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Study on Zero Energy Evaporative Cooling Chamber for Agricultural Products Storage

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ABSTRACT: *Post-harvest agricultural products are highly perishable due to containing higher moisture contents. Most of agricultural product need special storage like relatively low temperature and higher relative humidity to store for some time duration. In this regard, low cost Zero-energy cool chamber (ZEC) is constructed through locally available material for short-term storage of products. Thermodynamic evaluation of ZEC is mainly investigated by measuring its temperature and relative humidity in comparison with Outside/Ambient (OS) and Room (RM) conditions and its performance is based on evaporation rate that take place through medium. The cooling efficiency of ZEC is then determined under varying ambient conditions. The average temperature and relative humidity difference measured between ZEC and OS about 9°C and 45% respectively. Different analyses are performed including the comparison of physiological weight loss (PWL) and visual appearance (VA) for stored tomatoes at different three environmental conditions such as outside (OS), room (RM) conditions and zero energy cool chamber (ZEC). These analyses are performed on 1st, 4th, 8th, 12th, 16th, 20th, 24th, 28th, 32nd, 36th and 40th days of storage.*

Keywords: ZEC; Cooling efficiency; Tomato; Fruit quality.

1. INTRODUCTION

Fruit and Vegetables growing in developing countries like Pakistan are highly rich in vitamins, minerals and are highly perishable in nature. These nutrients are very important in development and proper growth of normal human body. Mostly, agricultural products contain fibers which are important for proper ingestion of diet. Deficiency of these vitamins and minerals in human body lead to the vast spread of diseases which weaken the human body and lead to death. [1]. So, they are important portion of a balanced diet for human beings. Moreover, it is estimated that one fifth of all food manufacturing and processing units have major source of their raw materials from fruits and vegetables to convert into beneficial product items [2]. The fruits and vegetables are harvested during the short duration in a year. But, the need of these products remains throughout the year.

Most of agricultural products contain high moisture content (60-95%) as compared to other dry material. Due to this, agricultural products behave like living organisms and perform respiration, transpiration and fermentation processes [3]. To maintain the freshness and quality of products, rate of moisture contents loss in shape of respiration from the products should be in control. Harvested products need special storage condition with respect to water and others contents. Most of agricultural product need relatively low temperature and higher relative humidity to store them for some time duration. The storage these perishable products is one of the critical problems especially at farm level for smallholding farmers [4]. Deterioration of agricultural products especially during the peak season is very high due to poor processing, insufficient and inefficient storage facilities [5,6]. A large amount of the products, we are wasting every year because spoilage takes place immediately just after harvesting [7]. Moreover, various studies provided by the authors regarding low-cost evaporative cooling systems for various applications and food security challenges are available in literature [8–12].

Refrigeration is one of the preservation methods to provide cooling to agricultural products. Cooling through refrigeration is mostly applied on the farm to control environment in cooling structures. But, refrigeration is expensive and hazard to environment [13]. Moreover, smallholding farmers not have enough capacity to buy, install and run the refrigeration system [14]. Therefore, a low cost, environmentally friendly and zero energy evaporative cooling chamber is developed in this study for short-term agricultural products storage.

2. EXPERIMENTS AND METHODOLOGY

The experimental setup of ZEC is constructed at Department of Agricultural Engineering, Bahauddin Zakariya University (30°15′49″N, 71°30′35″E), Multan, Pakistan. This region lies in arid climate. Where, in summer season temperature reach about 50˚C and minimum 30% relative humidity observed. ZEC is constructed with locally available materials sand, bricks, bamboos and jute cloth. The outer and inner wall of ZEC having dimension Length (L) =1.52 m, width (B) =1.07 m and height (H) = 0.61 m and Length (L) = 1.11 m, width (B) = 0.49 m and height (H) =0.61m, respectively. The leaved space 4 inches (0.1016m) between the two walls filled with uniform sand. ZEC is constructed in rectangular shape and the total volume space for the product storage is 0.33 m^3. The performance of ZEC is mainly investigated with inside and outside temperature and relative humidity of ZEC. Moreover, green uniformly graded tomatoes are selected for storing in order to check the performance of ZEC towards the agricultural products storage. Tomatoes are stored at different three conditions (i) inside zero energy cool chamber (ZEC), (ii) outside (OS), and (iii) room (RM) conditions. During the storage period, different physio-chemical analyses are performed to investigate the quality attributes. The analyses include the psychological weight loss (PLW), visual appearance (VA), total soluble solids (TSS), titratable acidity (TA) and pH for the stored tomatoes. These analyses are performed on 1st, 4th, 8th, 12th, 16th, 20th, 24th, 28th, 32nd, 36th and 40th days of storage. Temperature and relative humidity in the ZEC,

