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Review Article

Storage of Vegetables in Zero Energy Cool Chambers: a Review

M.K.Ghosal[1*] and Jyoti Ranjan Rath[2]
[1]Professor Dept. of Farm Machinery and Power, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar-751003, Odisha, India
[2]Research Scholars (Agril. Economics) Dept. of Farm Machinery and Power, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar-751003, Odisha, India

*Corresponding Author
M.K. Ghosal

Abstract: Lack of transportation facility, shortage of energy supply and lack of investment on storage, lower price of vegetables during the harvesting season, farmers in the rural areas often sell their products to the middleman or in the local market at low prices. They are not even able to get the return of invested money of cultivating vegetables or fruits. As a result, higher percentage of poverty level remains in farmer's community. There is therefore, the need of a low cost storage system such as zero energy storage system which doesn't require electricity for operating to store the agricultural produces in a small scale at farmer's level. Zero energy cool chamber (ZECC) is such a device designed and developed at IARI New Delhi for on-farm rural oriented storage structure which operates on the principle of evaporative cooling and is constructed using locally available raw materials i.e., bricks, sand, bamboo, rice straw, vetiver grass, jute cloth etc. The chamber is generally constructed above the ground and comprises of a double-walled structure made up of bricks. The cavity of the double wall is filled with riverbed sand. It is covered with a mat made from either jute cloth or vetiver grass supported with a bamboo frame. A thatched shed over the chamber is erected to protect it from direct sun or rain. In this paper, the feasibility study of ZECC has therefore been reviewed for short term storage of fruits and vegetables looking into the socio-economic condition of the majority of small and marginal farmers of our country.

Keywords: Storage of horticultural produces, Evaporative cooling, Zero energy cool chamber, Shelf-life of vegetables, Natural resources utilization.

INTRODUCTION

The essence of storage is of great importance because not all the harvested leafy vegetables in general will be used immediately after their harvest. Hence, measures of preserving the vegetables before it exceeds its shelf life are of great importance. Most of the farmers are not able to afford the cost of purchasing high-tech storage equipments for their harvested crops. Evaporative cooling has been found to be an effective and economical means of reducing temperatures and increasing humidity in an enclosure where the humidity is comparatively low. Minimizing deteriorative reactions in vegetables enhances their shelf lives, implying that the produce will be available for longer periods; this would reduce fluctuation in market supply and prices. Evaporative cooler works on the principle of cooling resulting from evaporation of water from the surface of the structure. The cooling achieved by this device also results in high relative humidity of the air in the cooling chamber from which the evaporation takes place relative to ambient air. The atmosphere in the chamber thus becomes more conducive for storage of vegetables. Therefore, it is required to develop and popularize a low cost, less energy consuming and environment friendly cool chamber which would not only be affordable for resource poor farmers but also for safe storage of the horticultural produces for a short period, resulting into a prospect of getting remunerative price of the produce. The evaporative cooling systems has prospect for use for short term preservation of vegetables after harvesting. It reduces the storage temperature and also increases the relative humidity within the optimum level of the storage thereby helps in keeping the vegetables fresh.

In order to overcome the problem of on-farm storage, low cost environment friendly Pusa Zero Energy Cool Chambers have been developed. The importance of this low cost cooling technology lies on the fact that it does not require any electricity or power

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to operate and all the materials required to construct the cool chamber are available easily at cheaper cost. Even an unskilled person can install it at any site, as it does not involve any specialized skill. Most of the raw materials used in cool chamber are also reusable.

The zero energy cool chamber works on the principle of evaporative cooling – a gift of nature, which happens when air, which is not already saturated with water vapour passes over a wet surface. Water evaporates into air raising its humidity and at the same time cooling the enclosure. Pusa Zero energy cool chamber can retain the freshness of the fruits and vegetables for a short period. Small farmers can easily construct these chambers near their houses or fields to store their harvested produce. In this way, the farmers can store their produce for few days and send the bulk of the commodity to the whole sale market so that they will not be forced to make any distress sale in the local market because in India 90 per cent of horticultural produce is sold in fresh form. The involvement of middle men in making this distress sale increases the price of horticultural produces by 60-100 per cent in retail outlets compared to the growing areas. The strategy of on-farm storage of vegetables harvested daily in small quantities over few days and sending them to distant markets without solely depending on the local market can definitely augment the income of the farmers. The cool chamber can reduce the temperature by few degrees and maintain a high relative humidity compared to the ambient condition, thereby helping in enhancing the freshness of the produce. Keeping this in view, an attempt is made in this paper to review the efficacy of IARI design Zero Energy Cool Chamber, studied by various researchers for enhancing the shelf-life of horticultural produces resulting into the livelihood security of vegetable growers.

