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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 1. Ber 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 ber (*Zizyphus mauritiana* Lamk.) cv 'Gola' during storage under semi-arid ecosystem of Gujarat was studied. Increase in physiological loss in weight (PLW), spoilage loss, total soluble solids, total sugars, reducing sugar and reduction in titratable acidity, and ascorbic acid during storage were observed in all treatments. Fruits treated with $CaCl_2$ 1.5% and stored in ZECC recorded least PLW (17.1%), spoilage loss (20%), respiratory activity (0.25 mg CO_2/kg/h) and exhibited 7 days of shelf-life, followed by $CaCl_2$ 1% + ZECC, while untreated fruits had 3 days of economic shelf-life. Fruits stored in ZECC recorded 6 days shelf-life. Highest respiration rate was in control (0.45 mg CO_2/kg/h) on 9th day of storage. Data on fruit quality attributes indicated that ZECC + $CaCl_2$ 1.5% or ZECC alone might be an ideal on-farm storage facility for maintaining the quality of ber fruits under semi-arid environment of Western India.

Keywords Ber · *Zizyphus mauritiana* · Zero energy cool chamber · Calcium chloride · Shelf-life · Spoilage

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Introduction

'Gola' is a leading early cultivar of ber (*Zizyphus mauritiana* Lamk.) but it suffers from short shelf-life at room temperature (12–28°C) (Singh et al. 2007a). To regulate the marketing and to get higher remuneration, it is necessary to prolong shelf-life of ber fruits. Calcium regulates respiration and other metabolic processes in the mature fruits and may preserve the cellular organization not only by preserving the cell membranes but also by maintaining the nucleic acid and protein synthesis (Faust and Shear 1972, Gupta et al. 1987, Jayachandran et al. 2005). Calcium treatment increased chlorophyll content in ber by maintaining chloroplast membrane integrity and retarding the activities of chlorophyllase and chlorophyll oxidase (Yadav et al. 2003). The storage of fruits in zero energy cool chamber (ZECC) enhanced their shelf-life by restricting the transpiration and respiration (Kumar and Nath 1993, Dhemre and Wasker 2003). The ZECC designed by Roy and Khurdiya (1983) enhanced shelf-life of fruits by lowering the temperature and maintaining high humidity inside the chamber. The fruits treated with mustard oil 2% emulsion and K_2SO_4 2% solution also showed an increase in the shelf-life of fruits (Singh et al. 2007b). On farm storage plays a vital role in maintaining quality soon after harvest. Therefore, an experiment was conducted to evaluate the efficacy of ZECC along with some post-harvest treatments on storability and fruit quality attributes of ber cv. 'Gola' under the ecosystem of Gujarat.

Materials and methods

Hand picked mature and healthy ber fruits of uniform size, free from pest and diseases, injuries, bruises and blemishes were selected from the experimental orchard of the laboratory during 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% emulsion (T_7), mustard oil 2% emulsion + ZECC (T_8), K_2SO_4 2% (T_9) and K_2SO_4 2% + ZECC (T_{10}). The experiment was laid out in factorial completely randomized design with 3 replications as described by Panse and Sukhatme (1985). The fruits were separated into lots of 2.5 kg for each treatment and were treated by dipping in different solutions for 5 min. ZECC was constructed following the design proposed by Roy and Khurdiya (1983). Control fruits were stored at ambient condition (12–28°C, 65±3% RH). The temperature of ZECC ranged between 9 and 22^{0}C with 90±3% RH. The PLW was determined by periodical weighing of fruits and differential weight loss was expressed in%. The physical conditions of fruits were observed visually for recording the spoilage loss and expressed in%. Total soluble solids (TSS), titratable acidity, total sugars, reducing sugars and ascorbic acid contents were determined by AOAC (1990) methods. The economic life (days) of fruits was determined by counting the number of days, after which cumulative spoilage percentage of fruits in particular treatment exceeded 12%, from the date of harvest of fruits. The respiration rate was measured as suggested by Loomis and Shull (1973).

Results and discussion

The PLW increased with storage time in all the treatments (Table 1). $CaCl_2$ 1.5% + ZECC was the most effective treatment in retaining the fruit weight in all the days of observations and showed only 17.1% PLW on day 9 of storage followed by $CaCl_2$ 1% + ZECC (T_5). Fruits stored in ZECC (T_2) proved to be superior to mustard oil 2% emulsion (T_7) and K_2SO_4 2% solution (T_4). The highest PLW (27.3%) was recorded in control (T_1) on 9th day. The increased weight loss in untreated fruits might be due to increased storage break down associated with higher transpiration and respiration rate compared to treated fruits. The low PLW in ZECC was due to high RH and low temperature. Kumar and Nath (1993), and Dhemre and Wasker (2003) also recorded similar trends during storage of aonla and mango fruits in ZECC. Spoilage of ber fruits started on 3rd day of storage in all the treatments (Table 1). The minimum spoilage loss was in $CaCl_2$ 1.5% + ZECC (T_6) followed by $CaCl_2$ 1% + ZECC, while it was maximum (60%) in control (T_1) on day 9 of storage. Singh et al. (2005) opined that calcium controlled the disintegration of mitochondria, endoplasmic reticulum and cytoplasmic membranes and thus helped in restraining respiration rate and ultimately reduced the spoilage loss. This is in agreement with the findings of Hiwale and Singh (2003) and Singh et al. (2007a) in guava and ber, respectively.

