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Effect of Integrated Postharvest Handling Practices on Quality and Shelf Life of Cactus Pear [*Opuntia ficus-indica* (L.) Mill.] Fruits

Getachew Shumye[1]*, Kebede Woldetsadik[2], and Ibrahim Fitiwi[3]

[1]Department of Plant Sciences, Wollega University, P.O. Box 395, Nekemt, Ethiopia
[2]Department of Plant Sciences, Haramaya University, P.O. Box 241, Haramaya, Ethiopia
[3]Department of Dryland Crop and Horticultural Sciences, Mekelle University, P. O. Box 231, Mekelle, Ethiopia

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Abstract

This experiment was conducted to determine the effect of postharvest handling practices on quality and shelf life of cactus pear [*Opuntia ficus-indica* (L.) Mill.] fruits through integrating postharvest chemical, packaging, and storage treatments. Storage in evaporative cooler (EC) significantly improved all the quality parameters of fruits due to the decrease in mean temperature by 2.81°C and increase of relative humidity by 11% than ambient storage. Packaging maintained fruit quality better than that of non-packaged ones. Similarly, chemical treatments, especially $CaCl_2$ and 2, 4- Dichlorophenoxyacetic acid enabled better retention of physical and chemical quality characteristics of fruits. The combined effects of the treatments resulted in maintenance of lower levels of pH and higher levels of total soluble solids, titratable acidity, ascorbic acid, pulp firmness, as well as marketability of cactus pear fruits. Hence, the shelf life of cactus pear fruits could be extended for two to three weeks with nutritional quality attributes maintained in good condition using combinations of chemicals, packaging fruits in polyethylene sheet and then storing them under EC.

Keywords

Cactus pear
Chemical treatment
Evaporative cooler
Packaging
Quality

INTRODUCTION

Cactus pear [*Opuntia ficus-indica* (L.) Mill.] is a dicotyledonous plant of the Cactaceae family native to central Mexico and the Caribbean. The plant has been domesticated as an important fruit crop in many areas of the world although wild populations are still unexploited (Mondragon, 2001). Fruits are highly perishable having a short shelf life of a few days. Cactus pear fruit is prone to postharvest losses. Deterioration is caused by mechanical damage during harvesting, removal of spines as well as by rotting. Moreover, high transpiration rate results in high percentage of weight losses (Rodriguez et al., 2005). Resistance to these factors differs among varieties (Corrales and Flores-Valdez, 2003), which are associated with morpho-anatomical characteristics of the peel (Corrales et al., 1997).

Marketing of fruits and vegetables in Ethiopia is complicated by high postharvest losses, which are estimated to be as high as 50% (FAO, 2005). This high loss has been attributed to several factors among which the lack of packaging and storage facilities and poor means of transportation are the major ones (Kebede, 1991; Wolde, 1991).
Low temperature handling and storage are the most important physical methods of

Email: getachewshumye@yahoo.com

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postharvest management (Johnson et al., 1997). Temperature of the produce and surrounding air can be reduced by forced air-cooling, hydro-cooling, vacuum cooling, ice cooling, and evaporative cooling (Thompson et al., 1998). The evaporative cooled environment is a good alternative for the small-scale peasant farmers, retailers, and wholesalers in Ethiopia, as it require low initial and running cost than other cooling methods (Seyoum and Woldetsadik, 2004).

Packaging of fruits is also one of the most commonly used postharvest practices that keeps them into unitized volumes that are easy to handle while also protecting them from hazards of transportation and storage (Burdon, 2001). Modified atmosphere packaging for storage and transportation of fruits and vegetables is commonly achieved by packaging them in plastic films. Storage in plastic films of different kinds with combinations of perforation and inclusions of chemicals are types of modified atmosphere storage (Burdon, 2001; Irtwange, 2006).

