e-planet **18** (2): 128-135 (December 2020)

Storage performance of horticultural crops in zero energy cool chamber: A case study in Mizoram, India

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Date of receipt: 02.11.2020 Date of acceptance: 09.12.2020

ABSTRACT

Post-harvest loss is one of the major problems faced by the farmers which are further amplified in the hilly region owing to the lack of suitable on-farm storage facilities and remote locations. Zero energy cool chamber (ZECC) is one such technique which increases the shelf life of crops by lowering the temperature and increasing the relative humidity (RH). A comparative study was conducted for the storage of broccoli, tomato, passion fruit and banana inside the ZECC and under ambient condition during different harvesting months *viz.* January, March, April and August to evaluate their shelf life under the influence of changes in temperature, RH and physiological loss in weight (PLW) over the storage period. The shelf life of these crops was increased from nearly 7 days to 12, 11, 12 and 20 days respectively. An average reduction in temperature (°C) from 16.85-11.98, 16.47-12.05, 20.94 -16.49 and 25.67-20.67, respectively with increase in RH (%) from 81.92-94.17, 63.36-77.27, 53.75-67.67 and 80.67-93.67 was recorded inside the ZECC and ambient condition respectively. The highest PLW inside ZECC was observed in passion fruit (5.15 %) and lowest in banana while broccoli recorded highest PLW (16.19 %) under ambient condition which is lowered to only 4.51 per cent inside ZECC.

Key words: Fruit crops, physiological loss, relative humidity, shelf-life, temperature

INTRODUCTION

Post harvest loss in horticultural crops is one of the potent constraints that the tribal farmers of Aizawl District of Mizoram in India is facing during this inopportune COVID 19 pandemics. Agricultural lands are located at undulated tough hilly terrain having steep slopes composing of highly porous soil which are prone to soil erosion and frequent landslides. The problem is further amplified by poor road connectivity in the region particularly the steep hill slopes where majority of the farmlands are found. The farmers practice is the traditional methods of *jhum* or shifting cultivation with least improved scientific and technological interventions (Singh et al., 2013). Harvesting of horticultural crops is done on weekends involving transportation to a nearby road or a spot from where they can convey it to the mandis by means of vehicle which is still a great challenge to the farmers, meanwhile adding to their cost of production. There is a huge amount of loss of fruits and vegetables on the way from farm to fork owing to their highly perishable nature at different steps along the post harvest chain. The loss is further enhanced by the lack of proper cool storage and refrigerated storage facilities at the farm level and market respectively (Rosa, 2006). In

cases when there is glut in the market, the farmers face difficulties in selling their produce which then are prone to spoilage resulting in considerable loss for the farmers. During the hardship of COVID 19 pandemic, the frequent imposition of lockdown in the region have impounded detrimental effect on the farmers' harvest to the existing post harvest loss. It has become very imperative for the tribal farmers' preparedness for such natural disaster and be equipped with suitable storage techniques for properly storing their hard-earned agricultural produces.

In a report published by the ICAR, the Indian post harvest losses in fruits and vegetable ranged 5.77 to 18.05 per cent (Narayana, 2014). The quality of vegetable crops deteriorates immediately after its harvest due to the high moisture content (Sundaram, 2013). Fruits and vegetables spoilage can greatly be controlled bydecreasing the storage temperature and increasing its relative humidity (RH) which restricts its biochemical and physiological changes to a minimum standard level (Devi and Singh, 2018 a,b; Kadar, 1992). Generally, storage conditions can be controlled by using various mechanical processes like air cooling, hydro-cooling, vacuum cooling, chilling devices and freezing (Kumar et al., 2018). Storage via refrigeration is one of the established techniques used widely for horticultural and fruit crops around the globe (Devi and Singh, 2018 a,b; Sunmonu et al., 2014). Refrigeration mechanical devices are mostly energy intensive involving huge capital investment and uninterrupted supply of electricity for operation. Moreover, its construction at remote areas or on-farm agricultural fields in rural areas is a meticulous task (Kumar et al., 2018; Basediya et al., 2013). Hence, such expensive mechanism is not render suitable for small and marginal farmers of rural areas (Kumar et al., 2018). Refrigeration storage is also reported to cause chilling injuries and damage of colour pigments in several tropical fruits and vegetables (Olosunde et al., 2009 ; Liberty et al., 2013).

