J Food Sci Technol (July–August 2010) 47(4):437–441
DOI: 10.1007/s13197-010-0072-7

ORIGINAL ARTICLE

Water use optimization in zero energy cool chambers for short term storage of fruits and vegetables in coastal area

Kalpana Rayaguru · **Md K. Khan** · **Sahoo N. R.**

Revised: 10 December 2009 / Accepted: 16 December 2009

Abstract Suitability of zero energy cool chamber (ZECC) for short term storage of fruits and vegetables was studied in coastal districts of Orissa. Quantity of water applied in ZECC was standardized. The optimum water level of 75 l/day and 90 l/day was required to achieve a steady and conducive storage environment for storage of fruits and vegetables in summer and winter months, respectively. The chamber was kept average temperature of its environment less by 5–8°C than the outside temperature and maintained more than 90% RH. The ZECC was very effective in extending the storage life of potato, tomato, brinjal, mango, banana and spinach by 3 to 15 days as compared to ambient conditions.

Keywords Evaporative cooled storage chamber · Fruits · Vegetables · Shelf-life

Introduction

A considerable amount of perishable horticultural produce is wasted every year in India due to lack of appropriate storage facilities (Rai 2002, Thakur et al. 2002). In a tropical country like India, maintenance of low temperature is a great problem. Mechanical cooling is energy intensive, expensive and not easy to install and run in rural areas. The zero energy cool chambers (ZECC), utilizing the principle of evaporative cooling is reported to maintain relatively low temperature and high humidity compared to ambient conditions which is required for short term storage of fruits and vegetables (Roy and Khurdiya 1986). Evaporative cooled storage structures are designed to reduce air temperature in cooling applications through the process of evaporation of water (Dash and Chandra 2001, Jha and Kudos 2006). In these structures warm air passing through the moist sand picks up water in the form of water vapour which increases the humidity in the air. Latent heat is absorbed by the increased humidity and in turn reduces the sensible heat in the air (Jha and Chopra 2006).

Orissa ranks second in the country in the production of vegetables and a good amount of fruits are also produced in tribal areas of the State. The wide variation in the coastal environmental conditions poses huge difficulty in storing fresh fruits and vegetables. The farmers are usually small and marginal land holders of villages and have poor resource availability. In the absence of proper storage technique the farmers usually sell their vegetables in the local markets soon after the harvest. This situation very often compels for a distress sale of the products at very low price.

Zero energy cool chamber (ZECC) developed at Indian Agricultural Research Institute, New Delhi and evaporative cool chamber of larger capacity developed at Central Institute of Post-harvest Engineering and Technology, Ludhiana, India, can help in storing fresh fruits and vegetables for a reasonable period of time (Pal and Roy 1988, Prava et al. 2006, Jha 2008). Application of water in the chamber

---

Rayaguru K. · Md K. Khan · Sahoo N. R.
All India Co-ordinated Research Project on Post-harvest Technology,
College of Agril Engineering and Technology,
Orissa University of Agriculture and Technology,
Bhubaneswar - 751 003, India

Rayaguru K. (✉)
E-mail: rayagurukalpana@yahoo.com

plays a vital role in regulating temperature and RH. Too dry cool chamber will not provide the desired cooling effect and too moist chamber causes unnecessary wastage of water and may sometimes lead to fungus growth (Ganeshan et al. 2004). Therefore, it is necessary to find out the optimum quantity of water needed under different situations of seasonal variations to achieve effective performance of the chamber. Hence, the present work was an attempt to study the feasibility of use of cool chamber in the coastal area of Orissa throughout the year. Experiments were carried out to determine the optimum quantity of water required to be used to obtain the desired storage environment.