Postharvest exogenous application of salicylic acid is shown to influence stomata opening (Khadiga, 1993), ion uptake and transport (Larque, 1979), inhibit ethylene biosynthesis, ripening, transpiration, and improve stress tolerance of perishable horticultural produces (Khan et al., 2003). Addition of calcium also improves rigidity of cell walls and obstructs enzymes involved with tissue softening and ripening (Chaplin and Scott, 1980). In a similar manner, postharvest 2, 4-Dichlorophenoxyacetic acid (2, 4-D) treatment induces healing of injuries, retarded senescence and control decay in several fruit and vegetable species (Kobiler et al., 2001; Wang et al., 2008).
There is a growing demand in international market for excellent quality cactus pear fruit (Mizrahi et al., 1997; Basile, 2001; Mokoboki et al., 2009) but less attention is given by the scientific community (Magloire et al., 2006). In Ethiopia, attention has not been given to this crop, especially to its postharvest handling practices. Hence, this experiment was initiated to study alternative methods of postharvest handling of cactus pear fruits that could improve the shelf life of the fruit. Considering these, this study was conducted to determine the effect of optimal postharvest handling practice on the quality and shelf life of the fruit through integrating postharvest chemical, packaging, and storage treatments.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted at the Horticulture and Plant Physiology Laboratories of Mekelle University during 2012 using fruits of local cactus pear cultivar. The site is located 787 km north of Addis Ababa at 13^o 29'N latitude and 39^o 28'E longitudes and at an altitude of 2223 m above sea level. The mean annual precipitation is 619.4 mm, and the mean maximum and minimum temperatures are 24.6°C and 12.2°C, respectively with 60.3% mean annual RH.

Materials preparation

Mature fruit (green-yellowish color) of cactus pear cultivar locally called “Liemol” was harvested from uniform plants grown in Southern Tigray (Mehoni). Harvesting was carried by hand with maximum care, using locally made tin-headed harvesting equipment to avoid mechanical damage. The fruits were immediately transported at night by vehicle covering them with leaf.
Fruits were selected for uniformity of color, size, shape, and freedom from defects. Immediately after selection, unblemished uniform fruits were dipped in 19 ^oC solution of 1% sodium hypochlorite (NaOCl) for 5 to 10 minutes to reduce microbial population from the surface of the fruits and to remove the field heat and adhering dust. Then fruits were washed with distilled water and air dried.

Treatments and experimental design

Treatments consisted 4 x 2 x 2 factorial combinations of chemical treatments [Control, 0.022 mM Salicylic Acid (SA), 5.703 mM 2, 4-Diclorophenoxilic acid (liquid herbicide) and 27 mM $CaCl_2$], two packaging options (unpackaged and packaged with low-density polyethylene sheet and two storage conditions (ambient condition in shade and naturally ventilated evaporative cooler). The treatments were laid in a completely randomized design with three replications.

The washed cactus pear fruits were divided into four groups of 300 fruits each. After transferring the fruits in to plastic containers, washed and rinsed with distilled water prior to use for the dipping treatments. The dipping treatments were prepared and performed at the same time for 5 minutes. After dipping, the treated fruits were air dried and then subdivided into 12 groups, having 25 fruits in each with 48 groups. Out of the 48 groups (experimental units), half were packaged and the remaining half were left unpackaged. Then, the treated fruits were stored in the evaporative cooler (EC) and ambient environment for 21 days. Five fruits from each treatment were also stored at the same conditions for assessment of marketability of fruits. Five fruits were taken randomly from each replication on 0, 7, 14, and 21 days of storage for determination of quality.

Temperature and relative humidity measurement

Temperature and relative humidity inside and outside of the EC was measured throughout the experimental period using thermometers and hygrometer, respectively. The readings were taken at every two hour interval during the daytime staring from 6:00 h and once at mid night. The average temperature difference (dT) between the EC and ambient was calculated using the following relationship:

$$dT = \frac{T\ out - T\ in}{n}$$

Where: T_{out} and T_{in} are temperature outside and inside the EC respectively
n is number of temperature recorded

The average residual RH difference (dRH) between inside and outside of the EC was calculated as:

$$dRH = \frac{RH\ in - RH\ out}{n}$$

Where:
RH_{in} and RH_{out} = RH inside and outside of the EC respectively
n = number of RH recorded

Percentage marketability

Descriptive quality attributes were assessed by observing the level of decay, damage, color, surface defects, shriveling, and total appearance to judge percentage marketability using the following formula.

$$\text{Marketability (\%)} = \frac{\text{Number of marketable cactus pear fruits}}{\text{Total number of cactus pear fruit}} \text{x100}$$

Fruit pulp firmness

The fruit pulp firmness was measured manually using a fruit pressure tester (penetrometer). Each fruit was placed on a table and the plunger was vertically pressed in two opposite sides independently. The average readings were recorded for pulp firmness determination.