The Zero Energy Cool Chamber was developed by Dr. S.K. Roy during 1980's at the Indian Agricultural Research Institute, Pusa, New Delhi and has been field tested and redesigned over the past few years to improve its function. Though this technology of on-farm storage of fruits and vegetables for shorter periods had been developed long back, the efforts to popularize this technology are now gaining momentum because of today's increasing environmental concern and rising cost of power. This is almost similar to earthen pots widely used to cool water. Transfer of heat due to evaporation of water from the surface of the cooling vessel ultimately leads to cooling the atmosphere within the vessel. The water contained in the sand between the two brick walls evaporates towards the outer surface of the outer wall, where the drier outside air is circulating naturally. By virtue of the laws of thermodynamics, the evaporation process automatically causes a drop in temperature of several degrees, cooling the inner container and preserving the vegetables inside. Hence, looking towards health, employment and income of small and marginal farmers through cultivation of fruits and vegetables, popularization of low cost zero energy cool chamber in a small scale among the farming community to store the harvested produce for a short period and subsequently to sell the product in the marketable form for achieving economic viability and livelihood security.

Literatures Studied

Refrigerated cold storage is considered to be a better option for storage of fruits and vegetables. But this method is not only energy intensive, but also involves large initial capital investment. Besides, it is not suitable for on-farm storage in the rural areas. Considering, the acute energy shortage in rural areas, there is better scope for adoption of small capacity, low cost, on-farm scientific storage structure like Zero Energy Cool Chamber (ZECC) developed at IARI, New Delhi by Roy and Khurdiya (1986) based on the principle of evaporative cooling. The process of evaporative cooling is an adiabatic exchange of heat when ambient air passes through a saturated surface to obtain low temperature and high humidity, which is desirable to extend the storage life of fruits and vegetables (Das and Chandra, 2001). Storage of horticultural products inside the cool chamber has showed reduction in physiological loss in weight, optimum colour, better firmness and extended shelf life by 1–2 weeks in other parts of the country. Cool chambers are effective in maintaining the fruit acceptability for a longer period and minimizing the weight loss during storage (Bhatnagar *et al.,* 1990). Relatively lower weight loss of fruits and vegetables under evaporative cooler than that of ambient condition has been reported by many researchers. Sandooja *et al.,* (1987) reported least deterioration in quality parameters of tomato such as TSS, acidity and ascorbic acid content when stored in zero energy cool chamber. Wasker *et al.,* (1999) reported slower rate of change of physicochemical constituents in fruits stored in cool chamber. Weight loss of fresh tomato has been reported to be primarily due to transportation and respiration, and limited shelf-life and losses in quality have been identified as the major problems faced in the marketing of fresh tomatoes (Bhowmic and Pan 1992). Zero energy cool chambers along with packaging materials, ventilation and anti fungal treatments can help in minimizing the losses of ascorbic acid in the stored lemon fruits to some extent compared to the storage under ambient conditions of storage (Prabha *et al.,* 2006). Performance of zero energy cool chamber for short term storage of fruits and vegetables has been reported in the literature, some of which are included in this review.

India Agricultural Research Institute develops a cooling system that can be built in any part of the country using locally available materials (Anonymous 1985). The basic structure of the chamber can be built from bricks and river sand, with a cover made from cane or other plant materials and sacks or cloth. There must be a nearby source of water. Construction is fairly simple, floor is built from a single layer of bricks, and then a cavity wall is constructed of bricks around the outer edge of the floor with a gap of 75 mm between the inner wall and the outer wall. This cavity is then filled with sand. About 400 bricks are needed to build a chamber of storage capacity of around 100 kg. A covering for the chamber is made with canes covered in sacking all mounted in a bamboo frame. The whole structure should be protected from sunlight by making a thatched roof to provide shade. After construction of the walls and floor, the sand in the cavity is thoroughly saturated with water. Once the chamber is completely wet, sprinkling of water is done twice a daily, which is enough to maintain the moisture and temperature of the chamber.

