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# DEVELOPMENT AND PERFROMANCE EVALUATION OF EVAPORATIVE COOLING STORAGE SYSTEMS FOR HORTICULTURAL PRODUCE

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## ABSTRACT

Different types of evaporative cooling systems were designed, developed and fabricated at Indian Institute of Horticultural Research (IIHR), Section of Agricultural Engineering, Bengaluru. The Evaporative cooling (EC) systems *viz.,* mud pot in pot, almirah cooler, mud pot with ventilation holes, almirah cooler with coir pith insulation, almirah cooler with charcoal insulation. The basic structure was almirah cooler made out of 60 x 60 x 60 cm mild steel structure with storage capacity of 50-60 kg of vegetables. The water tub was made out of galvanized iron sheet having volume about 0.048 $m^3$ (40-45 L). Experiments were conducted to study the keeping quality and shelf life of selected vegetables namely, french beans, carrot, okra, tomato and amaranth during summer and winter seasons, respectively. Almirah cooler with charcoal insulation was found to be the best system during winter and summer seasons. The maximum drop in temperature and relative humidity during winter and summer seasons for the best cooling system (Charcoal cooler) were found to be 1-5 ºC coupled with 20-35%, as well as 7-9 ºC coupled 45-55%, respectively. The shelf life of the charcoal cooler increased from 2-5 folds when it is kept under EC system.

## INTRODUCTION

India is the first largest producer of fruits and second largest producer of vegetables in the world. The varied agro-climatic conditions provide an enormous scope for the cultivation of a wide range of horticultural produce. As per the National Horticulture Database published by National Horticulture Board (NHB), during 2012-13, India produced 81.285 million metric tonnes of fruits and 162.19 million metric tonnes of vegetables. The area under cultivation of fruits stood at 6.98 million hectares while vegetables were cultivated at 9.21 million hectares (Bijay, 2013), which is about 18% of gross agricultural output. But unfortunately, a sizeable portion of above produce is lost in food cycle before reaching the consumer. It has been estimated that the post-harvest losses of horticultural produce in India are as high as 30% and the monetary value is about Rs. 44,000 Crores/Annum (Anon; 2009). One of the reasons for post-harvest losses is lack of proper storage facilities.

Farmers and traders still practice their age-old storage methods leading to large-scale wastage during storage and transportation. Traditionally, after harvest, most of the fruits and vegetables are kept in temporary wooden/bamboo huts constructed near the residential buildings or production catchment. In the warm plains of India, fruits and vegetables are stored in pits or cool dry rooms with proper ventilation on the floor or on bamboo racks. Inside the hut, fruits and vegetables are kept on floor or over racks and covered are with straw or plant leaves to avoid exposure to the atmosphere. By this method fruits and vegetables can be stored for few days without much damage and farmers sell it in local village weekly market according to their financial needs. Several simple practices are useful for cooling and enhancing storage system efficiency wherever they are used, and especially in developing countries, where energy savings may be critical. Mechanical refrigeration is, however, energy intensive and expensive, involves considerable initial capital investment, and requires uninterrupted supplies of electricity which are not always readily available, and cannot be quickly and easily installed. Available cold storage in India is used primarily for the storage of potatoes. Appropriate cool storage technologies are therefore required in India for on farm storage of fresh horticultural produce in remote and inaccessible areas, to reduce losses.

Low-cost, low-energy, environmentally friendly cool chambers made from locally available materials and which utilize the principles of evaporative cooling, were therefore developed in response to this problem. These cool chambers are able to maintain temperatures at 10-15 ºC below ambient, as well as at a relative humidity of 90%, depending on the season. 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 (Jha and Chopra 2006). Evaporative cooling is an efficient and economical means for reducing temperature and increasing the relative humidity of an enclosure, and has been extensively tried for enhancing the shelf life of horticultural produce (Jha and Chopra 2006; Dadhich *et al.*, 2008; Odesola and Onyebuchi 2009) which is essential for maintaining the freshness of the commodities (Dadhich *et al.*, 2008). Evaporative cooling is an environmental friendly air conditioning system that operates using induced processes of heat and mass transfer where water and air are working fluids (Camargo, 2007). Such a system provides an inexpensive, energy efficient, environmentally benign (not requiring ozone-damaging gas as in active systems) and potentially attractive cooling system (Zahra and John, 1996). The present study was taken up to study the effect of different evaporative cooling systems in increasing the shelf life of the commercially used fruits and vegetables during winter and summer seasons.