Total soluble solids (TSS)

An aliquot of juice was extracted using a juice extractor. A digital refractometer (WAY-2s digital Abb'e) was used to determine TSS by placing 1 to 2 drops of clear juice on the prism. Between samples the prism of the refractometer was washed with distilled water and dried with tissue paper before reuse. The refractometer was standardized against distilled water.

pH and titratable acidity (TA)

An aliquot of juice was extracted from the sample fruits and the pH of the juice was measured with a pH meter (UB-10 pH/mV meter ultra basic). The TA of the juice was measured according to the methods described by Maul et al. (2000). The TA expressed as percent citric acid, was obtained by titrating 10 ml of cactus pear juice with 0.1N NaOH in the presence of phenolphthalein.

TA was calculated from the following formula:

$$\text{TA (\%)} = \frac{\text{Titre x 0.1N NaOH x 0.064}}{1000} \text{ x 100}$$

Ascorbic acid

The ascorbic acid (AA) content of cactus pear fruits was determined by the Iodine Titration method. A sample of 20 ml of cactus pear fruits juice extract was pipetted in to 250 ml conical flask and 150 ml of distilled water, 5 ml of 0.6 mol l^{-1} potassium iodide, and 5 ml of 1 mol l^{-1} HCl and 1 ml of starch indicator solution were added. The sample was titrated with 0.002 mol l^{-1} potassium iodate solution. The endpoint of the titration was the first permanent trace of a dark blue-black colour due to the starch-iodine complex. The AA content was calculated from the titration with oxidation-reduction reaction.

Statistical Data Analysis

Significance tests were made by analysis of variance (ANOVA) for factorial arrangement in randomized complete design with SAS software (statistical analysis system, version 9.1). Comparisons of the treatment means were done using Least Significant Difference (LSD) test at P = 5%.

RESULT AND DISCUSSION

Temperature and Relative Humidity

During the storage period, the day-time ambient temperature varied between 13.02 ^oC and 22.36 ^oC with an average 18.83 ^oC. However, during the day time the temperature inside the EC varied between 12.12 ^oC and 18.02 ^oC with an average 16.02 ^oC (Fig. 1a). The relative humidity ranged between 80.29% and 91.19% under ambient conditions, with the average being 84.60% and between 91.90% and 98.81% in EC with the average of 95.64% (Fig. 1b).

The day-time average difference in dry bulb temperature between ambient and EC conditions was 2.81 ^oC and that of relative humidity was 11.04%. The minimum (0.9 ^oC) and maximum (4.44 ^oC) differences in temperature were found at 6:00 h and 12:00 h respectively (Fig. 1a). Similarly, the minimum (7.60%) and maximum (15.43%) difference in RH was recorded at 6:00 h and 12:00 h respectively (Fig. 1b). A higher rate of evaporation of water from the wet cooling pad could be the reason for such differences (Seyoum and Woldetsadik, 2004).

The EC was effective in minimizing the extremes of temperature and RH, which is in agreement with the reports by Seyoum and Woldetsadik (2000). However, at Dire Dawa, a warmer area, Seyoum and Woldetsadik (2004) reported that the evaporatively cooled chamber maintained temperature varying from 17-26 ^oC and relative humidity between 43-98%, which was by far better than the ambient storage. Reports by Tefera et al. (2007) and Getinet et al. (2008) also give 14-19 ^oC temperature and 82-96% RH for the same evaporative cooler at Dire Dawa.

There was little fluctuation in temperature and relative humidity in the EC during the storage period as compared to ambient condition. This is important in view of safe and effective storage of perishable commodities (Burdon, 2001). However, fruits stored under ambient conditions could be exposed to relatively harsh conditions at 12:00 AM because of high temperature and low relative humidity.