A zero-energy cool chamber was developed using locally available materials in New Delhi, India (Roy and Pal, 1994). The chamber is designed for on-farm use, operates by evaporative cooling, and is constructed from double brick with sand-filled cavity walls. The shelf life of tropical fruits held in the chamber was increased by 2 to 14 days (15–27% increase) as compared to storage at room temperature, and the physiological loss in weight was lower. The chambers were shown to be suitable for short term storage of fruits and vegetables.

Roy and Khurdiya (1982) constructed 4 types of evaporative cooled chambers for storage of vegetables. The first chamber was made of cheap quality porous bricks and riverbed sand, which was latter known as Zero energy cool chamber. The other three chambers were ordinary earthen pots placed in three tanks: the first one made of bricks, the second one an ordinary wooden box and the last, an ordinary fruit basket. The gap in all the cases was filled with sand. The sand and the gunny bags covering the top of the chambers were kept saturated with water. The cool chambers maintained a temperature between 23 and 26.5 °C and relative humidity (RH) between 94 and 97%as against the ambient temperature between 24.2 and 39.1 °C and RH 9– 36% during the months of May–June. Chamber 1, i.e. the Zero energy cool chamber, performed best with the enclosed air temperature remaining between 23 and 25.2 °C.

Roy (1984) reported that the performance of a 6-tone cool chamber whose side wall was constructed with two layers of bricks leaving approximately 7.5 cm gap in between them. This gap was filled with riverbed sand. The floor was made of wooden planks. Below the floor, a 33 cm deep tank was constructed with 4 air ducts made of bricks opening at the centre and submerged under wet sand. The sand in the wall and surrounding the ducts were saturated with a drip system. The top of the chamber was insulated and incorporated with an exhaust fan. The air while passing through saturated duct and walls cooled sufficiently and took away heat from the produce.

Anonymous (1985) and Roy and Khurdiya (1986) reported the detailed method of construction of a Zero energy cool chamber. A chamber for storage of about 100 kg horticultural produce was constructed with two layers of bricks as side walls leaving approx. 7.5 cm gap in between them. This gap was filled with riverbed sand. The top of the storage space was covered with khaskhas /gunny cloth in a bamboo-framed structure. There was no provision for mechanical ventilation. The sidewall and top cover were kept completely wet during the period of storage. It was observed that the cool chamber had a temperature of less than 28 °C during summer, when the maximum outside temperature was 44 °C. The average minimum temperature of the cool chamber was either less than or near the outside average minimum temperature, excepting in winter, when it maintained a few degrees centigrade more than the outside average minimum temperature.

Roy and Pal (1991) developed a low cost zero energy cool chamber—an on-farm rural oriented storage structure at IARI, New Delhi, using locally available raw materials such as bricks, sand, bamboo, dry grass, jute cloth etc., which operates on the principle of evaporative cooling. The chamber is an above-ground double-walled structure made up of bricks. The cavity of the double wall is filled with riverbed sand. The lid was made by using dry grass/straw on a bamboo frame. The rise in relative humidity (90% or more) and fall in temperature (10–15 °C) from the ambient condition could be achieved by watering the chamber twice a day. Performance evaluation of cool chambers at different locations of the country was found to be satisfactory for short term storage of mangoes. Eventually, 3 to 4 days more shelf life of mature green mangoes could be obtained in cool chamber storage as compared to ambient condition storage. However, ripe mangoes when stored in cool chamber had 9 days shelf life as compared to 6 days under ambient condition and also scored high organoleptic values. It is most effective during the dry season.