## MATERIALS AND METHODS

### Raw material (vegetables)

Matured and fresh good quality selected vegetables (French bean, carrot, okra, tomato) and leafy vegetable (amaranth) were procured from the local vegetable market in Bangalore itself for conducting experiments during winter and summer seasons.

### Temperature and relative humidity measurement

The data logger EQ-171(Ankom International) was used to measure and record the temperature and relative humidity. This sensor had an accuracy in measuring both temperature and relative humidity of accuracy (-40 to -10 and +40 to +70°C) ±2 ºC and accuracy (0 to 20 and 80 to 100%)±5%, respectively. The logger having a capacity to measure from 2 s to 24 h interval either manually or automatically.

### Sensory evaluation

Sensory evaluation is a multi-disciplinary approach that uses human panellists with their senses of sight, feeling to measure the acceptability of fruits and vegetables. The sensory evaluation were carried out regularly through physical appearance. There is no instrument that can replicate or replace the human response making the sensory evaluation. The fruits and vegetables was rated on a nine-point Hedonic scale. Nine points were awarded as like extremely-9, like very much-8, like moderately-7, like slightly-6, neither like nor dislike-5, dislike slightly-4, dislike moderately-3, dislike very much-2, dislike extremely-1.

### Physiological loss in weight (PLW %)

The PLW was measured to know the percent weight loss of the selected vegetables and 10% weight loss was kept as standard to find out the end of the shelf life of vegetables after storage.

$$\text{Physiological loss in weight(\%)} - \frac{\text{Intitial weight - Final weight}}{\text{Initial weight}} X100$$

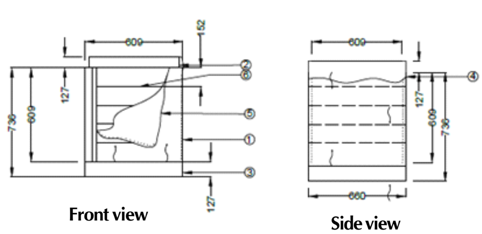
### Storage systems/structures

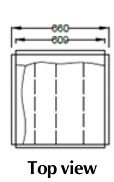
### Mud pot in pot

In this system two mud pots were taken one bigger pot having a diameter of 37 cm and depth of 32 cm and another small pot having a diameter of 28 cm and depth of 25 cm. About 3-5 cm thick sand layer was filled at the bottom surface of bigger pot and smaller pot was kept inside. Sand was filled in the gap between two pots. It acted as an insulation or packing material and cooled the surface of the pot with suitable application of water (10-15 L/day). Approximately 2-3 kg of vegetables were kept inside the smaller pot to determine the shelf life of vegetables.

The pots were completely covered with wet double layer gunny cloth for additional cooling of the pots. The gunny cloths were wetted by spraying water on the surface of the cloth. When gunny cloth was dried out, the change in phase takes place thus, decreased the temperature and increased the humidity inside the system. Data logger was kept inside the system and at ambient to measure and record both temperature and relative humidity at every 30 min time interval. Weight of the vegetables was measured every day and it was recorded. The experiment was conducted up to 10% weight loss of the stored vegetables and number of storage days at this stage was taken as the shelf life of vegetables. Sensory evaluation was carried out every day to know the consumer acceptability. The stepwise operation of mud pot in pot system are shown in Plate 1.

### Mud pot with ventilation holes

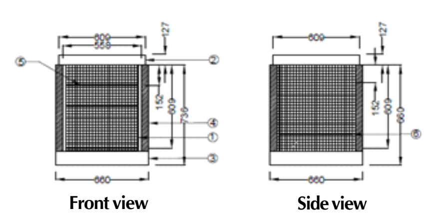


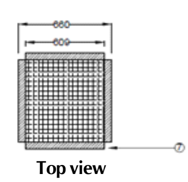




| Part no. | Name | Material used |
|---|---|---|
| 1. | Frame | MS angle |
| 2. | Upper water trough | GI sheet |
| 3. | Lower water trough | GI sheet |
| 4. | Side covering | Gunny |
| 5. | Vegetable storage trays | MS mesh |
| 6. | Mesh | MS mesh |

