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ORIGINAL ARTICLE

Effect of zero energy cool chamber and post-harvest treatments on shelf-life of fruits under semi-arid environment of Western India. Part 2. Indian gooseberry fruits

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Abstract Effect of zero energy cool chamber (ZECC) along with post-harvest treatments including $CaCl_2$, mustard oil and K_2SO_4 separately on shelf-life and fruit quality attributes of Indian gooseberry or aonla (Emblica officinalis Gaertn) during storage under semi-arid ecosystem of Gujarat was studied. Increase in physiological loss in weight (PLW), spoilage loss, total soluble solids, total sugar and reducing sugars, reduction in titratable acidity and ascorbic acid were observed during storage period in all the treatments. Fruits treated with 1.5% $CaCl_2$ and stored in ZECC recorded least PLW (16%), spoilage loss (16.5%), respiratory activity (83 mg CO_2 /kg/h) and exhibited 11 days of shelf-life, while untreated control had 6 days economic life. It was closely followed by 1% $CaCl_2$ + ZECC treatment. Fruits stored in ZECC recorded 9 days shelf-life. Highest respiration rate was in control (88.1 mg CO_2 /kg/h) on 13th day of storage. It may be concluded that 1.5% $CaCl_2$ and storage in ZECC treatment was found most efficient to retain the fruit quality attributes till 13th day of storage under semi-arid environment of western India.

Keywords Aonla · Emblica officinalis · Zero energy cool chamber · Calcium chloride · Shelf-life · Spoilage

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Introduction

The *aonla* or Indian gooseberry (*Emblica officinalis* Gaertn.) is highly nutritive and is the richest source of vitamin-C among the fruits except Barbados cherry (*Malpighia glabra* L) (Singh and Pathak 1987). Its cultivation has recently gained significance in Gujarat owing to its adaptability to varied agro-climatic conditions, comparative tolerance to various pests and diseases and high remunerative returns. Though, the fruits of *aonla* are firm and can easily be transported to the distant market, its storage stability needs to be explored particularly under harsh ecosystem of Gujarat. Effect of $CaCl_2$ or K_2SO_4 treatment and storage on quality of ber fruits is reported in Part I of the paper. This paper reports some aspects on quality of aonla fruits.

Materials and methods

Hand picked mature and healthy aonla fruits of uniform size, free from pest and diseases, injuries, bruises and blemishes were selected from the experimental orchard of the laboratory during the year 2006 and 2007 and subjected to post-harvest treatments. The treatments were control (T_1), ZECC (T_2), $CaCl_2$ 1% (T_3), $CaCl_2$ 1.5 %; (T_4), $CaCl_2$ 1% + ZECC (T_5), $CaCl_2$ 1.5% + ZECC (T_6), mustard oil 2% oil emulsion (T_7), mustard oil 2% oil emulsion + ZECC (T_8), K_2SO_4 2% (T_9), and K_2SO_4 2 % + ZECC (T_{10}). The experimental design and fruit quality analysis are as described in the previous paper.

Results and discussion

There was a sharp increase in PLW of fruits stored at room temperature where as the increase in PLW was very slow in fruits stored in ZECC (Table 1). $CaCl_2$ 1.5 %+ ZECC (T_6) was the most effective treatment in retaining the fruit weight in all the days of observations and showed only 16% PLW on day 13 of storage followed by $CaCl_2$ 1.5 %+ ZECC (16.5%) (T_5). The highest PLW (25.1%) was recorded in the control (T_1) on the day 13 of storage. Kumar and Nath (1993), and Dhemre and Wasker (2003) also recorded similar trends during storage of aonla and mango fruits in ZECC. Spoilage of aonla fruits started on the day 5 of storage in all the treatments except $CaCl_2$ 1.5% + ZECC (T_6) where it started on day 7 of storage (Table 1). The minimum spoilage loss was recorded in $CaCl_2$ 1.5 % + ZECC (T6) which was closely followed by $CaCl_2$ 1% + ZECC (T_5) while the maximum was in the control (T_1) on day 13 of storage. The fruits treated with $CaCl_2$ 1 or 1.5% proved to be superior to the fruits treated with mustered oil 2% emulsion (T_7, T_8)and K_2SO_4 2% solution (T_9, T_{10}).

On the basis of spoilage within 12%, the maximum economic shelf-life (11 days) was exhibited by $CaCl_2$ 1.5%+ ZECC (T_6). The untreated control (T_1) recorded 6 days of shelf-life.

