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Testing and Evaluation of Double Layer Evaporative Cooler for Vegetables Preservation in North

Chamal, B.M., Prabhaharan, M. and Thusahanthy, A.
Department of Agricultural Engineering, Faculty of Agriculture, University of Jaffna, Sri Lanka.

Abstract: Sri Lanka is faced a problematic issue of post- harvest preservation and processing of agricultural produces. Introduction of cost effective method for storage of vegetables is necessary to maintain freshness until marketing. The evaporative cooling principle was introduced under the construction of cooling chamber system. Therefore low cost zero energy double layer cool chambers were designed using clay bricks, anthill clay. Space between double layers was filled with saw dust and charcoal separately and water circulated from top to bottom. The cool chambers were made to enhance the shelf life and minimize the weight loss of vegetables. Temperature and relative humidity inside and outside of chamber were measured in hourly intervals in day time. The samples of Spinach, brinjal and carrot were selected for evaluation. Weight loss was measured at hourly intervals to check the effectiveness of the design. Physiological weight loss for all selected vegetables was low for samples placed charcoal media cool-chamber than the saw dust media cool-chamber than outside. Evaporative cooler design tested by the regression analysis was implied to fit the relationship between log mean temperature ratio against time duration of cooling in saw dust media and charcoal media cool-chambers. The cooling rate (CR) was expressed by the equation, respectively. The relationship derived to charcoal media cool-chamber was $y= -0.015x + 0.063$ with regression value of R is 0.978 and saw dust media cool-chamber $y = -0.033x +0.079$ with regression value of R is 0.856. The cooling rate and efficiency were higher in charcoal as a filling media cooler. Since the regression value was more than 80%, in the both design. Design evaporative coolers are satisfied the requirements of safe storage.

Keywords: Evaporative cooler, Zero energy cooler, Double layer cool chamber.

Corresponding Author: M.Prabhaharan, aenpraba@gmail.com

Introduction

We all need vegetables in our daily requirements. Vegetables are perishable in nature so it grown and sold timely. When vegetable reaches the market it accommodate a lot of post-harvest process or operation like assembling, grading, storage, transportation and distribution. Huge postharvest losses can be minimized to a certain level by creating appropriate facilities for storage. Various types of storage structures and techniques have evolved with time to certify appropriate storage conditions. Most of them are still practiced to ensure safe storage and timely supply of vegetables. (Sharma, 2016).The respiration rate of a product strongly determines its postharvest life. The field heat of a freshly harvested crop is usually high, and should be removed as quickly as possible. Therefore, pre-cooling is depends in good temperature management. After harvest temperature is the single most important factor in maintaining quality in the storage of fruits and vegetables. The relative humidity is also important of the storage unit directly influences water loss in produce. Most fruit and vegetable crops retain better quality at high relative humidity (80–95 %). The cool temperatures in storage rooms help to reduce disease growth, but sanitation and other preventative methods are also required (Simon, O. and Odey, 2012).

Basically, evaporative cooling storage facility can extend the shelf life of vegetables for quite period of time if it is well designed and constructed. Evaporative cooling is the cheapest and simplest method as well as more efficient way for preserving vegetables (Kamaldeen *et al*., 2013). Evaporative cooling happens when dry hot air passes over a wet surface and the cooling efficiency depends on temperature, relative humidity and evaporation rate of the air around the facility (EL-dessouky *et al*., 2004). The evaporative cooled storage structure has proved to be useful for short term, on-farm storage of fruits and vegetables in hot and dry regions (Chopra, 2006). Good storage condition can be provided to vegetable produce through the use or adoption of evaporative cooling system. Consequently, there is need for simple and cheap means of preservation, such as evaporative cooling which is simple and does not require any external power supply (Tabrez and Chaurasia, 2014).

Specific Objective

To investigate the designperformance of double layer evaporative cooler for vegetables preservation.

Materials and Methods `

Site Selection for Experiment

The research was carried out at the Department of Agriculture Engineering, Faculty of Agriculture, University of Jaffna, Ariviyal Nagar, Kilinochchi, Sri Lanka.

Preliminary Data Collection on Meteorological Parameters

The study was conducted during January to July 2019. In Kilinochchi District varies from, mean monthly average rainfall in 12.5mm and 21.1mm , the average temperature /distribution is 23 ^{0}C and 26 ^{0}C and average relative humidity is 47% and 41%. Vegetables such as Brinjal, has high moisture content nearly 92% Spinach, Carrot has nearly 87% of moisture content and thin skin surface (Bastin, 1997).

Design Description

This research describes the improved design of cool chamber with its performance for preservation of vegetables with incorporation of locally available bio materials. In the initial study, a double walled cool chamber (double wall) based on evaporative cooling principle was constructed (Chaurasia *et al.,* 2002). The cool chamber utilized the water evaporation from the surrounded walls (vertical walls only) for the reduction of temperature hence which maintains high humidity. The data of temperature and humidity were recorded in different periods.