A trending trace on the scope and applicability of evaporative cooling storage structure, Zero Energy Cool Chamber (ZECC) can be seen abundantly around the globe. Evaporative cooling is a well-known mechanism, the principle of which is based on cooling of a substance due to the conversion of sensible heat to latent heat when water evaporates and hence the rate of cooling is directly proportional to the rate of evaporation. The basic design of a ZECC consists of a doubled brick walled structure with sand-filled cavity. It is a great alternative to refrigeration cooling by providing many advantages like low cost, ease of construction and maintenance using locally available materials, environmental and user friendly, economical making it suitable for rural and remotely located farm areas. The cooling effect inside the chamber of a ZECC occurs as a result of evaporation of water from the brick walls and sand due to the transfer of heat from the air and brick having relatively higher temperature to the moistened sand via the process of conduction and convection, respectively (Roy and Khurdiya, 1986; Roy and Pal, 1989).Since the development of the ZECC based on the principle of passive evaporative cooling by Indian Agricultural Research Institute (IARI), New Delhi (Roy and Khurdiya, 1986), there has been numerous works conducted on the efficiency and effectiveness of the ZECC on various fruit and vegetable crops under different agro climatic conditions. Cool chambers are reported to be effective in maintaining the freshness of fruits and vegetables and minimizing the weight loss (Bhatnagar et al., 1990). Sarkar et al. (2014) evaluated the performance of ZECC in terms of inside and outside temperature and relative humidity at ICAR Research complex for Eastern Region, Patna, Bihar in India. Adopting ZECC designed by IARI Pusa, New Delhi, Devi and Singh (2018) conducted trials in Manipur, North Eastern hilly (NEH) Region in India for storing vegetable and fruit crops and found to be a very simple yet effective and farmers' friendly technology that can be adapted by the farmers. Khatun et al. (2018) used ZECC to increase the marketability of cauliflower and found that ZECC can reduce the temperature from 8^{o}C to 6^{o}C and increases relative humidity from 30% to 33% further the physiological loss in weight (PLW) was reduced by 10.94%. In a study conducted by Singh and Satapathy (2006) on different fruits and vegetables, the mean maximum

temperature inside the ZECC was reported to be 5°C to 6°C lower than the ambient temperature and the relative humidity (RH) was in the range of 80 to 94 % round the whole year. Similarly, different researchers and extension expert have tested and redesigned ZECC as in an attempt to optimize the storage conditions for vegetables and fruit crops (Sundaram, 2013; Lata and Singh, 2013; Kumar et al., 2014; Mishra et al., 2020). In the present study, viewing to the trending effective storage quality of ZECC, an attempt has been made to assess the keeping quality of the ZECC at farmer's farm located in the mid hill altitude offour important horticultural fruit crops of the region.

MATERIALS AND METHODS

Study was conducted at on-farm in Sihphir Veng lun Village, Aizawl District of Mizoram in India by Krishi Vigyan Kendra Aizawl, Selesih, Mizoram during the year 2019-20. The state capital, Aizawl District altitudes to 1231 m gauged at Chatlang and receives 2492 mm of rainfall during the year 2019-20 and the maximum and minimum temperature was recorded to be 33.53°C and 7.28°C respectively with minimum and maximum relative humidity (RH) of 49.32% and 88.23%, respectively (Directorate of Agriculture, 2017). Its agro-climatic zone comes under humid temperate sub alpine, humid sub-tropical hill and humid mild-tropical zones (Directorate of Agriculture, 2017; MISTIC, 2017). In an attempt to propagate and assess the performance of storage quality for different vegetable and fruit crops, ZECC has been implemented at on farm level at Sihphir village of Aizawl District at Mizoram, NEH Region in India.



