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Zero Energy Cool Chamber (ZECC): A Unique Low-cost Food Preservation System

Shrabani Kumbhakar[1], Ina Mukherjee[2], Debasree Ghosh[2,*]

ABSTRACT

Zero energy cool chamber (ZECC) is an environment friendly or eco-friendly and low-cost post-harvest technology which can be made up with locally available low-cost materials like brick, sand etc. For this reason, it can easily be constructed in rural and remote areas. It is mainly used to store fruits and vegetables. It does not need any electricity, that is why it also saves energy. Temperature and humidity are two important factors that play important role in ZECC. ZECC contains a double walled chamber which can be made of baked bricks with coarse sand, which is used to fill the annular space of the storage system. From various sources it has been observed that high ambient temperature plays a major role in storage of products and it accelerates the process of dehydration in fruits and vegetables and it also reduces the water content of fruits and vegetables, decreases their shelf-life and it also makes co-spoilage in due course of time. As the conventional methods of air conditioning and refrigeration are costly and they require electricity, so, in many rural areas, farmers are not be able to use this. ZECC is used not only to solve this problem, but also to extend the shelf life of fruits and vegetables.

Keywords: Eco-friendly system, low cost of construction, temperature and humidity, double walled chamber, genetic algorithms, air conditioning

AIMS AND OBJECTIVES

- The purpose of the study is to evaluate the importance of Zero Energy Cooling Chamber and to observe that ZECC can be used as an appropriate cooling technology for storing of horticultural products such as tomato, potato, onion etc.
- To evaluate the working principle and advantages of ZECC for using it as low-cost cooling system.
- To collect information about ZECC to aware people, especially farmers about the beneficiaries of ZECC as ZECC is economically beneficial because it does not need electricity and is made with locally available materials.

***Author for Correspondence**
Debasree Ghosh

[1]Student, Department of Food and Nutrition, Barrackpore Rastraguru Surendranath College, 85 Middle Road and 6 Riverside Road, Barrackpore, Kolkata, West Bengal, India
[2]Assistant Professor, Department of Food and Nutrition, Barrackpore Rastraguru Surendranath College, 85 Middle Road and 6 Riverside Road, Barrackpore, Kolkata, West Bengal, India

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INTRODUCTION

Zero Energy Cool Chamber or ZECC can be used as a short-term storage system. Biodegradable food products can be stored in ZECC [1]. Some tropical countries are facing huge problems in the storage of agricultural food products [2]. The term "Storage" can be considered as one of the most crucial operations in salvaging the agricultural produce from deterioration and losses after the process of harvesting. The post-harvest losses of fruits and vegetables occur as the degradation procedure happens in both quantity and quality of the stored product during the cycle of the product's harvest to consumption or during food production [3]. It has been also observed in various studies that the high ambient temperature accelerates the process of

dehydration in fruits and vegetables which further leads to reduction in the water content of the food product. It also decreases the shelf-life of the product. A consequent spoilage can also be occurred in due course of time because of high ambient temperature. Methods like air conditioning and refrigeration are mainly used on regular basis for the storage of fruits and vegetables. But these processes are very costly, and they also need electricity. In many cases, farmers of the rural areas cannot afford this. So, to overcome this problem, a low cost, eco-friendly cool chamber with improved technology was designed. Based on the principle of evaporating cooling, these types of cooling chambers were designed [4]. IARI Pusa, (New Delhi) first made the sketch for this type of cooling chamber [5]. India scores the second position in the world for the production of fruits and vegetables. Sometimes, during the procedure of production such as harvest, storage, grading, transport, packaging and distribution, the quality of the products becomes damaged (about 20–30%) [6]. Temperature and humidity play important role to preserve fruits and vegetables in cooling system. These two factors help to maintain the biochemical and physiological changes in the products [7]. Temperature helps to maintain the deterioration rate of fruits and vegetables which are stored in the cooling chamber [8]. To prevent this, zero-energy cool chamber is used. The zero-energy cool chamber (ZECC) helps to extend the shelf life of the food products. The outer and inner walls of ZECC are mainly made up with bricks. The gap between the outer and inner wall is filled up with sand. For the purpose of cooling, water is sprinkled on the sand [9]. During the conversion process, the surrounding temperature of the storage system decreased. In ZECC, temperature and relative humidity (RH) are important environmental factors which extremely affect the ripening process of fruits and vegetables and the final quality of the stored products. The water loss of the stored fruits and vegetables reduces during the process of storage in ZECC [10]. It helps to maintain the freshness of the products for a longer period of time [11]. As this type of storage system can made with locally available and low-cost materials, small farmers can easily construct these chambers to keep their horticulture produces fresh for a long period of time [12].