All dimensions are in mm

**Figure 1. Almirah cooler**

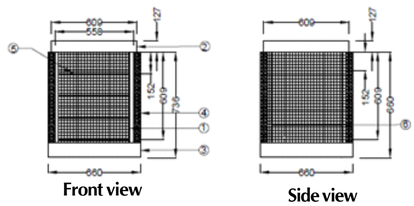


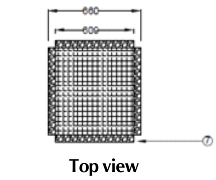




| Part no. | Name | Material used |
|---|---|---|
| 1. | Frame | MS angle |
| 2. | Upper water trough | GI sheet |
| 3. | Lower water trough | GI sheet |
| 4. | Packing material | Corpith |
| 5. | Vegetable storage trays | MS mesh |
| 6. | Mesh | MS mesh |
| 7. | Hinged door | Mesh |

All dimensions are in mm

**Figure 2: Almirah cooler with Coirpith insulation (Coirpith cooler)**




All dimensions are in mm

| Part no. | Name | Material used |
|---|---|---|
| 1. | Frame | MS angle |
| 2. | Upper water trough | GI sheet |
| 3. | Lower water trough | GI sheet |
| 4. | Packing material | Corpith |
| 5. | Vegetable storage trays | MS mesh |
| 6. | Mesh | MS mesh |
| 7. | Hinged door | Mesh |

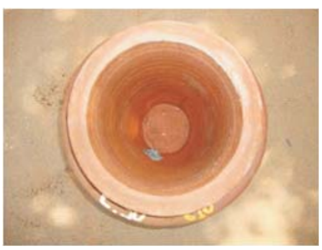
**Figure 3: Almirah cooler with charcoal insulation (Charcoal cooler)**

In this system mud pots which were circular in cross section were taken having diameter of about 23 cm, depth about 7 cm and there were about 10-14 holes at the bottom surface in individual pots for better ventilation. Approximately 1-1.5 kg of vegetables were kept inside each pot and then stacked one above the other.

The pots were completely covered with wet double layer gunny cloth for additional cooling of the pots. The gunny cloths were wetted by spraying water on the surface of the cloth. When gunny cloth was dried out the change in phase takes place thus, decreased the temperature and increased the humidity inside the system. The stepwise operation of mud pot with ventilation holes are shown in Plate 2.

## Almirah cooler

### Structural details



**Outer mud pot**

**Sand filled in gap**

**Keeping inner pot**

**Storing vegetables**

**Keeping data logger**

**Spraying water on sand**

**Covering with gunny cloth**

**Final system**

**Plate 1: Stepwise operation of mud pot in pot storage system**

**Mud pot with ventilation holes**

**Vegetables stored kept in pot**

**keeping vegetables in pot**

**Pots stacked**

**Stacked pots with cap**

**Covering with gunny cloth**

**Final system**

**Plate 2: Stepwise operation of Mud pot with ventilation holes**

Front view of Almirah cooler | Keeping upper water trough | Covering with gunny cloth | Keeping storage trays inside

Storing vegetables | Stored vegetables in trays | Covering front portion | Filled water to upper trough

**Plate 3. Step wise operation of Almirah cooler**

Top view Coir pith cooler | Keeping upper water trough | Keeping trays inside | Keeping vegetables in trays

Stored vegetables in trays | Filling water to upper tr | Covering with gunny cloth | Final system

**Plate 4 : Stepwise operation of Coir pith cooler**

Almirah cooler is basically a vertical stack of the removable trays kept in a mild steel frame of size 60 x 60 x 60 cm and fabricated using MS angle (2.5 cm x 2.5 cm x 6 mm thick). The trays were of size 56 x 56 x 8 cm and made up of MS wire mesh and the vegetables were stored inside these trays. The distance between two trays were (top to top) was 15 cm and there were 4 number of trays in the almirah cooler.

Two water troughs made up of GI sheet were designed, the upper water trough to hold water and the lower water trough to collect water. The overall dimensions of the upper water trough was 60 x 60 x 12.5 cm while (length, width and height) the lower trough was 62.5 x 62.5 x 12.5 cm. The capacity of the water trough was 35-40 L of water can be filled with out spillage. The design details were shown in Figure 1.