Materials and methods

A ZECC was constructed in Bhubaneswar, a coastal district of Orissa. The design was based on the evaporative cooling of a porous body (Pal and Roy 1988). The structure consisted of a rectangular, double walled chamber carrying heat insulating detachable roof. Each of 4 composite sides consisted of 2 inter spaced walls and this jacketed type room has the advantage of preventing heat leakage into the storage cabin. The thickness of the walls is 125 mm. The dimensions of the outer wall are 1650 mm × 1150 mm × 675 mm. The inter space (75 mm thick) is completely filled with river sand till the top of the cabinet. A drip pipe system was laid on the sand bed in the inter space for uniform wetting of the sand. This pipeline is connected to a bucket filled with water which is placed at an elevation higher than the top level of the chamber. Water is applied continuously and slowly in drops to this sand bed so that it remained wet throughout the day. This process kept the entire structure wet preventing evaporation of internal moisture from the stored fresh fruits and vegetables. The floor is plastered to a smooth finish. The top cover is prepared using gunny cloth and straw with a bamboo frame.

After saturating the bed initially, the subsequent water requirement per day was determined under no load conditions. For this, 5 levels of water 45, 60, 75, 90 and 105 l/day were applied and the corresponding changes in RH and temperature profiles were studied. For this, a bucket of 15 l capacity used for dripping purpose, which was filled 3,4,5,6 and 7 times a day, respectively. The process was carefully monitored and the bucket was supplied with water by a PVC water pipe connected to the tap of overhead water tank. The experiment was continued for 7 days and the average values of RH and temperature were noted. The variation in RH and temperature profile with different levels of water application was observed during both summer (April–May 2007) and winter months (November–December 2007) under no load conditions. From these data, percent increase in RH and percent decrease in temperature were determined. This helped to determine the optimum quantity of water required to achieve the desired RH and temperature.

Thereafter the storage experiment was carried out. Initially, the temperature and RH profile of the ZECC were measured using the optimum level of water. For this, the maximum and minimum values of these parameters were noted daily throughout the year (January–December 2008). From the data collected, weekly average values were determined. These observations were compared to those of ambient conditions. Temperature and RH at the centre of the ZECC and outside were recorded using a digital thermo-hygrometer (UKAS, model XHJT 302, least count 0.01°C and 1% RH) at 1 h intervals and curves showing change in temperature and RH for weekly and monthly average values were prepared.

Potato, tomato, brinjal, mango, banana and leafy vegetables (spinach) were stored in the chamber separately during summer and winter months. Matured fruits and vegetables were collected from near by farmers'field. Harvesting was carried out manually. Plastic containers were used for transporting the produce to the experiment site immediately after harvest. After sorting for uniform size and undamaged ones, the fruits and vegetables were washed with tap water to remove field heat and soil particles. To reduce microbial populations on the surface, the produces (except leafy vegetables) were disinfected with chlorinated water. A 20 min dipping time in 100 µg/ml chlorine supplemented water solutions was selected, as this was reported to be the optimum effective concentration and dipping time without significant effect on the overall quality of fruits and vegetables (Tefera et al. 2007). After disinfection, the samples were surface dried and divided into 2 sub-samples for storage in ZECC and at ambient temperature. Performance of the chamber was evaluated in terms of shelf-life in number of days with marketability ≥80% (Mohammed et al. 1999, Tefera et al. 2007) and physiological loss in weight (PLW) of the product during different seasons of the year. The fruits and vegetables were stored in plastic crates inside the chamber and their shelf-life was determined on the basis of an index of 20% spoilage or unmarketability. Marketability quality of fruits and vegetables was subjectively assessed by observing the level of visible mould growth, rotting, shriveling or discolouring. The PLW in percent was calculated by considering the differences in weight with respect to initial weight.

Results and discussion

The temperature inside the chamber reduced with the increase in water level and there was also an increase in RH, while the values fluctuated and did not follow any definite pattern under ambient conditions (Fig. 1). At a water rate of 45 l/day, the RH values in cool chamber were 72 and 64% in summer and winter, respectively. The values increased up to 95 and 94%, respectively as the water application rate reached up to 105 l/day. On the contrary the temperature in the cool chamber reduced with the increase in quantity of water applied. The average temperature values reduced from an ambient condition of 34 to 27^{0}C in summer and 21 to 17^{0}C in winter. The values are very close to the data reported by Ganeshan et al. (2004).