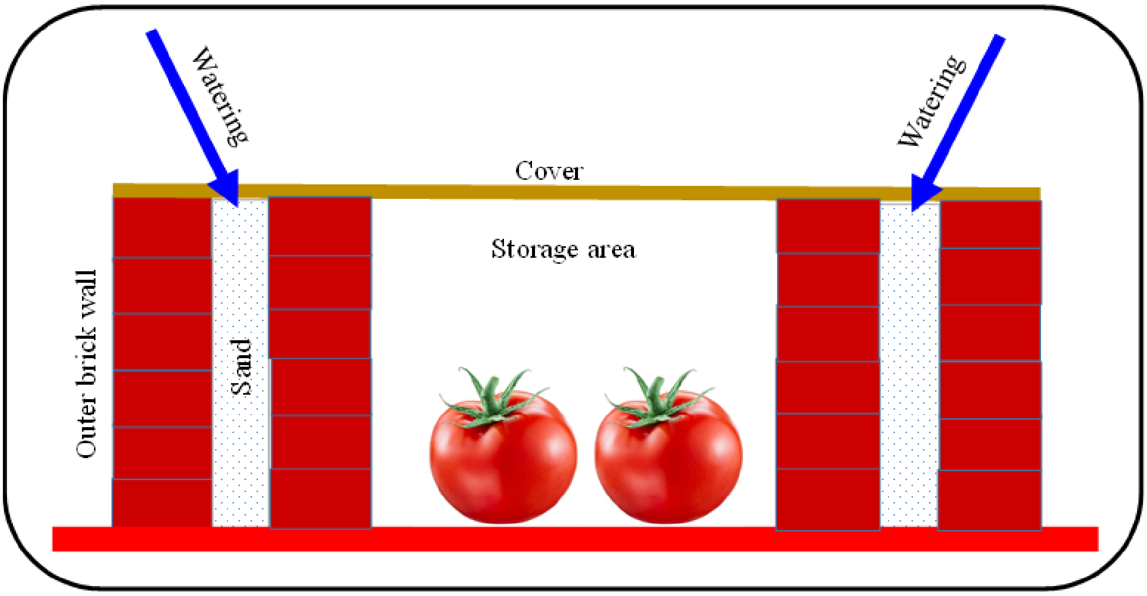

Fig. 1. A schematic description of zero energy cooling chamber (ZEC).

OS and RM are measured through the temperature/humidity sensor. Moreover, refractometer, pH meter and titration methods are used determine the total soluble solids, pH and titratable acidity, respectively.

3. RESULTS AND DISCUSSION

The cooling performance of Zero Energy Cool Chamber (ZEC) is based on evaporation rate that take place through cooling medium. Thermodynamic evaluation of ZEC is mainly investigated by measuring its temperature and relative humidity in comparison with Outside/Ambient (OS). Physio-chemical analyses are established in order to evaluate the quality of stored tomatoes. Physio-chemical analyses include the comparison PWL, VA, TSS, TA and pH for stored tomatoes at different three conditions such as outside (OS), room (RM) conditions and zero energy cool chamber (ZEC).

The variation in temperature and relative humidity profiles of ZEC, OS and RM are presented in **Error! Reference source not found.** and **Error! Reference source not found.**. The highest and lowest temperature inside of ZEC was measured as 31.05°C and 28.80°C, on 4th and 25th of July, respectively as shown in **Error! Reference source not found.**. Accordingly, the average inside temperature of ZEC was found 29.86°C when average OS temperature was 38.73°C. The average maximum/minimum temperature of OS and RM were measured as 41.38°C/32.5°C and 34°C/30°C, respectively. Referring to Figure 2, the average temperature difference between ZEC and OS was measured about 9°C. Ndukwu et al. [15] reported the temperature difference of 8.2°C in ZEC as compared to outside environmental condition. In another study, Chinenye et al. [16] measured the temperature difference of 10°C between the ZEC and OS condition.

The variation of relative humidity in ZEC, OS and RM are shown in **Error! Reference source not found.** which resulted that relative humidity of ZEC remained higher as compared to OS and RM condition. The maximum RH measured in ZEC, OS and RM was 97%, 68% and 78%, respectively. In an another study, Jahun et al. [17], RH inside the ZEC is reported 93% as compared to OS. Moreover, the average RH difference between ZEC and OS in the month of July measured as 45%.