Fig. 1. On-field construction of ZECC

ZECC construction

ZECC construction was accomplished with materials that are easily available within the local market *viz.* bricks, sand, cement, galvanized tin sheet, wood, lock, plastic coated GI wire net, plastic crates, etc. The construction methodology involves the following steps:

i. Selection of site for ZECC construction.
ii. Site demarcation, leveling and preparation of layout of dimension 165 × 115 cm^2.

iii. Erection of double brick wall to a height of 67.5 cm, leaving a gap of 7.5 cm between the two erected brick walls.
iv. Installation of protective frame made of wood and plastic-coated GI wire net with proper locking system.
v. Preparation of proper shed with help of wood frame and galvanized tin sheet of dimension 200 × 160 cm^2 for protection from direct sunlight and rain.
vi. Filling up of the gap between the double walls with sand and subsequently soaking it with water during storage.

Fig. 1 shows on-field construction of ZECC for the present study. Constructed ZECC structure was then used for storing the harvested vegetable and fruit crops *viz.* Broccoli (var. CLX 3512) during the month of January and February 2020, Tomato (var. Arka Rakshak) during February and March 2020, Passion fruit (var. Local: Sapthei) during March and April 2020 and Banana (var. Giant Cavendish) during August and September 2020. As to assess the performance of ZECC, parameters such as physiological loss in weight (per cent), Temperature (°C) and relative humidity (per cent), daily data required were recorded during the storage period.

Physiological loss in weight (PLW)

In determining the quality of stored vegetables and fruits crops, physiological loss in weight stands as one of the important parameters (Sarkar et al., 2014). It's per cent decline affects the storage quality of the vegetables and fruit. Loss of freshness and withed appearances in stored vegetables and fruit crop can be a resultant of a 5 per cent drop in PLW (Ben-Yehoshua, 1987; Sondi and Sondi, 2004). With recorded initial weight before storage (w_1) and final weight after storage (w_2), PLW in per cent can be estimated using the following equation (1).

$$PLW = \frac{(w_1 - w_2)}{w_1} \times 100$$

PLW = Physiological loss in weight (per cent).
w_1 = Initial weight before storage (kg).
w_2 = Final weight after storage (kg).

Temperature and relative humidity

Temperature and relative humidity are two very important parameters that affect the storage keeping quality of vegetables and fruit crops. Storage temperature governs the viability and growth probability of microorganisms that affects the conditions of product storage life. Further, vegetables and fruit crops when stored under higher relative humidity improves the shelf life but promotes growth of fungus and molds, therefore it is essential to relatively maintain a lower temperature. The required temperature and relative humidity for the present study was recorded using Metravi HT-305 Digital Meter.

RESULTS AND DISCUSSION

ZECC constructed were successfully used for storing harvested vegetable and fruit crops *viz.* Broccoli, Tomato, Passion fruit and Banana during the month of January, March, April and August 2020, respectively in order to restrict post harvest losses. In the process, performance evaluation of the storage keeping quality of ZECC was compared with that of the ambient condition assessing the parameters namely shelf-life (days), Temperature (°C), Relative Humidity (%) and PLW (%). The marketability of broccoli, tomato, passion fruit and banana were enhanced from 7, 6, 7 and 7 days under ambient condition to 12, 11, 12 and 20 days respectively when stored under ZECC (Fig. 2).

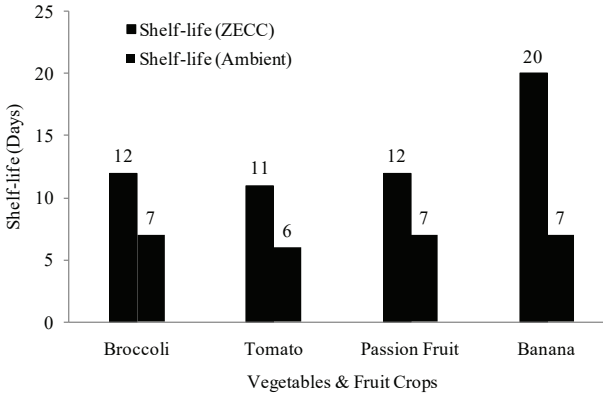


Fig. 2. Marketability of vegetable and fruit crops under ZECC and ambient condition

