highly favourable for excellent pear growing, thereby Jammu and Kashmir is leading producer in India with 88523 MT productions from an area of 13991 ha [7]. Currently, a substantial number of pear cultivars are grown, the majority of which are introductions, some of important cultivars are Kings Pear, Vicar of Winkfield, Beurre-de-Amanlis, Bartlett, Monarch, Devoe, Flemish Beauty, Red Bartlett, China Pear and Fertility [8]. Recently, SKUAST-Kashmir has introduced a new red-coloured European pear variety 'Carmen' grafted on Quince C rootstocks from Italy. The fruits of Carnem pear are quite appealing, being elongated, medium to large in size, and with a scarlet blush covering part of the skin [9]. In Kashmir valley, Carmen pear started bearing only one year after planting and fruits mature about 15 days earlier than the most common variety 'Bartlett' of the valley.

Growth hormones and nutrients are considered vital for several processes in the plant life cycle and play important role in productivity and quality of fruits. Among growth hormones, salicylic acid is one of the naturally occurring phyto-chemical and considered to be a potent plant hormone because of its diverse regulatory role in plant metabolism. It plays an important role in the regulation of plant growth and development, and responses to biotic and abiotic stresses [10]. Salicylic acid and its derivatives are also useful in enhancing the postharvest quality of several fruits [11, 12]. Calcium is an important role in fruit production and quality and is considered to be deficit in high rainfall areas besides less mobile in soil [13]. Amiri et al. [14] claimed that foliar application of nutrients is more efficient to improve quality of pear, as foliar sprays can supply essential elements directly to the foliage and fruits; however it is very difficult to achieve the goal because of the restricted uptake and penetration of calcium into the fruit and its movement within fruit tissue [15]. Keeping in view the above facts, the present investigation was carried to explore the role of salicylic acid and calcium chloride on the storage behaviour and biochemical quality of pear cv. Carmen.

2. MATERIALS AND METHODS

The present study was conducted at Experimental Farm and P.G. Laboratory of the Division of Fruit Science, SKUAST-Kashmir, Shalimar campus, Srinagar (J&K) on Pear cv. Carmen grafted on Quince C rootstock planted at a spacing of 3x3 m. The experimental site is located at an elevation of 1685 m above mean sea level and is characterized by very cold temperature (falls upto -7 ^{o}C) during December to March and moderately hot during summer months. April and May are cold and mild, June to August comparatively warm and September is mild. October and November are cold and generally dry.

The treatments comprised of four levels of salicylic acid (S_0: control, S_1: 100 ppm, S_2: 150 ppm and S_3: 200 ppm) with four levels calcium chloride (C_0: control, C_1: 0.20 %, C_2: 0.25 % and C_3: 0.30 %). Forty eight uniform trees were used for trial. The corresponding doses of salicylic acid and calcium chloride ($CaCl_2$) were applied as per the treatment combinations. The chemical treatments were applied as foliar spray to the trees through Knapsack Sprayer at 3, 6 and 9

weeks after petal fall till slight run off of the spray liquid from the leaves. The Randomized Complete Block Design in factorial arrangements with three replications was used for laying out the experiment.

Fruits were harvested at maturity. Initial weight of 10 sampled fruits in each treatment was recorded at harvest and at subsequent storage of 7, 14 and 21 days and thus physiological loss in weight at different storage period under study was worked out as per given formula:

$$\text{PLW}\ (\%) = \frac{W_0 - W_1}{W_1} \times 100$$

Where,

PLW = Physiological loss in weight
W_0 = Initial weight of stored fruits
W_1 = Fruits weight at 'x' day of storage

Rotting per cent of stored fruits was calculated on the basis of number of fruits that had rotted out of total stored fruits at 7, 14, and 21 days of storage using following formula:

$$\text{Rotting}\ (\%) = \frac{N_1}{N_0} \times 100$$

Where,

N_0 = Total number of stored fruits.
N_1 = Number of rotten fruits at 'x' day of storage.