The decrease in temperature and increase in relative humidity inside ZEC with respect to Outside (OS) conditions, due to evaporation through media, are used to calculate the cooling efficiency of ZEC. The calculated cooling efficiency of ZEC during the fruit storage presented in Figure (6). Cooling efficiency of cool chamber remained in range between 84% to 97% with the average value of 90%.

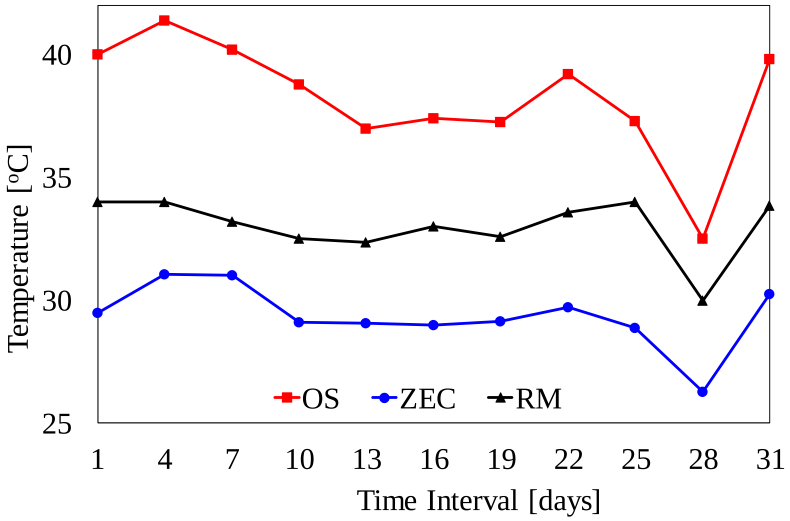

Fig. 2. Profile of temperature of ZEC, OS and RM.

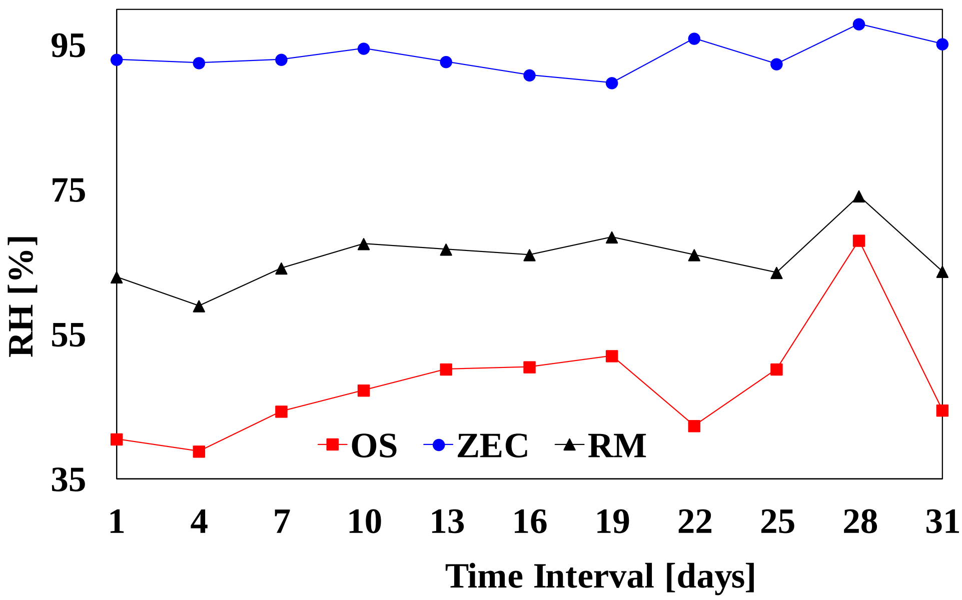

Fig. 3. Profile of relative humidity of ZEC, OS and RM.

Visual appearance is important to note the freshness of tomatoes by visualization. Mostly visual appearance is used to check freshness of tomatoes for selling and as for eating quality. The observation of study concluded that, the change in color of tomatoes took place immediately in some days stored in OS and RM as compared with stored in ZEC shown in Figure 4. It is due to rapid microorganism activity and greater production of ethylene from tomatoes stored at OS and RM which lead to the faster repining [18,19].