The TSS of fruits increased during storage irrespective of post-harvest treatments (Table 2). The TSS was maximum (13.9%) in the control (T_1) and minimum with $CaCl_2$ 1.5 %+ ZECC (T_6) on the last day of storage. Increase in TSS during storage was associated with the transformation of pectic substances, starch, hemi cellulose or other polysaccharides in soluble sugar and also with the dehydration of fruits (Bhullar et al. 1981, Hoda et al. 2000). Singh et al. (1987) reported similar results in grapes when stored in ZECC. Titratable acidity of fruits decreased continuously during storage regardless of post-harvest treatments. The minimum acidity (1.36 %) was in control (T_1) on the last

Table 1 Physiological loss in weight (PLW), spoilage loss and economic shelf-life (ESL) of aonla fruits during 3–13 days (D) of storage

Treatments (T)	P L W, %						Spoilage loss, %					ESL, days
	3	5	7	9	11	13	5	7	9	11	13	
T_1 (Control)	4.3	8.1	12.0	16.1	20.0	25.1	7.5	13.5	14.0	20.0	35.0	6
T_2 ZECC	3.4	6.8	9.2	11.8	13.0	17.5	2.0	5.1	10.1	16.0	21.0	9
T_3 $CaCl_2$ 1%	3.5	6.9	9.4	12.1	14.1	18.9	3.0	6.0	10.8	17.2	21.5	9
T_4 $CaCl_2$ 1.5 %	3.4	6.9	9.2	12.2	14.0	18.8	3.0	5.5	10.7	17.0	21.2	9
T_5 $CaCl_2$ 1% + ZECC	2.3	5.3	8.5	10.2	12.6	16.5	1.2	3.5	8.8	13.2	17.0	9
T_6 $CaCl_2$ 1.5% + ZECC	2.2	5.1	8.0	10.0	12.1	16.0	0.0	3.0	7.5	11.0	16.0	11
T_7 Mustard oil 2% emulsion	3.6	6.9	10.1	12.0	14.8	19.0	3.0	7.5	13.1	18.2	22.1	7
T8 Mustard oil 2% emulsion+ ZECC	3.1	6.8	9.0	11.5	13.1	17.4	2.0	5.0	9.5	15.4	20.0	9
T_9 K_2SO_4 2%	3.5	6.9	10.0	12.2	14.7	19.1	3.0	7.2	13.0	18.0	22.0	7
T_{10} K_2SO_4 2%+ ZECC	3.1	6.8	9.0	11.3	13.2	17.5	2.0	5.0	9.5	15.5	20.2	9
C D (p=0.05)	T= 0.15, D= 0.18, D × T= 0.24						T= 0.08, D= 0.13, D × T= 0.23					

ZECC: Zero energy cool chamber

Table 2 Changes in total soluble solids (TSS) and titratable acidity during 1–13 days (D) storage of aonla fruits

Treatments (T)	T S S, %							Titratable acidity, %						
	1	3	5	7	9	11	13	1	3	5	7	9	11	13
T_1	9.5	10.0	11.1	11.9	12.0	13.1	13.9	1.90	1.80	1.70	1.60	1.50	1.40	1.36
T_2	9.3	9.5	10.5	11.2	11.8	12.2	13.2	1.92	1.85	1.75	1.70	1.58	1.52	1.44
T_3	9.1	9.7	10.7	11.4	11.8	12.4	13.1	1.90	1.84	1.74	1.68	1.54	1.50	1.42
T_4	9.1	9.6	10.6	11.3	11.9	12.3	13.1	1.90	1.84	1.75	1.67	1.54	1.50	1.42
T_5	9.2	9.4	10.1	11.0	11.1	11.9	12.3	1.92	1.89	1.80	1.73	1.68	1.61	1.59
T_6	9.1	9.3	10.0	10.8	11.0	11.8	12.2	1.90	1.90	1.82	1.75	1.70	1.63	1.60
T_7	9.2	9.8	10.9	11.7	11.9	12.5	13.0	1.90	1.84	1.75	1.63	1.52	1.48	1.40
T_8	9.0	9.4	10.4	11.1	11.6	12.1	12.8	1.91	1.86	1.79	1.64	1.59	1.52	1.47
T_9	9.0	9.8	10.8	11.7	11.9	12.5	13.0	1.92	1.84	1.75	1.63	1.52	1.48	1.40
T_{10}	9.2	9.4	10.4	11.1	11.7	12.1	12.8	1.90	1.87	1.79	1.64	1.59	1.52	1.48
CD (p = 0.05)	T= 0.08, D= 0.13, D × T= 0.22							T= 0.01, D= 0.02 D × T= 0.03						

T_1–T_{10}: As in Table 1

Table 3 Changes in total sugar and reducing sugar during 1–13 days (D) storage of aonla fruits