Bhardwaj and Sen (2003) treated fresh mandarin fruits 'Nagpur Santra' with 0, 10 and 20% neem leaf extract and kept at ambient condition (14.7–31.2 °C, 19.4–55.1% RH) and in zero energy cool-chamber (11.1–22.0 °C, 89.9– 95.0% RH). The results showed that zero energy cool chamber with 20% neem leaf extract significantly reduced the physiological loss in weight (PLW, 17.88%), rotting (18.07%), loss in juice content (11.08%), organoleptic taste score (6.08) and reduction in diameter (11.54%). The TSS (11.61° Brix) and total sugar (7.15%) were increased gradually though the rate of change was less under same treatment. The maximum retention of acidity (0.400%)

and ascorbic acid (27.17 mg/100 ml juice) on 42nd day of storage was recorded in zero energy cool-chamber with 20% neem leaf extract. The fresh fruits could be kept upto 42 days in the same treatment as compared to 20 days in ambient condition, without any treatment (control).

Ganesan *et al.*, (2004) studied the application of different levels of water on Zero energy cool chamber with reference to the shelf-life of brinjal and concluded that the shelf-life at room temperature which was hardly 3 days enhanced to 9 days with the addition of 100 litres of water per day.

Singh and Satapathy (2006) evaluated the performance of IARI design Zero Energy Cool Chamber (ZECC) at ICAR Research Complex, Umiam, Meghalaya. The ZECC was evaluated for two consecutive years and shelf life of various fruits and vegetables like bitter gourd, capsicum, tomato, cauliflower, pineapple and peach was evaluated under cool chamber and ordinary room condition. It was observed that the mean maximum temperature inside the cool chamber was about 5 °C and 6 °C lower than the ambient during summer and winter season, respectively. Throughout the year, relative humidity (RH) inside the cool chamber was between 80 and 94%, whereas under the ambient it varies between 70 and 83%. The RH inside the cool chamber was nearly 13.34% and 12.34% higher during summer and winter months, respectively. It was observed that the shelf life of bitter gourd, capsicum, and cauliflower could be increased for 5 days whereas; the shelf life of tomato and peach and pineapple can be increased for about 6 and 9 days respectively, when it is kept inside the cool chamber as compared to ordinary room condition. Since it costs only about Rs.2500/- and can be easily constructed in the rural areas even by a layman, the fruits and vegetables growers can use it for short duration storage of horticultural produce.

Rayaguru *et al.*,, 2010 studied the suitability of zero energy cool chamber (ZECC) for short term storage of fruits and vegetables 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 maintained the temperature of its environment less by 5–8°C and more than 90% RH compared to outside ambient condition. 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.

Yadav *et al.*, (2010) studied the storage of tomato in various evaporative cooling systems in College of Agricultural Engineering and Technology, Ratnagiri, Maharastra, India. Three evaporative cooling systems to store the tomatoes i.e. drip cooling chamber with gunny bag walls (T_1), drip cooling chamber with vetiver mat walls (T_2), charcoal cooling chamber (T_3) and room temperature storage (T_0) were constructed. Treatment (T_1) showed better results followed by treatment (T_2), treatment (T_3) and treatment (T_0). The shelf life of tomato in treatment (T_1) was up to 21 days followed by treatment T_2 (18 days), treatment T_3 (15 days) and treatment T_0 (12 days). Thus shelf-life of tomato was increased by 9 days in treatment T_1. Considering the above all treatments, T_1 treatment i.e. drip cooling chamber with gunny bag walls was best suited for storage of tomato with low cost and negligible operating cost.

Islam and Morimoto (2012) developed a zero energy cool chamber (ZECC) consisting of a brick wall cooler and a storage container made of new materials. The ZECC requires no electric energy. The brick wall cooler made of bricks with a mixture of moistened sand and zeolite allows low inside temperature and high relative humidity to be maintained based on the principles of a natural evaporative cooling mechanism. Several types of storage containers coated with different antibacterial materials were applied to reduce decay. For example, silver-ion-coated storage containers were used to reduce decay. Heat treatment was also applied to the commodities in order to maintain freshness. Generally, tomato and eggplant had a shelf life of 7 and 4 days at room temperature, respectively, as compared to 16 and 9 days when stored in the ZECC. Tomato and eggplant treated with hot water reduced the percentage of rotting. Tomato treated with hot water at 60°C for three minutes and eggplant treated with hot water at 45°C for an hour when stored inside silver-ion-coated containers in the ZECC showed extended shelf life of up to 28 and 15 days, respectively**.**