Tomatoes are highly perishable product due to containing higher moisture contents. The freshness of tomatoes is generally determined by its water contents. If water is present in high percentage, tomatoes will be fresh otherwise may shrivel under outside environmental condition. The shriveling of tomatoes leads to decrease in weight. Three equal weight of tomatoes are stored at OS, RM and ZEC. The physiological weight loss (PWL) of tomatoes is measured using Equation (3). The variation in PWL for different environmental conditions is shown in Figure (7). It is measured, on the 4th storage day, as 2.4%, 11.4% and 13.6% in ZEC, RM and OS, respectively. On 8th day of storage, total PWL increased to 5.5%, 20.9% and 31.4% for tomatoes stored at ZEC, RM and OS conditions respectively. Moreover, on the 12th day of storage, PWL increased to 6.95%, 29.52% and 48.4% stored at ZEC, RM and OS respectively. These results are almost within the range of other studies: Olosunde et al. [20] , reported the PWL after 3rd storage day as 1.38% and 14.5% in ZEC and OS, respectively. Moneruzzaman et al., [21] also reported the PWL as 6.28% and 13.31% on 3rd and 12th day of respective storage. Therefore, such variation in PWL under different storage conditions (OS, RM and ZEC) is due to the corresponding temperature and relative humidity, as also reported by [5,22]. The measurement of PWL is further extended to rest of storage periods.

In this regard, on 16th day of storage, PWL is measured as 8.1%, 38.57% and 65.3% stored at ZEC, RM and OS conditions, respectively. Later, on 20th day of storage, the PWL measured 10.5%, 52% and 87% for product stored in ZEC, RM and OS, respectively. Thus, the tomatoes stored in OS become spoiled after 20th days due to higher PWL (87%). In this regard, Getinet et al. [23] reported that tomatoes decayed as percentage in PWL increased above 85%. Olosunde et al. [20] reported the PWL of tomatoes stored in ZEC as 10.25 % after 21 days. On 24th day of storage, the PWL is increased to 11.75% and 62.6% stored at ZEC and RM, respectively. The PWL of tomatoes stored in RM condition increased to 74, 84 and 89% of original weight after respective 28th, 32nd and 36th days of storage, respectively. Therefore, tomatoes stored in RM also become spoiled after 32th days due to higher PWL (85-89%). The PWL of sample stored in ZEC increased to 13%, 16%, 18% on 28th, 32nd and 36th days of storage, respectively. However, Getinet and Seyoum [24] reported the PWL of 19% for green tomatoes stored in evaporative cooling chamber after 32 days. The PWL of tomatoes in ZEC increased to almost 20% of the original weight on 40th storage day. The PWL calculated minimum for tomatoes stored in ZEC as compared with storing at RM and OS condition. It is due to higher shriveling rate for OS condition as for ZEC due to difference in temperature Javanmardi and Kubota [25]. The lower temperature and higher relative humidity inside the ZEC results in lower PWL Moneruzzaman et al. [21] as compared other studied conditions. It might be due to the slow transpiration rate of stored tomatoes in the ZEC as reported by [18,25,26]. The PWL is also depend upon the storage temperature [27].