During summer % increase in RH was highest at a water rate of 75 l/day and it reduced to 6.8 (at 90 l/day) and 1.0 (at 105 l/day) (Fig. 2). Percent reduction in temperature remained almost same when water application was increased from 75 to 90 l /day in summer (Fig. 2). Percent decrease in temperature in winter was 6.9% (90 l/day) and then reduced to 2.8% (at 105 l/day). This indicates that the annular space gets saturated at certain levels of water application depending on different climatic conditions. This gives rise to the maximum evaporation of water and thereby establishing the desired level of storage. Higher application of water beyond this level is unnecessary. Therefore, under the experimental coastal conditions of Orissa, water application rate of 75, 90 l/day is the cut-off points during summer and winter, respectively to achieve the effective performance of the cool chamber. Anyanwu (2004) indicated that the cooler storage chamber temperature depression from ambient air temperature varied from 0.1 to 12°C. Getinet et al. (2008) studied under ambient and in a multi-layer pads evaporative cooler in semi-arid Eastern part of Ethiopia. The differences in RH and dry bulb temperature between ambient and inside the cooler were 54.8% and 15.1°C, respectively. The evaporative cooler reduced dry bulb temperature by 5°C and raised the RH by 18% compared to single pad evaporative cooler. Taha et al. (1994) have shown that by using a porous material as a special type of evaporative cooler the ambient temperature could be reduced by 10–13°C.

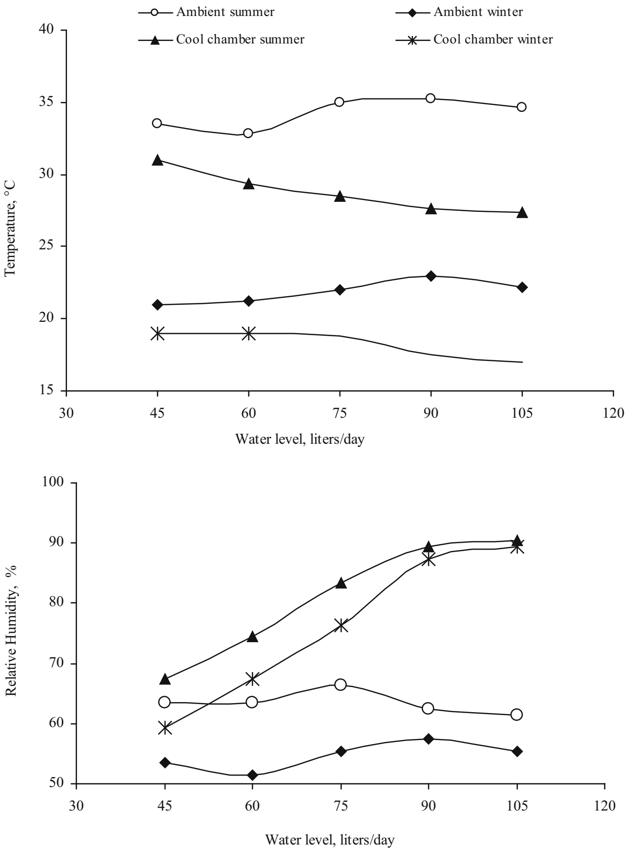

Fig. 1 Effect of water level on temperature and relative humidity in cool chamber