Dash *et al.*, (2016) studied the storability of leafy vegetables (greens) in zero energy cool chamber in coastal region of Odisha India. Leafy vegetables are highly perishable and need immediate storage in a favourable environment after harvest for maintaining their freshness and marketability. Their importance is now-a-days gaining momentum among the consumers because of various health benefits. However, farmers are not interested to grow leafy vegetables due to their high perishability and lack of proper storage facilities which force them to sell their harvested material immediately to whatever prices offered to them, ultimately resulting in reduced net profit to the growers. An attempt has therefore been made by the authors to study the feasibility of using a low cost and almost zero energy consuming storage device for short-term storage of leafy vegetables of about 1 week and to encourage the farmers to go for cultivating greens in a small scale mostly in their back yard for achieving nutritional and livelihood security. One such storage device used for the study is zero energy cool chamber, developed at Indian Agricultural Research Institute, New Delhi. Zero energy cool chamber for their study was modified by incorporating a gravity fed micro-dripper watering system for uniform and continuous wetting of sand bed. A zero energy cool chamber constructed in coastal area of Odisha i.e. at Bhubaneswar was used to study the storability of most prevailing leafy vegetables such as amaranthus, spinach and coriander during April-May 2015. It was found that amaranthus, spinach and coriander could be stored 7, 4 and 2 days in the marketable form in zero energy cool chamber under coastal conditions compared to 2, 1 and 1 day in room condition respectively during summer period. Based on the above discussed literatures, the following conclusions have been drawn on the use of a low cost cool chamber i.e. zero energy cool chamber in case of small and marginal farmers in order to enhance the shelf life of greens and to prevent their distress sales.

CONCLUSION

One of the major constraints faced by marginal and small farmers engaged in cultivation of vegetables is the perishability of the produce which forces them to sell the produce to whatever prices offered in the nearby market point. Taking the produce to a distant market is not feasible owing to the small quantity of sundry vegetables being harvested every day. On the other hand, the consumers are also paying a high price for a poor quality produce as there is no cold chain market facilities established in all the places. Considering the above constraints, the farmers growing multiple vegetables each on a smaller area should have some alternate technologies for storing their produce at least for a shorter period so that the everyday's harvest could be accumulated and taking a bigger volume of the produce once in few days to the market becomes an economically viable option for the grower and the consumer is also benefited by the supply of fresh and nutritious vegetables. India is the fruit and vegetable basket of the world. Approximately 23–35% of the horticulture produce goes waste due to improper post harvest operations and due to lack of enough storage facilities. Evaporative cooling system has a very large potential to maintain suitable thermal comfort. Nowadays, evaporative cooled storage system is increasingly being used for on-farm storage of fruits and vegetables. Evaporative cooling system not only lowers the air temperature surrounding the produce, it also increases the moisture content of the air. This helps prevent the drying amount of the produce, therefore extends the shelf life of horticultural produce. Evaporative cooling system is well suited where; temperatures are high, humidity is low, water can be spared for this use, and air movement is available. There are many different styles of evaporative coolers. The design depends on the materials available and the users' requirements. It is most suitable for the short term storage of vegetables and fruits soon after harvest. Zero Energy Cool Chamber (ZECC) is one of the effective evaporative cool chambers in which short term storage of fruits and vegetables is possible. It not only reduces the storage temperature but also increases the relative humidity of the storage which is essential for maintaining the freshness of the commodities. The ZECC developed at IARI is a no energy requiring low temperature storage structure which could help in keeping most of the tropical vegetables afresh by a few days after harvest. The bulk of the vegetables may be taken in plastic crates and are placed inside the ZECC. The added advantage of the structure is that it is environmentally friendly and even the farmers themselves could construct it with locally available recyclable materials. Thus the zero energy cool chamber could serve as a viable and feasible on-farm storage structure for storing of horticultural produces by farmers without any recurring expenditure on energy source as it works on the basis of evaporative cooling. This could be a solution for the vegetable growers of the tropical country like India especially during the periods of dry weather with high temperature and low relative humidity in the atmosphere.

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