The Principle on which ZECC or Zero Energy Cool Chamber is Working

In ZECC, the cooling effect is created due to evaporation of water. In ZECC, the warm air passes over the cooler water. The heat passes from the air to the water. It helps to evaporate the water. Thus, air becomes cooled in ZECC [13].

MATERIALS AND METHOD USED IN ZECC

The design of ZECC was based on the principle of evaporative cooling technology of a porous body [14]. The structure of the cool chamber consisted of a rectangular, double walled chamber along with heat carrying insulating detachable roof [15]. The main advantage of this kind of jacketed type room of the chamber is to prevent the heat leakage into the storage cabin. The thickness of the walls should be 125 mm. The dimensions of the outer wall should be 1650 mm×1150 mm×675 mm. The inter space (approximately 75 mm thick) till the top of the cabinet should completely filled with river sand [16]. A pipeline is placed above the sand. It is mainly done for the uniform wetting of the sand. This pipeline is attached to a bucket which is filled with water [17]. It is very important to sprinkle water on the sand. It helps to maintain the sand bed wet throughout the day. The floor of the chamber should be plastered to a smooth finish. Gunny cloth and straw along with a bamboo frame are used to make the top cover [18].

The subsequent water requirement per day should be determined after saturating the bed of the chamber and it should be done under no load conditions [19]. The process should be carefully monitored. The bucket that supplies water with the help of a PVC water pipe is connected to the tap of overhead water tank [20].

The stage experiment can be carried out easily by the above sated procedures. The temperature and RH of the ZECC should be measured properly [21].

The Work Pattern of ZECC Also Depends on the Following Factors

- The quality of fruits and vegetables should be measured on the basis of different type of storage [22].
- The physiological loss in weight (PLW) should be measured. vegetables [23].

The Percentage of Vitamin C Present in the Vegetables stored in ZECC [24]

It is very important to maintain the percentage of vitamin C during storage. The vitamin-C content in the stored vegetables can be determined by a process called visual titration method and it is done by the use of 2,6-dichlorophenol-indophenol.

Importance of Statistical Analysis on ZECC [25]

Experiment on the basis of statistical analysis should be done. The data of the experiment can be analyzed with the help of one-way ANOVA, which is followed by Tukey's HSD test.

The inner and outer temperature of ZECC should be compared and noted. It plays a significant role in the making of ZECC [26].

An example regarding PLW has been given below:

In this experiment, gourd and okra have been taken. The below equation shows the calculation of PLW in the mentioned vegetables:

$$PLW=[(W1-W2)/W1]\times 100$$

Where, W1=Weight of sample before storage, kg;
W2=Weight of sample after storage, kg.

It has been observed that, there is significant difference in the physiological loss in weight (PLW) percentage of gourd that is stored inside ZECC, room, and freeze conditions compared to room storage Condition [27].

The highest PLW of gourd was recorded on the fifth day for room storage conditions which was followed by freeze storage condition [14, 28].

DESIGN OF THE ZERO-ENERGY COOL CHAMBER

The design of the cooling chamber is described by the equations discussed below. The sides of the inner wall of ZECC should be parallel to the outer wall. The packing material between the two walls should be constructed in ZECC [29]. The inner wall formed a cavity in which the produce should be stored [30]. Length, width, height and the space between the two walls are used to determine the temperature and humidity of ZECC [4].

The design of the rear side of the storage system can be calculated by the following equation:

$$Ar=Hr\times Lr$$

In the above equation, Ar represents Area of rear side, Lr represents Length of rear side, Hr represents Height of rear side [31].

Design of the Left-Hand and Right-Hand Sides of the ZECC should be measured [32]; Design of Reservoir Seat of the cooling chamber

The storage system contains a reservoir seat which can be made with the help of following equation:

$$As=Ls\times Bs$$

In the above equation, As represents Area of reservoir seat, Ls represents Length of reservoir seat, Bs represents Breadth of reservoir seat of the system [33].