The volume of almirah cooler was 0.2085 $m^3$ having a storage capacity of approximately 50-60 kg of vegetables. Gunny cloth was used to cover all the sides of the almirah cooler chamber to have evaporative cooling effect. These gunny cloths were suspended from the upper water trough to the lower water trough. When water was filled in the upper water trough, the water from the upper water trough flowed down to lower water trough due to capillary action and a flow rate of 0.212 L/min was obtained. When the water flowed down it wetted the gunny cloth and air passing through the holes of gunny to get evaporatively cooled surface and thus, maintains the humidity inside the system. The stepwise operation of almirah cooler was given in Plate 3.

**Operation**

Different vegetables were stored in the wire mesh trays of the almirah cooler water was filled in the upper water trough flowed


**Plate 5: Stepwise operation of Charcoal cooler**

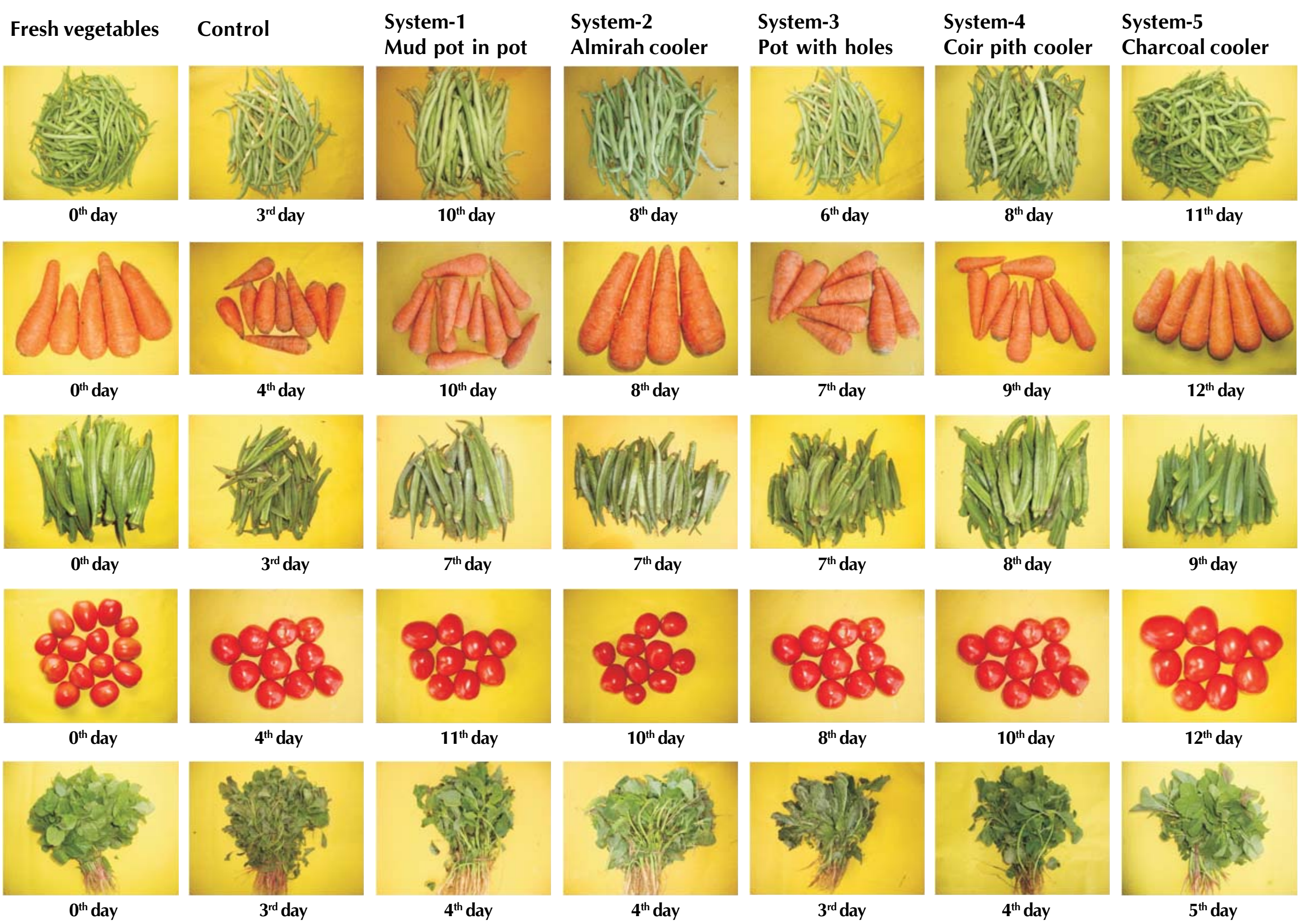



**Plate 6: Comparison of appearance/freshness of vegetables at the end of their shelf life stored under different systems during winter**

to the collector (lower water trough) wetting the gunny cloth. Evaporation of water in the gunny cloth by the passing air reduced the circulating air temperature which ultimately cooled the stored vegetables. The stepwise operations of the almirah cooler was shown in Plate 4.