Fruit firmness was determined with the help of Effegi Pressure Tester and expressed in kg cm^{-2}. Total soluble solids of fruit were determined with the help of Digital Hand Refractometer and the values were expressed in ^{o}Brix. The biochemical characteristics of fruit (reducing sugar, total sugar, titrable acidity and ascorbic acid) were determined as per the standard procedures of AOAC [16].

Data generated from investigations were appropriately computed and statistically analysed, and means were compared at 5 per cent level of significance as per the procedure of Snedcor and Cochran [17].

3. RESULTS AND DISCUSSION

Foliar application of salicylic acid and calcium chloride resulted significant reduction in physiological loss in weight of Carmen pear fruits during ambient storage period (Fig. 1). Minimum physiological loss in weight (2.38 %, 4.24 % and 6.46 %) was recorded with salicylic acid @ 200 ppm at 7, 14 and 21 days of storage, respectively which was statistically at par with the results observed with the application of salicylic acid @ 150 ppm. At 21 days of storage, salicylic acid @ 200 ppm was significantly superior over rest of the treatments. Maximum physiological loss in weight of fruit at 7, 14 and 21 days of storage was observed under control (3.46, 5.98, and 8.86 %, respectively). Calcium chloride @ 0.30 per cent registered minimum weight loss (2.43 %, 4.33 % and 6.91 % at 7, 14 and 21 days of storage, respectively) which was statistically at par with calcium chloride @ 0.25 % after 7 days of storage (2.71 %), whereas at 14 and 21 days of storage, calcium chloride @ 0.30 % was significantly superior over rest of the treatments. Maximum physiological loss in weight (3.16, 5.81, and 8.66 % at 7, 14 and 21 days of storage, respectively) was recorded in control. Salicylic acid maintains lower rate of respiration by inhibiting ethylene levels during storage which in turn decreases the activity of cell wall degrading enzymes and prevent softening and weight loss**.** Low physiological loss in weight of fruits in present study is attributed to the facts that calcium also delays natural physiological processes like respiration, onset of the climacteric, ripening process and senescence [18]. Similar results were reported in apricot [19] pear [20], strawberry [21] and plum [22].

Increased rotting percentage of fruits was observed with the advancement of storage period; however foliar application of salicylic acid and calcium chloride had significant effect on reducing the rotting percentage (Fig. 1). Minimum rotting of fruits (5.00, 11.67 and 20.00 % at 7, 14 and 21 days of storage, respectively) was noted with salicylic acid @ 200 ppm that was significantly the highest than others treatments. Also, foliar application of calcium chloride @ 0.30 % registered minimum rotting of fruits and was found superior among all the treatments. Lower values of rotting of fruits in present study is due to the ability salicylic acid in induced defensive enzymes chitinase, polyphenol oxidase and peroxidase [11, 23] that reduces the fungal and bacterial infections causing rotting of fruits. Calcium chloride application was found beneficial in reducing the rotting of fruits to a great extent during storage. Reduced rooting percentage of fruit due to calcium chloride application in present study might be attributed to high calcium concentrations in fruits that decreased flesh browning which are directly associated with calcium content in fruits [24].