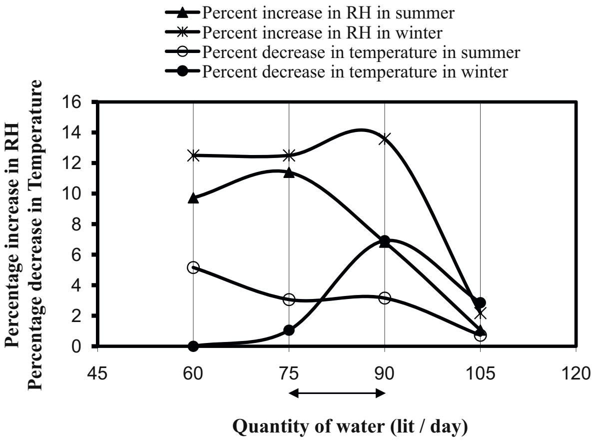

Fig. 2 Selection of optimum quantity of water application

Figure 3 gives year round comparative environmental condition of the cool chamber as also the ambient conditions. The temperature and RH profile indicated that higher the RH of the ambient condition less was the cooling effect in cool chamber. The drop in temperature was dependent more on outside RH, and fluctuations in temperature and RH inside were much less than outside. Under this circumstance, 26th week onwards an increase of only 10 to 15% RH could be observed and corresponding temperature reduction was also less. But this period belonged to rainy season in Orissa. Thus this period may not be very much ideal for fruits and vegetables storage. But during other periods an average temperature fall of 5 to 8°C and up to 30% rise in RH could be observed. The fluctuation in ambient temperature and RH during a day could be reduced to a great extent inside the chamber and more or less a steady environment could be maintained inside the cool chamber round the clock (Fig. 3).

The shelf-life of all the products stored in cool chamber was extended from 3 to 15 days depending on the type of

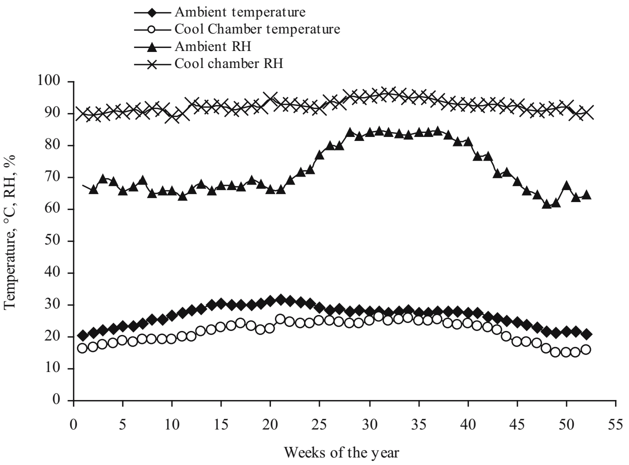

Fig. 3 Weekly average temperature and relative humidity (RH) (ambient and cool chamber)

Table 1 Shelf-life enhancement of fruits and vegetables in cool chamber

	Summer				Winter			
	PLW, %		Shelf-life, days		PLW, %		Shelf-life, days	
Product	Cool chamber	Ambient	Cool chamber	Ambient	Cool chamber	Ambient	Cool chamber	Ambient
Potato	8.5	12.6	21	8	6.6	9.6	32	17
Tomato	4.8	8.4	8	3	3.3	7.5	18	7
Brinjal	2.6	4.2	4	2	1.8	3.5	7	4
Mango	6.5	15.2	8	4	*	*	*	*
Banana	4.5	7.6	5	2	*	*	8	5
Leafy vegetables	*	*	*	*	9.2	22.8	5	2

*experiments not carried out

product and seasons of the year (Table 1). However, tomato and potato showed noticeable difference in shelf-life as compared to ambient conditions. Moreover, all the products stored in cool chamber were fresh and firm. The PLW values shown were at their respective shelf-life conditions. It was observed that the products stored under ambient conditions were having less shelf-life with higher PLW. The trend got reversed for the products stored in cool chamber and the PLW was within 10% in each case which may be considered as safe and acceptable. Table 1 reveals that the shelf-life of potato, tomato and brinjal in cool chamber was 32, 18, 7 (winter) and 21, 8, 4 (summer) days where as that under ambient condition was 17, 7, 4 (winter) and 8, 3, 2 (summer) days, respectively. Similar findings have been reported by Mordi and Olorunda (2003) and Prava et al. (2006). PLW was highest for leafy vegetables followed by mango stored under ambient conditions after 2 and 4 days of storage, respectively. A remarkable saving in PLW was observed for the same products stored in cool chamber with a shelf-life extension up to 5 and 8 days, respectively. Anyanwu (2004) illustrated superior performance of cooler over open air preservation of vegetables soon after harvest during the diurnal operations. Getinet et al. (2008) showed that the shelf-life of tomatoes kept in cool chamber was substantially increased. Thiagu et al. (1991) compared evaporative cooled stored tomatoes with control fruits stored under room conditions. The rate of moisture loss for control fruits was 6.5 times higher than for evaporative cooled stored fruits. Thus except 4 months of rainy season (June to September), the ZECC may be considered to be suitable for short term storage of fruits and vegetables in the coastal districts of Orissa. The structure may be recommended for use in Western and central Orissa more effectively where the climate is relatively dry.