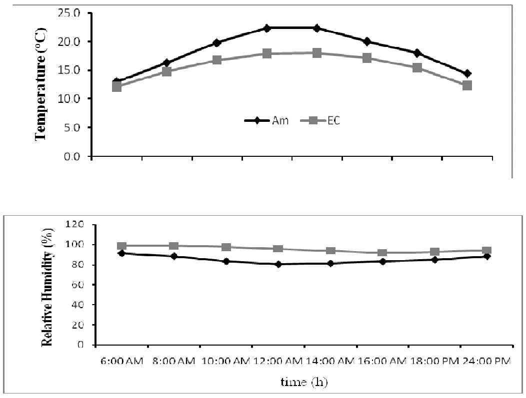

Figure 1. (a) dry-bulb average ambient (Am) and evaporative cooler (EC) temperature (°C) and (b) average ambient and evaporative cooler relative humidity (%) during storage of cactus pear fruit for a period of 21 days.

Marketability Percentage

Chemicals, packaging and storage conditions had highly significant ($P < 0.001$) interaction effect on the marketability of cactus pear fruits till 14 day of storage. The marketability of cactus pear fruits decreased from 100% to about 33.3% in the EC within 21 days of storage but in ambient condition it reduced to 40% in 14 days and then fruits totally become unmarketable (Table 1).

On day 7, all fruits stored in the EC and those packaged and $CaCl_2$ treated fruits stored in ambient condition were in the same marketability status. Similarly, on 14th day all chemically treated and packaged fruits stored in the EC had 100% marketability that dropped to 60% in the unpackaged controls. Under ambient condition, marketability of the fruits reduced drastically since they were exposed to higher temperature and lower relative humidity that resulted in more weight loss and exposed them to decaying organisms. Furthermore, higher respiration rate at higher temperature may lead to senescence because the stored food reserve, which provides energy could be exhausted (Paull, 1993, Siddiqui et al., 2011a).

Cactus pear fruits stored in the EC remained fresh and firm for a period of two weeks. They looked shiny and had attractive color compared to those stored at ambient condition. This might be attributed to reduced rate of respiration and transpiration of fruits due to relatively lower temperature and higher RH inside the evaporative cooler (Thompson et al., 1998; Seyoum and Woldetsadik, 2000; Irtwange, 2006). Packaged fruits had more number of marketable fruits than the unpackaged control fruits under both storage conditions. The modified atmosphere created inside the package as well as the reduction in water loss (González et al., 2003) can explain these beneficial effects.

Table 1. Interaction effect of chemicals, packaging material and storage environments on the marketability (%) of cactus pear fruits over a storage period of 21 days

Treatments			Storage period, days		
			7	14	21
EC	Packaged	Control	100(90°)^a	80(63.4°)^b	40(39.2°)
		$CaCl_2$	100(90°)^a	100(90°)^a	60(50.8 °)
		2, 4-D	100(90°)^a	100(90°)^a	60(50.8°)
		SA	100(90°)^a	100(90°)^a	46.7(43.1°)
	unpackaged	Control	100(90°)^a	60(50.8°)^c	33.3(35.0°)
		$CaCl_2$	100(90°)^a	73.3(59.2°)^b	53.3(46.9°)
		2, 4-D	100(90°)^a	80(63.43°)^b	40(39.2°)
		SA	100(90°)^a	80(63.4°)^b	40(39.2°)
AC	Packaged	Control	73.3(59.2°)^c	60(50.8°)^c	-
		$CaCl_2$	100(90°)^a	60(50.8°)^c	-
		2, 4-D	80(63.4°)^b	60(50.8°)^c	-
		SA	80(63.4°)^b	73.3(59.2°)^b	-
	Unpackaged	Control	60(50.8°)^d	40(39.2°)^d	-
		$CaCl_2$	80(63.4°)^b	60(50.8°)^c	-
		2, 4-D	80(63.4°)^b	60(50.8°)^c	-
		SA	60(50.8°)^d	60(50.8°)^c	-
LSD (5%)			3.15	4.4	3.05
CV (%)			13.6	9.0	2.39

Fruit Pulp Firmness

Firmness of cactus pear fruits was significantly ($P < 0.001$) altered by the effect of chemicals, packaging and storage environments over the storage period. Pulp firmness was maintained higher in $CaCl_2$ treated fruits than other treatments. However, the softening process of the control fruits was faster than the other treatments (Table 2).