A data logger was kept inside the system and at the ambient to

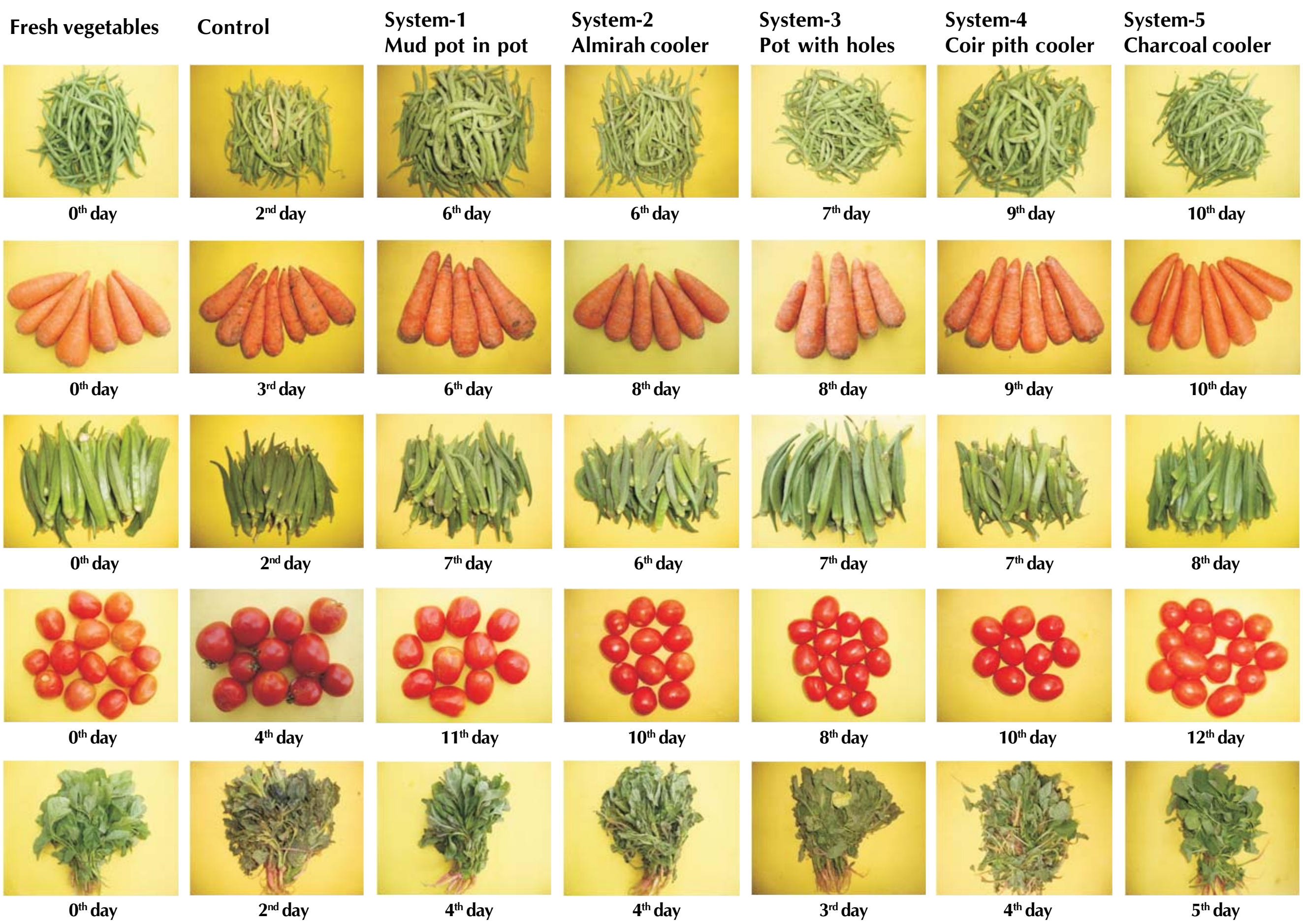



**Plate 7: Comparison of appearance/freshness of vegetables at the end of their shelf life stored under different systems during summer**

measure and record both temperature and relative humidity (RH) for every 30 min time interval. Weight of the vegetables was measured every day. The data were recorded up to 10% weight loss of the stored vegetables and number of storage days at this stage was taken as the shelf life of vegetables. Sensory evaluation was carried out every day to know the consumer acceptability.