The Volume of the Cool Chamber

It is very important to determine the capacity or volume of the storage system [34]. ZECC can be constructed by the following steps:

- By identifying an elevated level space in the ZECC along with the facilities of proper water supply in the storage system [35].
- The measurement of the floor should be appropriate. The layout of the cooling system can be constructed with bricks [36].
- The gap between the two walls of the cooling system should be filled with sand [37].
- The sand which is used to fill the gaps of the walls should be used after soaking it in water [38].
- It is very important to protect the ZECC from direct sun or rain. The top of the cooling chamber should be covered by using Bamboo straw and other locally available materials [39].

Dry bonding farm bricks are used to construct the walls of the test unit [40]. A puncture hose pipe is used to make the sand wet. The pipe is connected with a water reservoir [41]. During the test period, the reservoir was filled with approximately 80 l water every morning to facilitate the flow of water through gravity [42].

Measurement of Temperature and Humidity of the ZECC

These two units play major role in the storage of fruits and vegetables in ZECC. The unit was tested by measuring the changes in temperature and humidity. It can be measured with the help of two Hairuis temperature and humidity data loggers (model DWL-20E). Minimum and maximum temperatures and humidity over a 7-day period should be recorded for each season on an average basis [43].

Determination of Colour Changes and Firmness of the Stored Food Products in ZECC

The physical characteristics of the stored food product and the procedure of storage are mainly responsible to determine the color changes and firmness of the product [44].

RESULT AND DISCUSSION

Advantages of using ZECC: Following are Some Advantages of Using ZECC

The zero-energy cool chamber (ZECC) is an eco-friendly, energy saving and cost-effective alternative substitute of electric refrigeration [45]. ZECC does not require electricity for its operation, so it saves a lot of energy. This cooling system can be easily constructed in rural areas [46]. ZECC can maintain fruits' (such as mango) quality and extend its shelf life; therefore it can be used as a temporary storage structure for fruits [47, 48]. The work pattern of ZECC can be calculated by using neural networks and genetic algorithms. ZECC maintains better quality of the stored fruits and vegetables than cold storage [49]. It is very effective in extending the shelf life of fruits and vegetables like potato, tomato, brinjal, mango, banana, and spinach. The firmness and titratable acidity were minimum in the fruits which are harvested with pedicel and stored under ZECC [50]. The shelf-life of the fruits stored in ZECC with attached pedicel could be enhanced to about 90 days [51].

Disadvantages of using ZECC

Sometimes fungal and insects attack the stored products in the ZECC because of improper storage system and if the ZECC is made with bad quality products. The cooling rate of ZECC is slower than refrigerator [52]. The operation of ZECC relies on a reliable source of water throughout the year, so sometimes the performance of ZECC is hampered due to insufficient water supply.

DISCUSSION

Although ZECC has some drawbacks, but it is also very useful as it does not need any electricity. High ambient temperature reduces the water content of the products stored in ZECC, decreases the shelf-life of the food products and due to this, a consequent spoilage of the products can also occur in due course of time. To overcome all of these problems, a low construction cost and eco-friendly storage system is used. These types of structures can be easily constructed in rural areas as it is made up with

locally and easily available low-cost materials such as brick, sand etc. Temperature and relative humidity are two important environmental factors that play a major role in this type of storage system. It is viable to use ZECC storage in a semi-arid region to retain the freshness for longer time of the products stored in it.

With improved technology, easily and low-cost maintenance, Zero Energy Cool Chamber reduces the spoilage of fruit and vegetables stored in the ZECC, especially in the remote villages of India where people cannot afford costly storage systems. ZECC is based on the principle of evaporation technique. ZECC is cheap and portable. It also maintains the shelf life of the stored fruits and vegetables. Poor farmers can easily use it due to its low construction cost.

CONCLUSION

The zero-energy cool chamber (ZECC) is eco-friendly as it is mainly made with reusable and natural materials; it is an energy saving and cost-effective cooling system which is a very good and alternative substitute of refrigeration. As ZECC does not require electricity for its operation, it saves a lot of energy. Rural people can easily make it as it can be made up with brick, sand etc. The working pattern of ZECC is based on evaporation technique. It is a cheap and portable storage system which is ideal for the remote and rural areas where people struggle to keep their produce fresh.

There is big scope for study for storage of different types of vegetables and fruits for different regions and its suitability by using Zero Energy Cool Chamber. From various reviews of literature and all the methods, it has been observed that ZECC plays a major role in increasing the shelf life of fruits and vegetables.

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