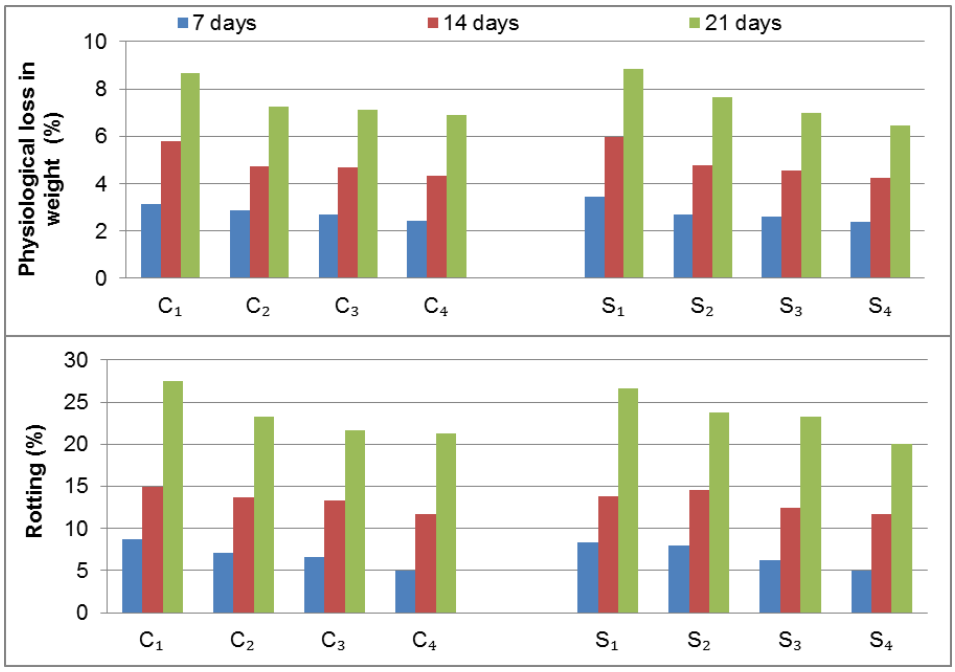

Fig. 1. Effect of Foliar application of salicylic acid and calcium chloride on physiological loss in weight and rotting percentage of pear fruits cv. Carmen on 7, 14 and 21 days ambient storage conditions

Fruit firmness was decreased with increase in storage duration at 7, 14 and 21 days of ambient storage (Fig. 2). Foliar application of salicylic acid and calcium chloride showed a significant role in maintaining the fruit firmness during storage (Fig. 2). Salicylic acid @ 200 ppm resulted maximum fruit firmness of 9.39, 8.30 and 7.62 kg cm^{-2} at 7, 14 and 21 days of storage studies, respectively though it was at par with salicylic acid @ 150 ppm (9.35, 8.26 and 6.99 kg cm^{-2} at 7, 14 and 21 days of storage, respectively) whereas minimum fruit firmness (8.59, 7.40 and 5.37 kg cm^{-2} at 7, 14 and 21 days of storage, respectively) was recorded in control. Application of calcium chloride @ 0.30 % resulted maximum firmness (9.61, 8.54 and 7.06 kg cm^{-2}) which was statistically at par with calcium chloride @ 0.25 % (9.32, 8.24 and 6.70 kg cm^{-2}) at 7 and 14 days only whereas at 21 days of storage calcium chloride @ 0.30 % was superior over rest of the treatments. Minimum fruit firmness of 8.63, 7.46 and 5.98 kg cm^{-2} at 7, 14 and 21 days of storage, respectively was recorded in control. Maintenance of higher fruit firmness could be via the efficacy of salicylic acid in decreasing ethylene production. Moreover, cell swelling is affected by salicylic acid which leads to higher firmness of fruits [23, 25]. Calcium chloride was effective in retaining the fruit firmness during storage as calcium plays an important role in maintaining cell wall structure by interaction with pectic acids in the cell walls to form calcium pectate [26]. Earlier, Val and Fernandez [27] also reported that firmness was improved with calcium sprays on late season Calrico peaches.

Total soluble solids (TSS) in fruits were increased with the foliar applications of salicylic acid (Fig. 2). At 7 days of storage, highest total soluble solid content (14.43 ^{o}Brix) was recorded with the salicylic acid @ 200 ppm which was at par with the application of 150 and 100 ppm salicylic acid (14.30 and 14.16 ^{o}Brix, respectively) whereas lowest TSS (14.01 ^{o}Brix) was recorded in control. At 14 and 21 days of storage, maximum TSS was recorded in control (16.35 and 18.82 ^{o}Brix, respectively) which was superior among all other treatments; whereas, minimum total soluble solids after 14 days (15.21 ^{o}Brix) and 21 days (16.49 ^{o}Brix) of storage were observed with salicylic acid @ 200 ppm. Foliar application of calcium chloride exhibited significant influence on total soluble solid content of fruits during storage and after 7, 14 and 21 days of storage, highest total soluble solid (14.87, 16.80 and 18.7 ^{o}Brix, respectively) was recorded in control while it was significantly lowest i.e. 13.56, 14.94 and 16.50 ^{o}Brix at 7, 14 and 21 days of storage, respectively with calcium chloride @ 0.30 %.