Temperature and relative humidity

In the present study the respective temperature and RH were recorded daily during early morning, noon and evening using Metravi HT-305 Digital Meter. The recorded trends of the temperature and RH inside ZECC and under ambient conditions during the months January, March, April and August 2020 are shown in Fig. 3 to 10. An average reduction in temperature from 16.85 to 11.98°C, 16.47 to 12.05°C, 20.94 to 16.49°C and 25.67 to 20.67°C for the month January, March, April and August respectively was observed. Highest and lowest daily reduction in temperature of 7.25 and 3.1°C were recorded in the month of April and March respectively. Recorded average increase in relative humidity in adoption of ZECC was found to be 81.92 to 94.17, 63.36 to 77.27, 53.75 to 67.67 and 80.67 to 93.67 per cent for the similar respective months. The highest and the lowest daily increases in RH were recorded in the month of January reading 25 and 8 per cent. Such decrease in temperature and increase in relative humidity inside the ZECC accords laws of thermodynamics where evaporation process causes a drop in several degrees of temperature and relatively increases the RH (Sundaram, 2013). As briefly stated by Sarkar et al. (2014) higher temperature with available moisture increases the rate of evaporation from the wetted sand and brick walls of ZECC. In such state, the surrounding atmospheric conditions around the ZECC attempts to maintaining equilibrium with ZECC causing the water from the wetted sand and walls to evaporate. During this process, the ZECC temperature lowers down due to the energy losses in evaporative cooling.