Fruits stored in EC were firmer than fruits stored in ambient condition. This might be due to the presence of higher relative humidity and lower temperature in EC, which retarded the respiration and transpiration rate of the fruits. Packaged cactus pear fruits were relatively firmer than the unpackaged fruits throughout the storage period. The modified atmosphere packaging with high CO_2 inhibits the breakdown of peptic substances, which retains fruit texture and remains firmer for a longer period (Salunkhe and Desai, 1984).

Table 2. Effect of chemicals, packaging and storage environments on the pulp firmness (kg cm^{-2}) of cactus pear fruits over a storage period of 21 days

Treatments	Storage period, days		
	7	14	21
Chemicals			
$CaCl_2$	7.93[a]	7.42[a]	6.70[a]
2, 4-D	7.53[c]	6.66[b]	6.45[b]
SA	7.78[b]	6.21[c]	6.10[c]
Control	6.56[d]	5.44[d]	5.15[d]
LSD (5%)	0.15	0.18	0.23
Packaging			
Packaged	7.72[a]	6.55[a]	6.23[a]
Unpackaged	7.19[b]	6.32[b]	5.97[b]
LSD (5%)	0.11	0.13	0.16
Storage			
EC	7.91[a]	7.52[a]	-
Am	6.99[b]	5.35[b]	-
LSD (5%)	0.11	0.13	-
CV	2.39	3.35	2.992

Means followed by the same letter within the same column are not significantly different at P = 5%. Initial (0 day) pulp firmness was 8.490 kg cm^{-2} and the data from day 14 onwards is meant for the EC storage only, and SA = salicylic acid.

Total soluble solids

There was highly significant ($P < 0.001$) interaction effect of chemicals, packaging and storage environment on the total soluble solids (TSS) content of the fruits. On day 7, under both storage conditions, packaged fruits had higher TSS content compared to unpackaged ones while the unpackaged control fruits had lower TSS content than other treatments with respect to their storage condition. The highest TSS was recorded in packaged $CaCl_2$ treated fruits stored in EC but the lowest was recorded in unpackaged control fruits stored under ambient condition. However, on day 14 the unpackaged control fruits stored at ambient condition had the lowest TSS, which was lower than the TSS of fruits at day 21 in the EC.

The fruits treated with chemicals and packaging combined with EC, showed better maintenance of TSS content towards the end of storage time with relatively higher TSS value for packaged SA treated fruits. The atmospheric modification i.e. reduced O_2 and increased CO_2 created in the package, combined with lower temperature in the EC might have delayed senescence of the fruits because of reduced respiration rate (Mathooko, 2003; Siddiqui et al., 2011b). Hence, both chemically treated and packaged fruits do not rapidly deplete their soluble solids as those of the unpackaged control fruits as observed in this study.

Table 3. Interaction effect of chemicals, packaging material and storage environments on the total soluble solids and pH of cactus pear fruits over a storage period of 21 days

Treatments			TSS (^{0}Brix)			pH		
			Storage periods, days			Storage periods, days		
			7	14	21	7	14	21
EC	Packaged	Control	9.80^{fg}	9.50^{cd}	8.56^{e}	5.58^{e}	5.74^{g}	5.41^{e}
		$CaCl_2$	11.00^{a}	10.00^{ab}	9.76^{bc}	5.48^{fg}	5.81^{f}	5.83^{bc}
		2, 4-D	10.73^{abc}	10.15^{ab}	9.98^{ab}	5.49^{fg}	5.52^{ij}	5.44^{e}
		SA	10.67^{bc}	10.23^{a}	10.13^{a}	5.45^{g}	5.48^{j}	5.52^{de}
	unpackaged	Control	9.67^{g}	9.33^{d}	8.18^{f}	5.71^{c}	6.20^{c}	6.58^{a}
		$CaCl_2$	10.50^{cd}	9.92^{abc}	9.06^{d}	5.52^{f}	5.91^{e}	5.91^{b}
		2, 4-D	10.47^{cd}	9.73^{bcd}	9.62^{c}	5.45^{g}	5.55^{i}	5.66^{cd}
		SA	10.50^{cd}	10.03^{ab}	8.22^{ef}	5.52^{f}	5.68^{h}	5.81^{bc}
AC	Packaged	Control	9.60^{g}	9.33^{d}	-	6.05^{b}	6.08^{d}	-
		$CaCl_2$	10.83^{ab}	9.93^{ab}	-	5.47^{fg}	5.90^{e}	-
		2, 4-D	10.83^{ab}	10.13^{ab}	-	5.587^{e}	5.67^{h}	-
		SA	10.23^{de}	9.98^{ab}	-	5.66^{d}	5.67^{h}	-
	unpackaged	Control	8.13^{h}	7.60^{e}	-	6.56^{a}	6.79^{a}	-
		$CaCl_2$	10.0^{ef}	9.79^{bc}	-	5.50^{f}	5.70^{gh}	-
		2, 4-D	10.23^{de}	9.87^{abc}	-	5.65^{d}	5.69^{gh}	-
		SA	10.04^{ef}	9.94^{ab}	-	6.02^{b}	6.26^{b}	-
LSD (5%)			0.28	0.43	0.36	0.05	0.05	0.18
CV (%)			1.62	2.64	2.24	0.50	0.55	1.82