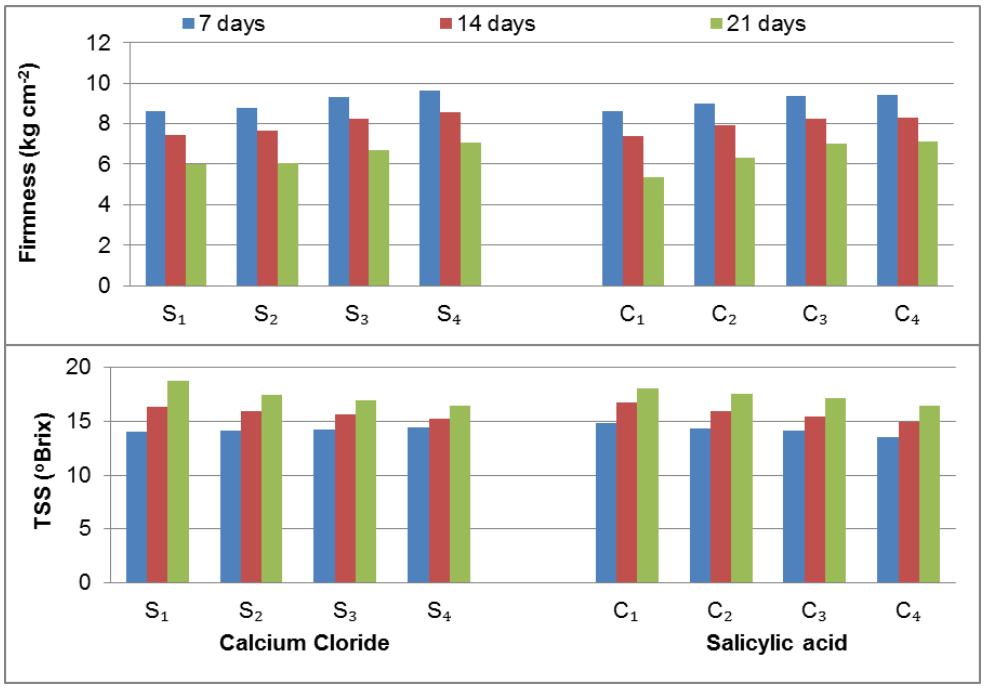

Fig. 2. Effect of foliar application of salicylic acid and calcium chloride on fruit firmness and total soluble solids of pear fruits cv. Carmen on 7, 14 and 21 days ambient storage conditions

Significant effect of foliar application of salicylic acid and calcium chloride on reducing sugars of fruits was observed during the ambient storage (Table 1). Rate of increase in reducing sugars in fruit under salicylic acid treatments was slow as compared to control; and after 7 days of storage, maximum total sugars content (11.32 %) was recorded with salicylic acid @ 200 ppm, which was statistically at par with the application of 150 ppm (11.26 %) and 100 ppm (11.21 %) salicylic acid whereas minimum reducing sugar was recorded under control (10.54 %). At 14 and 21 days of storage, maximum reducing sugar (12.52 and 13.62 %, respectively) was recorded in control which was significant higher among all other treatments. Minimum reducing sugars content after 14 and 21 days of storage (11.69 and 12.42 %, respectively) were determined with salicylic acid @ 200 ppm. Maximum reducing sugars content i.e. 11.55, 12.29 and 13.62 % at 7, 14 and 21 days of storage, respectively was recorded under control. which was statistically at par with the application of calcium chloride treatment @ 0.20 % (11.40, 12.20 and 12.32 %, respectively). After 7, 14 and 21 days of storage, minimum reducing sugars (10.46, 11.60 and 12.62 %, respectively) were recorded with calcium chloride @ 0.30 per cent.