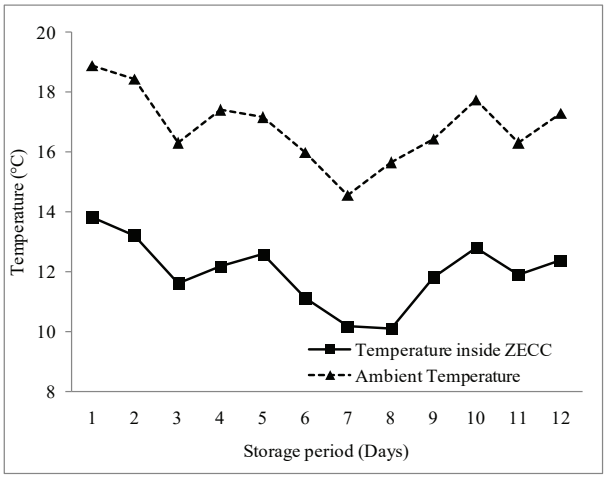


Fig. 3. Temperature variation in ZECC and ambient condition during January 2020

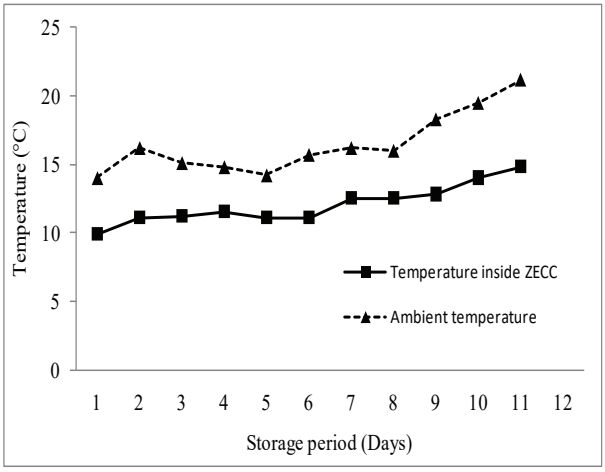


Fig. 4. Temperature variation in ZECC and ambient condition during March 2020

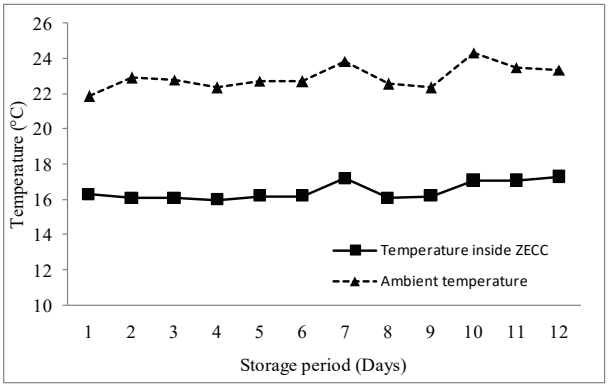


Fig. 5. Temperature variation in ZECC and ambient condition during April 2020

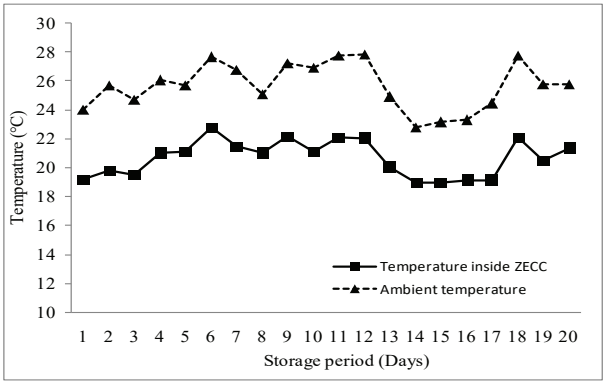


Fig. 6. Temperature variation in ZECC and ambient condition during August 2020

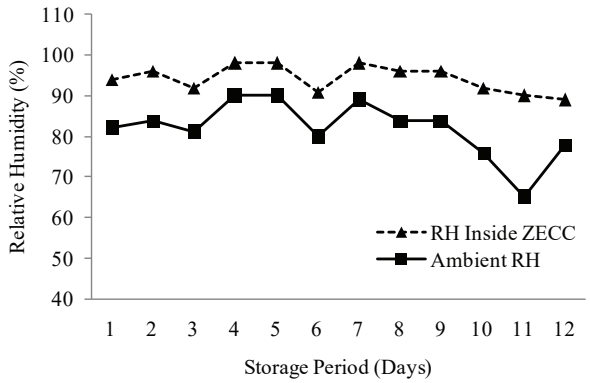


Fig. 7. Relative humidity variation in ZECC and ambient condition during January 2020

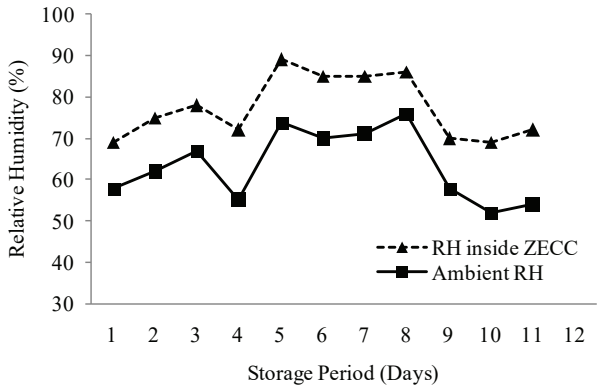


Fig. 8. Relative humidity variation in ZECC and ambient condition during March 2020

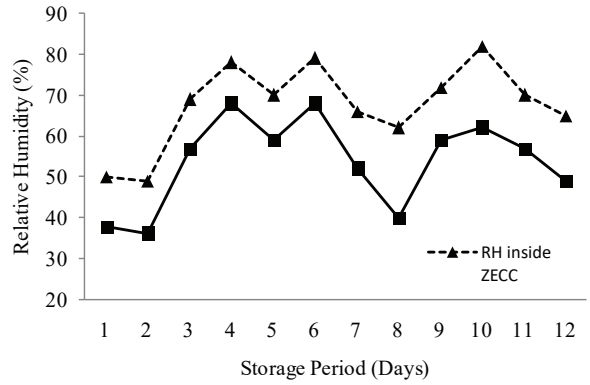


Fig. 9. Relative humidity variation in ZECC and ambient condition during April 2020