Means within the same column followed by the same letter are not significantly different at P = 5%. Initial (0 day) TSS and pH values were 10.85 ^{0}Brix and 5.56 respectively, and the data from day 14 onwards is meant for the EC storage only, and SA = salicylic acid.

pH values

The pH fruit juice was recorded to be the highest in unpackaged fruits receiving no chemical treatment and stored under ambient condition while the lowest values were obtained in packaged fruits treated with SA stored in the EC. On day 7 and 14, pH values of cactus pear fruits stored in the EC were relatively lower than fruits under ambient condition. Under both storage conditions, packaged fruits had lower pH values compared to their respective unpackaged treatments. The highest pH values were recorded in unpackaged control fruits in both storage conditions while the lowest pH value was observed in packaged SA treated fruits stored in EC and in packaged $CaCl_2$ treated on day 7 and packaged 2, 4-D and SA treated fruits on day 14 stored in ambient condition.

The tendency of increasing pH value and reduced acidity is observed with storage time since the fruit with proceeding of the ripening process is going to diminish its predominant acid (Medlicott et al., 1986). The pH increased faster in cactus pear fruits stored at ambient temperature compared with fruits stored in the cooler, these could be associated with the utilization of acids for catabolism of sugar at faster rate under ambient condition (Siddiqui and Dhua, 2010). The lower pH values of packaged fruits could be explained by the relatively reduced respiration rate in the package. Reduced O_2 and increased CO_2 could delay the rate of respiration in the package (Mathooko, 2003); hence, it may inhibit loss of organic acids (Wang, 1990).

Titiratable acidity

Chemicals, packaging, and the storage environments significantly affected titratable acidity (TA) of the fruits. Under both storage conditions, packaged fruits had higher TA compared to their respective unpacked treatments. The highest TA was recorded in the packaged salicylic acid treated fruits except on 20th day of storage while the lowest TA was observed in control fruits stored in both storage conditions. TA is directly related to the concentration of organic acids present in the fruit. Ball (1997) suggested that acidity decreases due to fermentation or break up of acids to sugars in fruits during respiration. This study showed higher retention of TA in chemical treated cactus pear fruits compared to the control fruits, which might be due to reduction in metabolic changes of organic acid into carbon dioxide. Storage at ambient temperature resulted in faster decline in TA content of fruits than at EC. The relatively higher ambient temperature leads to higher rate of reduction of TA which could be a result of use of organic acids as a substrate of respiration under higher temperatures. According to Mohammed et al. (1999), higher fruit acidity is an advantage, which causes a lower incidence of spoilage.

Table 4. Interaction effect of chemicals, packaging material and storage environments on the Titratable Acidity (TA) and ascorbic acid (AA) contents of cactus pear fruits over a storage period of 21 days