On the basis of spoilage within 12%, the maximum economic shelf-life of 7 days was exhibited by $CaCl_2$ 1.5% + ZECC (T6) followed by $CaCl_2$ 1% + ZECC (T5) and ZECC (T2) alone, however the untreated control (T_1) recorded 3 days only.

The TSS content increased linearly up to 7th day of storage and declined thereafter (Table 2). Increment in TSS was minimum in fruits treated with $CaCl_2$ 1.5% ZECC (T_6) followed by $CaCl_2$ 1%, ZECC (T_5), while it was highest in control (T_1). Increase in TSS during storage might be associated with the transformation of pectic substances, starch, hemicellulose or other polysaccharides in soluble sugar and also with the dehydration of fruits (Singh et al. 2003, 2004, 2005). The slow increase in TSS during storage in treated fruits was due to slow weight loss that caused less dehydration of fruits (Singh et al. 2007b). Titratable acidity of fruits decreased continuously with the progress in storage period regardless of post-harvest treatments (Table 2). Minimum acidity was in control (T_1) on the last day of storage, while maximum was in $CaCl_2$ 1.5% + ZECC (T_6) followed by $CaCl_2$ 1% + ZECC (T_5). The reduction in acidity during

Table 1 Physiological loss in weight (PLW), spoilage loss and economic shelf-life (ESL) of ber fruits during 3–9 days (D) of storage, peroid

DAH Treatments (T)	PLW, %				Spoilage loss, %				ESL, days
	3	5	7	9	3	5	7	9	
T_1 (Control)	7.0	15.0	23.2	27.3	11.0	20.0	30.0	60.0	3
T_2 ZECC	4.3	8.5	15.9	18.5	7.0	10.0	14.0	36.9	6
T_3 $CaCl_2$ 1%	5.3	9.0	17.0	20.0	8.0	11.2	17.9	42.5	5
T_4 $CaCl_2$ 1.5%	5.0	8.9	16.9	19.5	8.0	11.0	17.0	40.0	5
T_5 $CaCl_2$ 1% + ZECC	3.2	7.4	14.5	17.5	5.0	9.0	13.0	24.2	6
T_6 $CaCl_2$ 1.5% + ZECC	3.0	7.2	14.0	17.1	4.5	8.0	11.9	20.0	7
T_7 Mustard oil 2% emulsion	5.4	10.8	18.2	21.9	8.9	11.5	18.9	45.0	5
T_8 Mustard oil 2% emulsion+ ZECC	4.1	8.3	15.4	18.3	6.3	9.5	13.5	32.5	6
T_9 K_2SO_4 2%	5.2	10.7	18.0	21.0	8.5	11.4	18.5	44.1	5
T_{10} K_2SO_4 2%+ ZECC	4.0	8.2	15.3	18.0	6.0	9.0	13.4	32.0	6
C D (p= 0.05)	T= 0.11, D= 0.15, D x T= 0.2				T= 0.19, D= 0.2, D x T= 0.23				

ZECC: Zero energy cool chamber, ESL: Economic shelf-life of fruits storage might be associated with the conversion of organic acids into sugars and their derivatives or their utilization in respiration (Singh et al. 2003, 2005, Dhemre and Wasker 2003). Treated fruits could maintain a higher level of acidity up to last day of storage. It might be due to reduced respiration rate in the later stage of storage as influenced by ZECC and calcium treatments. Similar findings have been reported by Singh et al. (1987), Dhemre and Wasker (2003) and Singh et al. (2005) in grapes, mango and aonla, respectively.

Total and reducing sugars increased up to 7th day of storage and declined thereafter (Table 3). The increment in sugars during storage was least in fruits treated with $CaCl_2$ 1.5% + ZECC (T_6) followed by $CaCl_2$ 1% + ZECC (T_5) while it was maximum in control (T_1). Less increment in sugars during storage in the treated fruits was due to less weight loss that caused less dehydration of fruits (Khader et al. 1988, Kumar and Nath 1993, Dhemre and Wasker 2003). The changes in sugar content during storage are very much related with TSS. An increase in sugars during storage was probably due to conversion of starch and polysaccharides into soluble sugars and dehydration of fruits (Hoda et al. 2000, Dhemre and Wasker 2003).