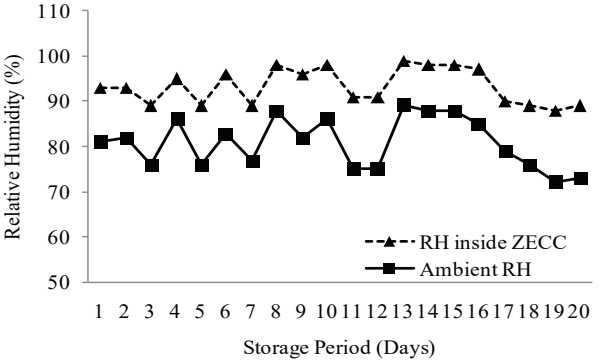


Fig. 10. Relative humidity variation in ZECC and ambient condition during August 2020

Physiological loss in weight (PLW)

Harvested crops are properly weighted and stored in plastic crates, a total of six numbers as shown in Fig. 1, when storing inside the ZECC. Estimated PLW in broccoli when stored for 12 days in ZECC was found to be 4.51 per cent only as compared to that of ambient condition that could only be stored for 7 days with 16.19 per cent of PLW. Stored tomato in ZECC for 11 days registered 3.9 per cent of PLW compared to a 5.54 per cent PLW under ambient condition for a mere of only 6 days. Stored banana for 20 days at ZECC registered a PLW of 2.5 per cent whereas under ambient condition it registered a PLW of 3.65 per cent after 7 days. Lastly, stored passion fruit at ZECC after 12 days, the PLW was found to be 5.15 per cent, where under ambient condition, the PLW was found to be 6.7 per cent after 7 days of storage. Fig. 11 show a comparative bar chart of physiological loss in weight (per cent) for different crops stored under ZECC and ambient condition, respectively.

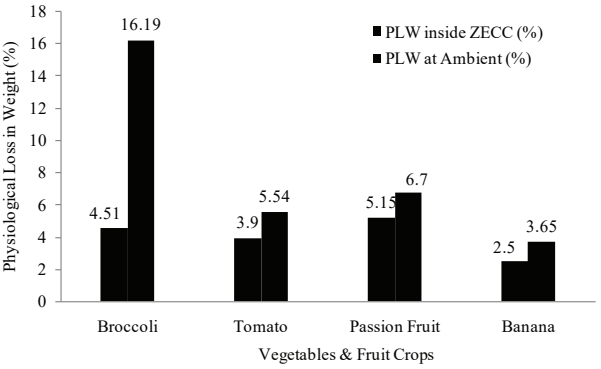


Fig. 11. Physiological loss in weight of vegetable and fruit crops under ZECC and ambient condition

CONCLUSION

In the search of a suitable storage technique, that is economical and simple yet effective in restricting the post harvest losses in horticultural crops, the Zero Energy Cool Chamber (ZECC) can be of great feasibility and adaptable. In the present study, constructed at on-field it was found that the ZECC can enhance the keeping quality from at least an average of 6-14 days as compared to that stored under ambient condition. An average reduction in temperature and relative humidity of 5.19°C and 13.14 per cent was observed respectively. Highest and lowest daily reduction in temperature of 7.25 and 3.1°C were recorded in the month of April and March respectively whereas, highest and lowest daily increase in RH were recorded in the month of January, reading 25 and 8 per cent. Further, highest reduction in the PLW was observed in stored broccoli at ZECC during the month of January 2020, an 11.68 per cent reduction. Adopted at farmers' farm, parts of harvested crops were successfully stored at ZECC and these stored crops were easily sold in other weekends. These have given the farmers an ample opportunity to avoid losses of harvested crops that are left off unsold in sale weekends. Being effective, the ZECC have gain popularity among the farming community in the region and more farmers have turn up willing to adopt it. Exhibited performance of the ZECC, its constructional and operational ease have shown that, its application in the region can be of great beneficial for the needy tribal farmers in restricting and mitigating the post harvest losses.

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