The cool chamber was also tested for storage of vegetables as compared to store in room. Further design of the cool chamber was improved by making the holes in both chambers by using drillers. These holes increased the evaporation rate of the cool chamber for faster cooling. Provisions were also made for water evaporation from both side of the cool chamber by providing suitable paths which further enhanced temperature reduction and retained high humidity in the chamber. Two cuboids double layer cooling chamber were built with same dimensions on the stage using clay and clay bricks. They were like tanks but they had double layers and there was spacing in between of double layers. The spacing between walls was filled with Sawdust for one cooling chamber and other chamber with Charcoal. The drainages were made on the top of those insulate materials to supply water.

Foundation of Cool Chambers

The shed was constructed using black polyphone and white gunny bags. The frame of the shed was made using box bar and wooden. This structure was permanently built using clay bricks with clay floors. First floor was built using one layer of bricks. Basement was built with length, width and height 210, 110 and 10 cm respectively. Outside of the basement was covered by clay. Both of cool chambers were built above the clay stage.

Double Layer Brick Wall

Clay bricks were used to build double layer walls. Clay bricks are having good properties of high porosity, good heat absorber and good surface for evaporation, and also easily available and cheap. The height of walls are 50 cm. 10 cm gap was madebetween inside and outside walls. Sawdust and charcoal was filled the gap between the vertical walls up to 50 cm. The walls were constructed by using clay instead cement. It was graphically explained in Plate 1

Plate 1: Fabricated double-Layer evaporative Cool-Chambers

Sample Selection and Preparation

The chamber was sterilized by 200 ppm chlorinated water. Water was supplied to the cool chamber two times per day, 10 minutes is enough to saturate the porous layers by water circulation. Sample were stored as two methods in both of cool chambers separately. Samples were wrapped using wrapping papers. Other samples were kept without wrapping. Three replicates were used for both methods to correction of data analyzing.

Temperature and Relative Humidity Measurement

The temperature was measured by using wet and dry bulb thermometers. The temperature at all places in the Cool-Chamber was at the same time measured. The temperature at the middle layer was used as the inside temperature. The thermometer was placed at outside the cool chamber to measure outside temperature. The relative humidity of the Cool-Chamber was measured using "Psychometric Chart". All the temperatures were recorded at an hourly interval from 8.00 am to 5.00pm.

Determination of the Physiological Weight Loss (PWL)

Vegetables were kept in cool chambers as 2 types such as wrapping and unwrapping. Rapping polythene papers were used to rapping the vegetables. Digital electronic balance was used to get weight of vegetables. The readings were collected as daily interval. Charcoal and sawdust chambers data were collected separately.

***Physiological Loss in Weight** = (X1-X)/X1*10*

Where *X1*- Initial weight of vegetable (g), *X*- Weight of vegetable at the next day (g).

The brick layers filled with saturated charcoal and sawdust were supplied moisture therefore inside air is saturated by water vapour coming from saturated charcoal and saw dust. It helps to keep inside air cool. The atmospheric relative humidity did not affect the chamber relative humidity. RH values are calculated normally using below equation.

$$\text{Relative Humidity} = \frac{\text{Amount of moisture in the cool chamber (m)}}{\text{Maximum amount of moisture that could exist in the Cool Chamber at a speci*ictemperature (M)}}$$

Temperature Ratio (CR)

Temperature ratio (CR) was calculated against proper time interval during cooling operation using flowing equation. The cooling rate was expressed by slope of the equation respectively. The regression vale was explained the efficiency of cooling.

Temperature Ratio (CR)= (Temperature at time (Db) – Ambient Tem (Db)) / (Initial Tem(Db)) - Ambient Tem (Db))

Results and Discussion

Temperature and Relative Humidity Variations

The relationship between temperature profile inside of cool chambers and ambient condition during experimental period (Figure 1 and 2). The temperature difference was high during noon because of high external temperature due to high solar intensity. Range of average temperatures inside Cool-Camber varied from 22°C to 24°C while ambient air temperature varied from 24°C to 31°C. Around 2 – 7^0Ctemperature gradient was recorded in sawdust mediacoolers throughout the experiment Figure 2.Range of average temperatures inside charcoal media Cool-Camber varied from 22°C to 24°C while ambient air temperature varied from 21.4°C to 22.5°C. Around 2.6 – 8.5°C temperature gradient was recorded throughout the experiment Figure 3.

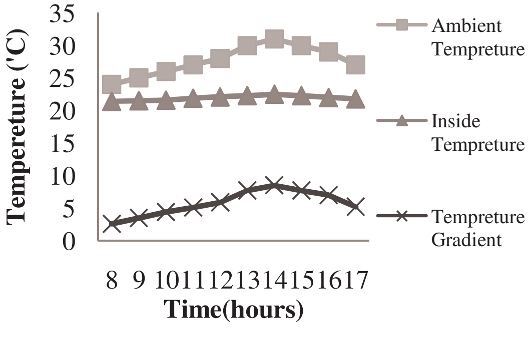

Figure 1: Temperature profile in sawdust cool-chamberand ambient condition

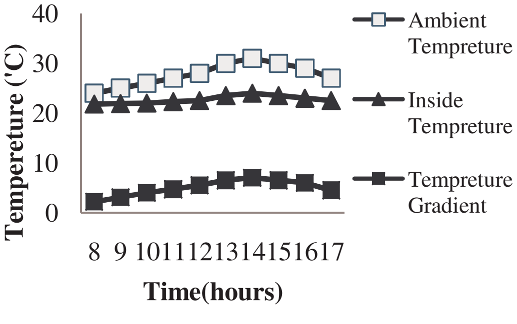

Figure 2: Temperature profile in charcoal cool-chamber and ambient condition.