Total sugars content in fruits were increased during storage period with the pre-harvest foliar application of salicylic acid and the rate of increase in total sugars content under salicylic acid treatments was slow as compared to control (Table 1). After 7 days of storage, maximum total sugars content (12.99 %) was recorded with salicylic acid @ 200 ppm which was statistically at par with 150 ppm (12.81 %) and 100 ppm (12.62 %) salicylic acid treatments whereas minimum was recorded under control (12.48 %). After 14 and 21 days of storage, maximum total sugars were recorded under control i.e. 14.57 and 15.57 per cent, respectively which was significant over other salicylic acid treatments whereas minimum total sugars content were observed with salicylic acid @ 200 ppm i.e. 14.53 and 15.67 %, respectively. Foliar application of calcium chloride application significantly influenced total sugar content during storage and after 7, 14 and 21 days of storage, maximum total sugars content in fruits i.e. 13.27, 14.47 and 15.43 %, respectively was recorded in control which were statistically at par with the results obtained under calcium chloride treatment @ 0.20 per cent (13.03, 14.37 and 15.37 %, respectively). Minimum total sugars i.e. 12.20, 13.43 and 14.50 per cent were recorded with calcium chloride @ 0.30 per cent after 7, 14 and 21 days of storage, respectively.

Total sugars and reducing sugars of fruits increased over the period of storage but the rate

of increase was slow in fruits harvested from trees sprayed with salicylic acid and calcium chloride treatments. Salicylic acid is an ethylene inhibitor which makes it effective in reducing respiration rates and metabolic activities thereby slowing down the ripening process [28, 29] and thus might resulted lower values of total soluble solids and sugars during storage. The present results are in agreement with the findings of Salari et al. [30] and Srivastava and Drivedi [31] those also reported that the rate of respiration gets retarded due to application of salicylic acid and thereby delaying the increase in soluble solid content in strawberry and banana fruits respectively. According to Minh [32] $CaCl_2$ treatment would be an effective approach to extend shelf life of banana fruit in commercial distribution.

Titrable acidity in fruits was decreased with the increase in storage period and the foliar applications of salicylic acid and calcium chloride had significant effect on titrable acidity fruits during storage (Table 2). Maximum titrable acidity after 7, 14 and 21 days of storage (0.52, 0.48 and 0.42 %, respectively) was recorded with salicylic acid @ 200 ppm which was statistically superior over other treatments whereas minimum titrable acidity after 7, 14 and 21 days of storage were recorded in control i.e. 0.40, 0.35 and 0.30 per cent, respectively. Calcium chloride @ 0.30 per cent resulted maximum titrable acidity in fruits i.e. 0.50, 0.46 and 0.40 per cent after 7, 14 and 21 days of storage, respectively, although at 21 days of storage it was at par with 0.25 % (0.37 %). Minimum titrable acidity in fruits i.e. 0.42, 0.37 and 0.30 per cent at 7, 14 and 21 days of storage, respectively was recorded in control. Kirinus et al. [33] in peaches and Srivastava and Dwivedi [31] in banana also recorded that salicylic acid maintain higher acid content at the end of storage period. Attri et al. [34] reported that acidity in pear fruits reduced faster in control fruits as compared to calcium treated fruits during storage. Similar results were also reported in apple by and Ibadullah et al [35].

Foliar application of salicylic acid and calcium chloride showed significant results for ascorbic acid content which was decreased with increased storage period of fruits (Table 2). The highest ascorbic acid content (9.19, 8.83 and 8.04 mg 100 g^{-1}) was recorded with the application of salicylic acid @ 200 ppm after 7, 14 and 21 days of storage, respectively which was statistically superior among all other treatments. Lowest ascorbic acid content (8.30, 7.89 and 6.88 mg 100 g^{-1}) at 7, 14 and 21 days of storage, respectively were recorded in control. Calcium chloride @ 0.30 per cent resulted the maximum ascorbic acid content (9.18, 8.69 and 7.78 mg 100 g^{-1}) at 7, 14 and 21 days of storage, respectively although it was statistically at par with calcium chloride 0.25 per cent (8.95, 8.56, 7.67 mg/100 g), whereas minimum ascorbic acid content (8.61, 8.09 and 7.36 mg 100 g^{-1}) was registered under control at 7, 14 and 21 days of storage, respectively (Table 2). Ascorbic acid content in fruits was decreased with the advancement of storage period. Salicylic acid has a potential role in minimizing fruit decay and maintaining fruit quality [36]. Awad et al. [37]