Ascorbic acid content of fruits decreased progressively during storage in all treatments (Table 4). Maximum ascorbic acid content was retained by fruits treated with $CaCl_2$ 1.5% + ZECC (T_6), followed by $CaCl_2$ 1% + ZECC on last day of storage, while it was found least in control (T_1). Variation in decreasing trend of ascorbic acid might be due to different levels of oxidation in different treatments. During storage, ascorbic acid oxidase, peroxidase, catalase and polyphenol oxidase might be causing decrease in ascorbic acid content of fruits (Mapson 1970). Activities of oxidizing enzymes might have been reduced in treated fruits that resulted in higher level of ascorbic acid content up to the last day of storage. This finding is in agreement with those

Table 2 Changes in total soluble solids (TSS) and titratable acidity during 1–9 days (D) of storage of ber fruits

	TSS, %					Titratable acidity, %				
	1	3	5	7	9	1	3	5	7	9
T_1	19.2	20.8	21.0	21.6	21.3	0.37	0.29	0.24	0.2	0.17
T_2	19.1	20.0	20.4	21.2	21.0	0.35	0.32	0.27	0.23	0.2
T_3	19.1	20.1	20.5	21.3	21.1	0.38	0.31	0.27	0.23	0.2
T_4	19.2	20.1	20.5	21.2	21.1	0.35	0.31	0.27	0.23	0.2
T_5	19.2	19.6	20.1	20.9	20.6	0.34	0.32	0.29	0.25	0.22
T_6	19.1	19.5	20.0	20.8	20.5	0.46	0.34	0.3	0.27	0.23
T_7	19.1	20.2	20.6	21.3	21.2	0.36	0.32	0.25	0.21	0.18
T_8	19.1	19.9	20.3	21.1	20.8	0.34	0.3	0.26	0.22	0.21
T_9	19.2	20.2	20.6	21.3	21.2	0.34	0.31	0.25	0.21	0.18
T_{10}	19.2	19.8	20.3	21.0	20.7	0.35	0.3	0.26	0.22	0.21
CD (p=0.05)	T= 0.06, D= 0.1, D x T= 0.18					T= 0.02, D= 0.01, D x T= 0.03				

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

Table 3 Changes in total sugars and reducing sugar during 1–9 days (D) of storage of ber fruits

	Total sugars, %					Reducing sugar, %				
	1	3	5	7	9	1	3	5	7	9
T_1	13.1	14.0	14.5	14.9	14.7	5.0	5.1	5.4	5.5	5.3
T_2	13.0	13.8	14.1	14.3	14.1	4.9	5.0	5.2	5.4	5.2
T_3	13.0	13.9	14.2	14.5	14.3	4.9	5.0	5.3	5.4	5.2
T_4	13.0	13.9	14.1	14.4	14.2	4.9	5.0	5.2	5.4	5.2
T_5	13.1	13.7	13.8	14.2	14.1	4.9	4.9	5.1	5.2	5.2
T_6	13.0	13.6	13.8	14.1	14.0	4.9	4.9	5.1	5.2	5.1
T_7	13.0	13.9	14.3	14.7	14.6	4.9	5.1	5.3	5.4	5.3
T_8	13.0	13.8	14.1	14.2	14.0	4.9	5.0	5.2	5.4	5.2
T_9	13.1	14.0	14.2	14.6	14.5	4.9	5.0	5.3	5.4	5.3
T_{10}	13.0	13.8	14.1	14.2	14.0	4.9	5.0	5.2	5.3	5.2
C D (p 0.05)	T= 0.2, D= 0.1, D x T=0.27					T= 0.05, D= 0.06, D x T=0.09				

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

Table 4 Changes in ascorbic acid and respiration rate during 1–9 days (D) of storage of ber fruits.

Treatments	Ascorbic acid, mg/ 100 g					Respiration rate, mg CO_2/kg/h				
	1	3	5	7	9	1	3	5	7	9
T_1	96.3	85.1	67.1	60.1	50.0	0.18	0.25	0.74	0.65	0.45
T_2	96.0	89.1	77.0	70.1	66.0	0.17	0.23	0.40	0.55	0.35
T_3	95.1	89.0	74.0	67.0	64.0	0.17	0.23	0.46	0.58	0.38
T_4	94.1	89.1	75.1	68.0	65.2	0.17	0.23	0.45	0.56	0.36
T_5	97.0	91.0	85.0	81.0	74.5	0.16	0.19	0.26	0.45	0.26
T_6	98.0	92.0	86.1	82.5	75.0	0.16	0.18	0.24	0.40	0.25
T_7	95.0	90.0	71.0	65.0	60.0	0.17	0.23	0.48	0.60	0.42
T_8	96.0	89.2	80.0	72.1	66.9	0.17	0.20	0.35	0.53	0.32
T_9	96.1	89.0	72.0	65.0	62.0	0.17	0.23	0.47	0.60	0.40
T_{10}	96.0	89.2	81.2	72.3	67.9	0.17	0.20	0.30	0.50	0.30
C D (p 0.05)	T=1.5, D= 1.6, D x T= 1.7					T= 0.02, D= 0.08, D x T=0.07				

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

of, Singh et al. (2005), in goose berry and Singh et al. (2007b) in ber.