Variation of Relative Humidity and RH Gradient in Saw Dust and Charcoal Chamber

The relative humidity of inside the Cool-Chamber varied from 85.75% to 94.89 % .while the outside RH varied from 79.41% to 91.96%.The RH gradient between inside and outside the sawdust Cool-Camber was found to be 2.93 % to 10.48%. These differences are shown in Figures 3 and 4. The Cool-Chamber inside relative humidity varied from 94.15 % to 97.43 % .while the outside RH varied from 79.41% to 91.96%. The RH gradient between inside and outside of the charcoal media Cool-Camber was found to be 3.73 % to 15.63%.

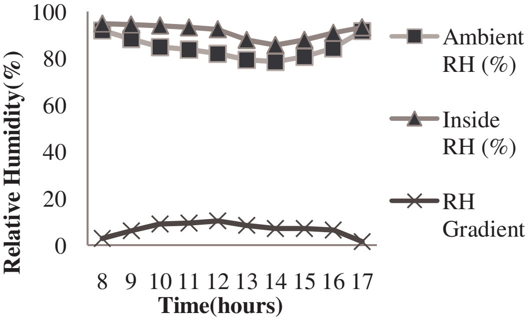

Figure 3: Relative Humidity in sawdust cool-chamber and ambient condition.

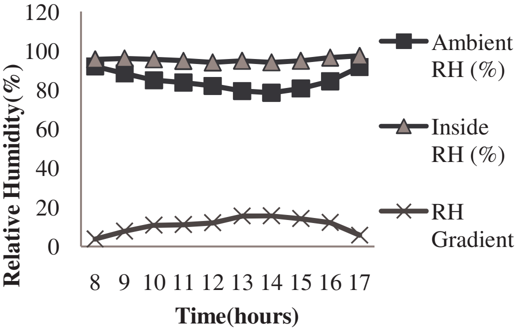

Figure 4: Relative humidity in charcoal cool -chamber and ambient condition

Physiological Weight Loss

Average weight loss of sample kept in Saw dust chamber is significantly different from the sample kept under Charcoal Chamber. Since there is a temperature difference between Cool-Chamber and ambient, weight loss of samples kept under restricted condition is low and this gives for samples fresh in appearance. Relationship between average weight loss percentage and keeping time kept under Saw dust and Charcoal Chambers. Significant difference in found in losses in weight between samples stored in Saw dust and Charcoal Chambers. When wrapped, the vegetables moisture loss of vegetables became low (Figure 5).

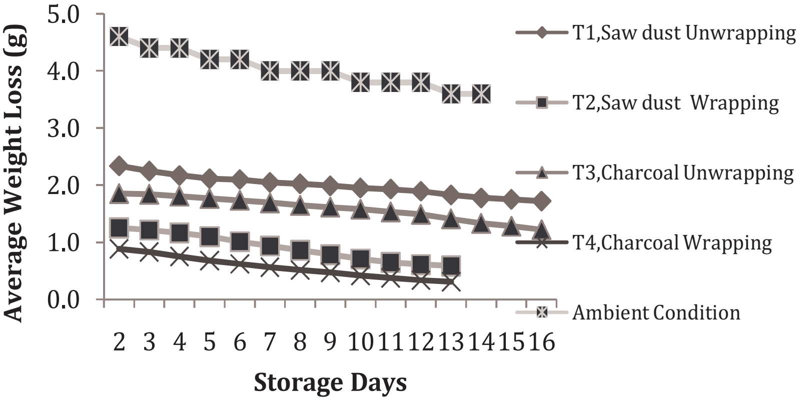

Figure 5: Weight losses pattern of selected Vegetables

When without wrapping condition Vegetables shelf life was increased than wrapping condition. Loss of moisture content is high at sawdust media cool-chamber Loss of moisture content is high at sawdust media cool-chamber, without wrapping in the beginning of storage due to fast respiration rate. It leads to higher weight loss percentage and it reduces thereafter due to the reduction in moisture content. Weight loss percentage of vegetables is nearly constant in both of chambers due to proper conditions for storage developed by water circulation.

Evaporative Cooler Performance Analysis of Saw Dust and Charcoal Media Chamber

The cooling rate was calculated by slope of the equation respectively (Figure 6 and 7). The regression vale was explained the efficiency of cooling. The relationship derived to charcoal media cool-chamber was $y = -0.015x + 0.063$ with regression value of 0.978 and saw dust media cool-chamber $y = -0.033x + 0.079$ with regression value of 0.856.The cooling rate and efficiency of cooling was high charcoal as filling media within double layer coolers. Since the R^2 value was more than 80%, the efficiency and design satisfy the requirement of dryer.

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