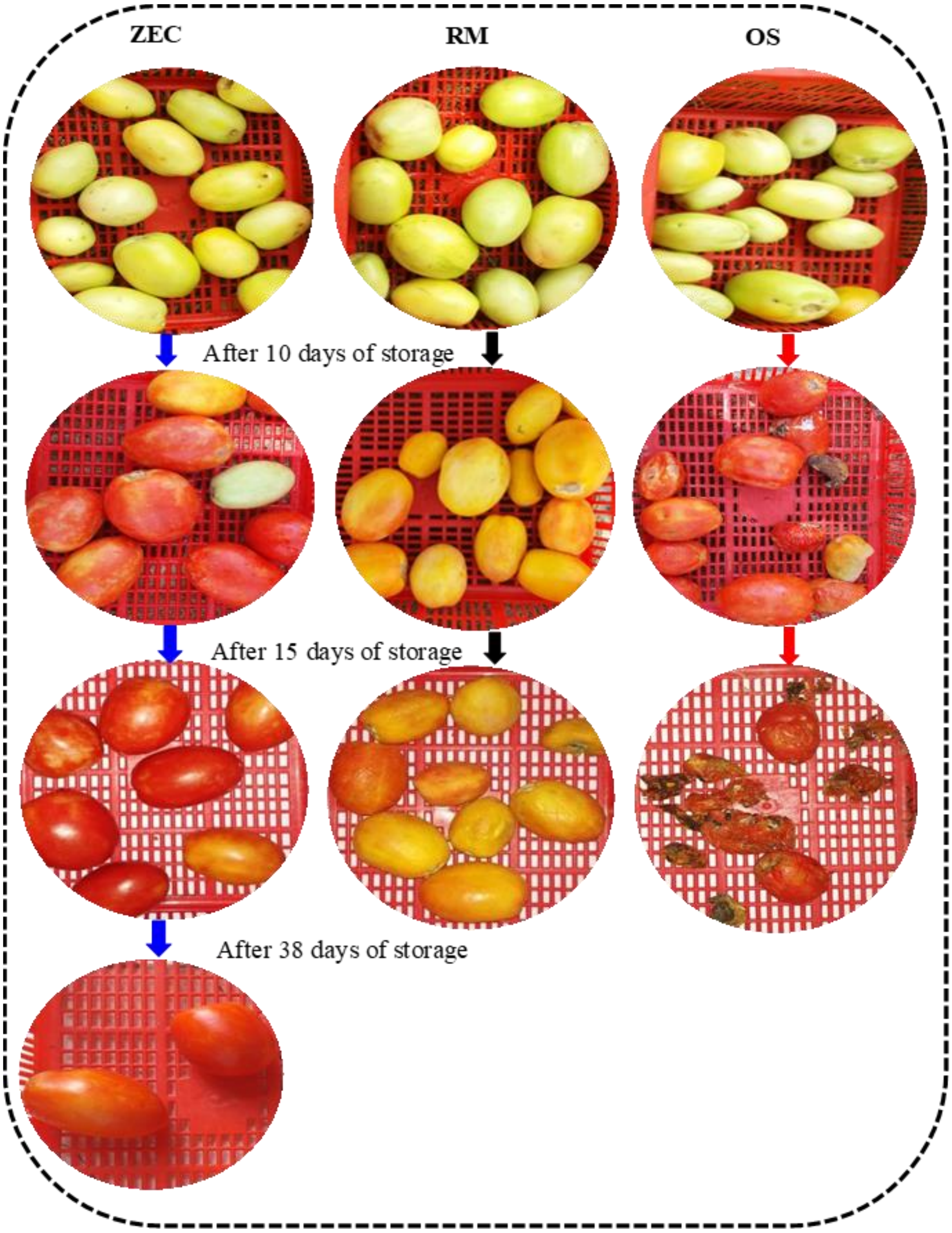

Fig. 4. Variation in color profile of stored tomatoes under different conditions in ZEC, ambient conditions, and room conditions.

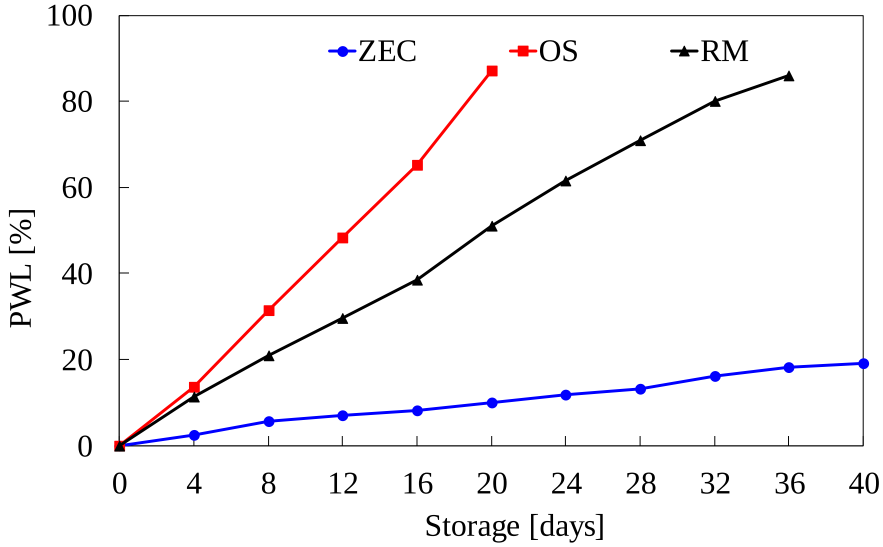

Fig. 5. Profile of PWL for stored tomatoes in ZEC.

4. CONCLUSIONS

In this study, the zero-energy cooling chamber (ZEC) was studied for the potential storage of agricultural products (specifically tomatoes) was experimentally studied and thermodynamically analyzed for the climatic conditions of Multan (Pakistan). The ZEC system was constructed with locally available material which has the potential for short-term storage of agricultural products at farm level to enhance the post-harvest storage life of the agricultural products. The ZEC system generated temperature gradient which remained lower than ambient conditions throughout the testing period as compared to outside ambient (OS) and room (RM) conditions. On the other hand, its relative humidity measured higher than other studied conditions (OS and RM). It is concluded that ZEC decreases the temperature up to 10-12oC as compared to OS. The lower temperature and higher relative humidity (85-90%) of ZEC slow down the physiological weight loss. It also controls the chemical parameters for qualitative and nutritive storage of tomatoes.

Conflict of interests

The authors declare no conflict of interests.

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