Conclusion

The cool chamber is a low cost structure, which can be easily constructed at the farmers' level. The optimum water level of 75 and 90 l/day is required to achieve a steady and conducive storage environment for storage of fruits and vegetables in summer and winter months, respectively. The shelf-life of fresh product can be extended by 3 to 15 days so that the distress sale of the product may be avoided. The chamber does not need any mechanical or electrical energy for operation.

Acknowledgements Authors are grateful to Indian Council of Agricultural Research, New Delhi for providing financial assistance to undertake this work.

References

Rai DR (2002) MAP and its effect on quality and shelf life of fruits and vegetables. J Food Sci Technol 39:619–623

Thakur KS, Lalkaushal BB, Sharma RM (2002) Effect of different post harvest treatments and storage conditions on the fruit quality of kinnow. J Food Sci Technol 39: 609–618

Roy SK, Khurdiya DS (1986) Studies on evaporatively cooled zero energy input chamber for storage of horticultural produce. Indian Food Packer 40:26–31

Dash SK, Chandra P (2001) Evaporative cooling systems for Storage of Fruits and vegetables. Indian Food packer 55: 79–87

Jha SN, Kudos SKA (2006) Determination of physical properties of pads for maximizing cooling in evaporative cool store. J Agril Eng 43:92–97

Jha SN, Chopra S (2006) Selection of bricks and cooling pad for Constructions of evaporative cooled storage structure. J Inst Eng (I) (AG), 87:25–28

Pal RK, Roy SK (1988) Zero energy cool chamber for maintaining post harvest quality of carrot. Indian J Agric Sci 58: 665–667

Prava A, Sharma HR, Goel AK, Verma R (2006) Changes in ascorbic acid content of lemon fruits stored in zero energy cool chamber & under ambient atmosphere. J Dairying Foods Home Sci 25:73–75

Jha SN (2008) Development of a pilot scale evaporative cooled storage structure for fruits and vegetables in hot and dry region. J Food Sci Technol 45:148–151

Ganeshan M, Balsubramanian K and Bhavani RV (2004) Studies on the application of different levels of water on zero energy cool chamber with reference to the shelf life of Brinjal. J Ind Insti Sci May June 84:107–111

Tefera A, Seyoum T, Woldetsadik K (2007) Effect of disinfection, packaging and storage environment on the shelf life of mango. Biosystems Engg 96:201–212

Mohammed M, Wilson LA, Gomes PL (1999) Post-harvest sensory and physiochemical attributes of processing and non processing tomato cultivar. J Food Quality 22:167–182

Anyanwu EE (2004) Design and measured performance of a porous evaporative cooler for preservation of fruits and vegetables. Energy Conversion Management 45:2187–2195

Getinet H, Seyoum T, Woldetsadik K (2008) The effect of cultivar, maturity stage and storage environment on quality of tomatoes. J Food Eng 87:467–478

Taha AZ, Rahim AAA, Eltom OMM (1994) Evaporative cooler using a porous material to be used for preservation of food. Renewable Energy 5:474–476

Mordi JI, Olorunda AO (2003) Effect of evaporative cooler environment on the visual qualities and storage life of fresh tomatoes. J Food Sci Technol 40:587–591

Thiagu R, Chand N, Habibunnisa EA, Prasad BA, Ramana KVR (1991) Effect of evaporative cooling storage on ripening and quality of tomato. J Food Quality 14:127–144