Table 1. Effect of foliar application of salicylic acid and calcium chloride on sugars content of Carmen pear fruits fruit during ambient storage

Treatment	Reducing sugars (%)			Total sugars (%)		
	7 days	14 days	21 days	7 days	14 days	21 days
Salicylic acid						
S_1- Control	10.54	12.52	13.62	12.48	14.57	15.57
S_2- 100 ppm	11.21	12.10	13.01	12.62	13.89	15.04
S_3- 150 ppm	11.26	11.79	12.58	12.81	13.81	14.95
S_4- 200 ppm	11.32	11.69	12.42	12.99	13.71	14.51
SEm±	0.10	0.14	0.12	0.12	0.12	0.15
$CD_{0.05}$	0.26	0.43	0.31	0.30	0.30	0.37
$CaCl_2$						
C_1- Control	11.55	12.38	13.62	13.27	14.47	15.53
C_2- 0.20 %	11.40	12.20	13.32	13.03	14.37	15.40
C_3- 0.25 %	10.93	11.93	12.59	12.42	13.60	14.65
C_4- 0.30 %	10.46	11.60	12.10	12.20	13.43	14.50
SEm±	0.10	0.14	0.12	0.12	0.12	0.15
$CD_{0.05}$	0.26	0.43	0.31	0.30	0.30	0.37

Table 2. Effect of foliar application of salicylic acid and calcium chloride on titrable acidity and ascorbic acid content of Carmen pear fruits fruit during ambient storage

Treatment	Titrable acidity (%)			Ascorbic acid (mg 100 g^{-1})		
	7 days	14 days	21 days	7 days	14 days	21 days
Salicylic acid						
S_1- Control	0.40	0.35	0.30	8.30	7.89	6.88
S_2- 100 ppm	0.44	0.39	0.33	8.90	8.22	7.32
S_3- 150 ppm	0.48	0.44	0.38	9.09	8.64	7.98
S_4- 200 ppm	0.52	0.48	0.42	9.19	8.83	8.04
SEm±	0.01	0.01	0.01	0.11	0.11	0.12
$CD_{0.05}$	0.02	0.02	0.03	0.27	0.27	0.29
$CaCl_2$						
C_1- Control	0.42	0.37	0.30	8.61	8.09	7.36
C_2- 0.20 %	0.45	0.41	0.36	8.73	8.25	7.41
C_3- 0.25 %	0.47	0.43	0.37	8.95	8.56	7.67
C_4- 0.30 %	0.50	0.46	0.40	9.18	8.69	7.78
SEm±	0.01	0.01	0.01	0.11	0.11	0.12
$CD_{0.05}$	0.02	0.02	0.03	0.27	0.27	0.29

reported that changes in fruit ascorbic acid content during storage increased gradually with increasing salicylic acid rates at all periods of storage; while, decreased sharply with increasing the time of storage. Attri et al [34] also found that maximum ascorbic acid content of pear treated with salicylic acid and calcium was retained during storage.

4. CONCLUSION

Foliar application of salicylic acid and calcium chloride were promising in minimizing physiological loss in weight and rotting percentage of fruit besides maintaining biochemical quality of fruits during storage at ambient conditions. Fruit firmness, titratable acidity and ascorbic acid content decreased with increased storage duration while total soluble solids, total sugars and reducing sugars content of fruits were increased with increase in days of storage. Salicylic acid @ 200 ppm and calcium chloride @ 0.30 % was helpful in minimizing physiological loss in weight, rotting per cent and maintaining the fruit firmness, titratable acidity and ascorbic acid content. In conclusion, salicylic acid @ 200 ppm and calcium chloride @ 0.30 % found to be effective for improving storability and maintaining the biochemical quality of Carmen pear fruits at ambient storage, hence it can be recommended for postharvest management of pear fruits.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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