			TA (%)			**AA (mg 100 g^{-1} fresh weight)**		
Treatments			Storage period, days					
			7	14	21	7	14	21
EC	Packaged	Control	0.045	0.017^{j}	0.015^{e}	50.65^{defg}	49.75^{h}	49.11^{c}
		$CaCl_2$	0.053	0.044^{e}	0.031^{b}	46.05^{h}	61.13^{b}	60.42^{a}
		2, 4-D	0.053	0.052^{b}	0.051^{a}	56.25^{abc}	56.32^{f}	61.76^{a}
		SA	0.059	0.058^{a}	0.025^{c}	58.18^{a}	64.44^{a}	59.97^{a}
	unpackaged	Control	0.045	0.017^{j}	0.013^{f}	47.77^{fgh}	47.22^{i}	46.91^{c}
		$CaCl_2$	0.052	0.043^{e}	0.025^{c}	56.39^{ab}	59.97^{c}	55.64^{b}
		2, 4-D	0.051	0.032^{g}	0.025^{c}	48.88^{efgh}	54.08^{g}	61.76^{a}
		SA	0.058	0.026^{h}	0.022^{d}	47.83^{fgh}	59.07^{d}	56.39^{b}
AC	Packaged	Control	0.045	0.023^{i}	-	47.04^{gh}	46.28^{j}	-
		$CaCl_2$	0.051	0.05^{c}	-	52.36^{cde}	58.58^{e}	-
		2, 4-D	0.053	0.048^{d}	-	53.70^{bcd}	59.20^{d}	-
		SA	0.059	0.051^{bc}	-	51.02^{def}	64.76^{a}	-
	Unpackaged	Control	0.045	0.017^{j}	-	49.08^{efgh}	44.75^{k}	-
		$CaCl_2$	0.049	0.034^{f}	-	49.26^{efgh}	61.10^{b}	-
		2, 4-D	0.050	0.043^{e}	-	50.60^{defg}	56.39^{f}	-
		SA	0.055	0.043^{e}	-	57.23^{ab}	64.44^{a}	-
LSD (5%)			ns	0.002	0.001	3.89	0.44	2.30
CV (%)			2.881	2.578	2.140	4.54	0.46	2.33

Means within the same column followed by the same letter are not significantly different at P = 5%. Initial (0 day) TA was 0.061% while initial AA content was 68.57 mg100 g^{-1} fresh weight; Data from day 14 onwards is meant for the EC storage only, and SA = salicylic acid.

Ascorbic acid

The interaction effect of chemicals, packaging, and storage environment on the ascorbic acid (AA) content of cactus pear fruits was highly significant ($P < 0.01$). On day 7, the lowest AA content was observed in packaged $CaCl_2$ treated fruits stored in the EC while the highest was observed in packaged salicylic acid treated fruits stored in the same condition (Table 4). On 14^{th} day, unpackaged control fruits stored in ambient condition had the lowest AA while the highest was recorded in both packaged and unpackaged salicylic acid treated fruits stored in the same condition as well as those packaged salicylic acid treated stored in the cooler.

Initially AA content rapidly decreased and then increased after 7 days of storage but in both packaged and unpackaged control fruits stored in both storage conditions showed a rapid decreasing trend in AA content. The retention of ascorbic acid in the treated fruits might be due to the lowering of respiration of fruit or oxidation of ascorbic acid in the treated fruits (Saira et al., 2009; Siddiqui and Dhua, 2010). High temperature increases enzymatic catalysis that leads to biochemical breakdown of compounds in the fruits (Yeshida et al., 1984). Furthermore, possible reduction in internal O_2 and a decrease in ethylene concentration might explain the presence of higher value of AA in packaged fruits through delay in respiration and ripening of the packaged fruit (Kader, 1995).

CONCLUSION

The evaporative cooler unit maintained the temperature between 12.12 ^oC and 18.02 ^oC and the relative humidity between 91.9% and 98.81% during storage period. Evaporative cooling significantly affected quality parameters in cactus pear fruits and improved their shelf life. There was significant difference among chemical treatments in their effect on marketability, pulp firmness, TSS, pH, TA and AA and they showed a general trend of positive effect on all these quality parameters during storage. Moreover, effectiveness of chemical treatments was improved with modified atmosphere packaging created using polyethylene sheets, which coupled with evaporative cooler. Fruits treated by combinations of the chemical treatments, packaging in polythene bag and storing in evaporative cooler remained 100% marketable with better nutrient composition for a storage period of two weeks while marketability of non-treated control fruits dropped to 40% with substantial reduction in compositional quality attributes. Hence, the shelf life of cactus pear fruits could be improved in the experimental area through the use of combinations of chemicals, such as the ones used in this study, packaging fruits in polyethylene sheet and then storing under evaporative cooler.

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