There was a continuous increase in respiratory activity up to 7th day of storage and declined thereafter (Table 4). The lowest respiratory activity (0.25 mg CO_2/kg/h) was in $CaCl_2$ 1.5% + ZECC (T_6) followed by $CaCl_2$ 1% + ZECC (T_5), while it was highest in control (0.45 mg CO_2/kg/h) (T_1) on the last day of storage. These results are in consonance with the findings of Singh et al. (2007a, b) in ber.

Conclusion

The ZECC developed by Roy and Khurdia (1983) at IARI, Pusa, New Delhi for the on-farm storage of fruits significantly contributed towards the retention of post-harvest quality attributes. ZECC + $CaCl_2$ 1.5% (T_6) gave 7 days of shelf-life and it may serve as an ideal on-farm storage facility for maintaining the quality of ber fruits under semi-arid environment of Western India.

References

AOAC (1990) Official methods of analysis. 15th edn, Association of Official Analytical Chemists, Washington DC

Dhemre JK, Wasker DP (2003) Effect of post-harvest treatments on shelf-life and qualily of mango in evaporative cool chamber and ambient conditions. J Food Sci Technol 40:316–318

Faust M, Shear CB (1972) The effect of calcium on respiration of apples. J Am Soc Hort Sci 97:437–439

Gupta OP, Siddiqui S, Chauhan KS (1987) Evaluation of various calcium compounds for increasing the shelf life of ber. Indian J Agric Res 21:65–70

Hiwale SS, Singh SP (2003) Prolonging shelf life of guava (*Psidium guajava* L.). Indian J Hort 60: 1–9

Hoda MN, Yadav GS, Singh S, Singh J (2000) Storage behaviour of mango hybrids. Indian J Agric Sci 71:469–472

Jayachandran KS, Srihari D, Narayana Reddy Y (2005) Pre-harvest sprays of different sources of calcium to improve the shelf-life of guava. Indian J Hort 62:68–70

Khader SESA, Singh BP, Khan SA (1988) Effect of GA_3 as a post harvest treatment of mango fruit on ripening, amylase and peroxidase activity and quality during storage. Sci Hort 63: 261–266

Kumar S, Nath V (1993) Storage stability of aonla fruits- A comparative study of zero energy cool chamber *versus* room temperature. J Food Sci Technol 30:202–203

Loomis WI, Shull CA (1973) A gas street method for measuring respiration. In: Methods in plant physiology, 1st edn, McGraw-Hill Book Co, New York, p 101–103

Mapson CW (1970) Vitamins in fruits: Stability of L – ascorbic acid. In: Biochemistry of fruits and their products, Academic Press, London, P 376–387

Panse VG, Sukhatme VG (1985) Statistical Methods for Agricultural Workers, 2nd edn, ICAR, New Delhi

Roy SK, Khurdiya D (1983) Zero energy cool chamber for storage of horticultural produce. Science in Service of Agriculture. Indian Agricultural Research Institute, New Delhi

Singh JP, Singhrot RS, Sharma RK, Sadooja JK (1987) A note on comparison of zero energy cool chamber versus room temperature in combinatrion with antifungal fumigants for storage of grapes. Haryana J Hort Sci 16:92–97

Singh S, Singh AK, Joshi HK (2003) Storage behaviour of Indian gooseberry (*Emblica officinalis* Gaertn.) under semi arid ecosystem of Gujarat. Indian J Agric Sci 73:530–534

Singh S, Singh J, Hoda MN (2004) Studies on storage behaviour of promising mango hybrids. Indian J Hort 61:284–286

Singh S, Singh AK, Joshi HK (2005) Prolonging storability of Indian gooseberry under semi arid ecosystem of Gujarat. Indian J Agric Sci 75:647–650

Singh S, Singh AK, Joshi HK (2007a) Storage behaviour of ber cultivars under semi arid environment. Indian J Arid Hort 2: 32–35

Singh S, Singh AK, Joshi HK, Bagle BG, More TA (2007b) Prolonging shelf life of ber under semi arid environment. Indian J Arid Hort 2:40–44

Yadav IJ, Sharma RK, Siddiqui S, Godara RK (2003) Effect of preharvest sprays of calcium on fruit physical characteristics, quality and peel pigmentation of Ber (*Zizyphus mauritiana* Lamk.) cv. Umran. Haryana J Hort Sci 32:75–76