Treatments (T)	Total sugar (%), in days after harvest							Reducing sugar (%), in days after harvest						
	1	3	5	7	9	11	13	1	3	5	7	9	11	13
T_1	6.1	6.9	7.1	7.5	7.9	8.1	8.2	4.2	4.5	4.6	4.8	5.0	5.3	5.4
T_2	6.1	6.5	6.7	7.0	7.4	7.6	7.7	4.1	4.3	4.5	4.7	4.8	5.0	5.2
T_3	6.3	6.5	6.8	7.0	7.5	7.1	7.7	4.1	4.4	4.6	4.8	4.9	5.1	5.3
T_4	6.2	6.5	6.7	7.0	7.5	7.6	7.7	4.0	4.4	4.6	4.8	4.9	5.1	5.3
T_5	6.0	6.3	6.6	6.9	7.1	7.2	7.6	4.0	4.2	4.4	4.6	4.7	4.9	5.1
T_6	6.1	6.2	6.5	6.8	7.0	7.2	7.5	4.1	4.2	4.3	4.5	4.7	4.8	5.0
T_7	6.1	6.6	6.7	7.0	7.5	7.7	7.8	4.1	4.4	4.6	4.8	5.0	5.2	5.4
T_8	6.1	6.4	6.7	6.9	7.3	7.4	7.6	4.1	4.3	4.5	4.7	4.8	5.0	5.2
T_9	6.1	6.6	6.8	7.0	7.6	7.7	7.8	4.0	4.4	4.6	4.8	4.9	5.1	5.3
T_{10}	6.0	6.4	6.7	6.9	7.4	7.5	7.6	4.1	4.3	4.4	4.6	4.8	5.0	5.1
CD (p=0.05)	T=0.14, D=0.53, D × T=0.73							T=0.07, D=0.06, D × T=0.13						

$T_1 - T_{10}$: As in Table 1

Table 4 Changes in ascorbic acid and respiration rate during 1–13 days (D) storage of aonla fruits

Treatments (T)	Ascorbic acid, mg/ 100g							Respiration rate, mg CO_2/kg/h						
	1	3	5	7	9	11	13	1	3	5	7	9	11	13
T_1	590.2	520.7	460.6	415.9	390.5	350.4	340.4	72.1	74.0	75.1	79.1	82.1	85.0	88.1
T_2	592.4	546.8	490.7	460.6	400.3	390.5	370.7	72.1	73.5	74.0	76.1	78.0	82.5	85.8
T_3	590.5	540.6	480.6	438.6	390.4	380.5	360.9	72.0	73.6	74.2	76.5	78.5	83.5	86.1
T_4	590.4	542.4	482.9	458.9	392.7	382.3	362.8	72.0	73.6	74.1	76.2	78.1	83.0	86.0
T_5	593.4	550.5	508.6	478.8	425.8	405.4	390.0	72.1	73.1	73.5	74.5	77.0	81.0	84.0
T_6	594.6	555.4	510.9	480.3	430.7	412.2	390.2	72.0	73.0	73.4	74.1	76.0	80.0	83.0
T_7	590.3	535.1	578.0	450.8	380.4	378.4	335.3	72.1	73.8	74.5	77.0	79.0	83.9	86.2
T_8	590.5	548.4	502.5	470.6	422.3	395.2	380.5	72.0	73.3	73.8	75.2	77.6	82.0	85.5
T_9	590.5	534.6	475.5	448.3	378.3	370.1	332.5	72.0	73.7	74.4	76.8	79.0	83.8	86.3
T_{10}	592.9	547.5	501.3	448.8	423.2	394.3	382.8	72.0	73.2	73.7	75.1	77.5	81.8	85.5
CD (p=0.05)	T=8.30, D=9.13, D × T=15.10							T=0.54, D=0.75, D × T=0.91						

$T_1 - T_{10}$: As in Table 1

day of storage, while the maximum was observed in $CaCl_2$ 1.5%+ ZECC (T_6). The reduction in acidity during storage might be associated with the conversion of organic acids into sugars and their derivatives or their utilization in respiration (Bhullar et al. 1981, Dhemre and Wasker 2003). The treated fruits could maintain a higher level of acidity up to last day of storage. Similar findings have been reported by Singh et al. (1987), Dhemre and Wasker (2003) in grapes and mango, respectively.

Total and reducing sugars increased during storage in all the treatments (Table 3). It was maximum in control (T_1) and minimum in the fruits treated with $CaCl_2$ 1.5%+ ZECC (T_6) on the last day of storage. An increase in sugars during storage was probably due to conversion of starch and polysaccharides in to soluble sugars and dehydration of fruits (Hoda et al. 2000, Dhemre and Wasker 2003).

The ascorbic acid content of fruits decreased during storage in all the treatments (Table 4). Maximum ascorbic acid content was retained by the fruits treated with $CaCl_2$ 1.5% and stored in ZECC (T_6) on the last day of storage, closely followed by $CaCl_2$ 1% + ZECC (T_5), while it was least in control (T_1). This finding is in agreement with Singh et al. (2005, 2007) in aonla and ber. There was continuous increase in respiratory activity till the last day of storage (Table 4). The lowest respiratory activity (83.0 mg CO_2 /kg/h) was noted in $CaCl_2$ 1.5% + ZECC (T_6) followed by $CaCl_2$ 1% + ZECC (T_5), while it was highest in control (T_1) (88.1 mg CO_2 /kg/h) on the last day of storage.

Conclusion

The study clearly indicated that ZECC developed by Roy and Khurdiya (1983) at IARI, New Delhi for the on farm storage of fruits significantly contributed towards the retention of post-harvest quality attributes. On the basis of fruit quality attributes, it may be concluded that the fruits treated with $CaCl_2$ 1.5% and stored in ZECC (T_6) could be stored up to 11 days under semi-arid ecosystem of Gujarat.

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