### Coir pith cooler

A similar frame like almirah cooler was fabricated, along with that a 5 cm thickness space was provided at the sides of the frame to fill the packing material. Approximately 4-5 kg of industrial coir pith was compressed and filled for better cooling as shown in Figure 2. The operation procedure was similar to that of almirah cooler. The step wise operations of coir pith cooler given in Plate 5.

### Charcoal cooler

A similar frame like almirah cooler was fabricated, along with that a 5 cm thickness space was provided at the sides of the frame to fill the packing material. Approximately 6-8 kg of charcoal was filled for better cooling, as shown in Figure 3. The operation procedure was similar to the almirah cooler. The stepwise operations of charcoal cooler were given in Plate 6.

### Statistical analysis

Descriptive statistics were followed for analyzing the experimental data of the present study. The paired t-test was conducted to determine whether there was a significant difference between summer and winter and also to determine the difference between storage system and control were tested for significance. The data were analyzed for main interaction effects at probability level of 5% and 1% and also standardization was done by drawing one-way ANOVA.

## RESULTS AND DISCUSSION

### Temperature and relative humidity

The average daily temperature and relative humidity of ambient and different EC systems loaded with vegetables during the winter season (November-January) are presented in Table 1. The maximum drop in temperature and increase in relative humidity was observed in almirah cooler with charcoal insulation was found to be 4.89 ºC and 30.15%, respectively. The lowest was observed in alimirah cooler with 1.86 ºC and 25.35%, respectively. The results obtained were similar to the results by Rusten and Eric 2009 and Nadre, *et al.,* 1999, Mordi and Olorunda, 2003, Singh and Satapathy (2006).

**Table 1: Determination of the shelf life of vegetables in different evaporative cooling systems during winter season**

| Storage period, days | 1 | | | | | | 2 | | | | | | 3 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | S1 | S2 | S3 | S4 | S5 | C | S1 | S2 | S3 | S4 | S5 | C | S1 | S2 | S3 | S4 | S5 |
| Temperature (°C) | 23.2 | 20.1 | 21.0 | 21.5 | 20.2 | 19.0 | 22.4 | 20.2 | 20.8 | 21.0 | 20.1 | 18.7 | 24.5 | 21.6 | 22.0 | 22.5 | 21.5 | 19.5 |
| Relative humidity (%) | 62.4 | 98.4 | 95.4 | 93.5 | 95.3 | 96.8 | 66.5 | 97.7 | 94.6 | 92.4 | 95.8 | 95.7 | 64.1 | 96.5 | 93.7 | 93.1 | 94.6 | 96.8 |
| French beans | | | | | | | | | | | | | | | | | | |
| PLW (%) | 3.8 | 0 | 0 | 2.0 | 0 | 0 | 7.2 | 0 | 0 | 3.5 | 0 | 0 | 10.8 | 0 | 0 | 5.2 | 0 | 0 |
| Sensory evaluation (10) | 7.9 | 9.0 | 9.0 | 8.6 | 9.0 | 9.0 | 6.4 | 8.8 | 8.5 | 7.4 | 8.6 | 8.8 | 3.8 | 8.2 | 8.0 | 7.0 | 8.2 | 8.4 |
| Carrot | | | | | | | | | | | | | | | | | | |
| PLW (%) | 1.5 | 0 | 0 | 0 | 0 | 0 | 4.0 | 0 | 0 | 2 | 0 | 0 | 7.8 | 0 | 0 | 4.5 | 0 | 0 |
| Sensory evaluation(10) | 8.0 | 9.0 | 9.0 | 8.8 | 9.0 | 9.0 | 6.8 | 8.7 | 8.6 | 8.3 | 8.7 | 8.8 | 5.6 | 8.2 | 8.1 | 7.8 | 8.2 | 8.5 |
| Okra | | | | | | | | | | | | | | | | | | |
| PLW (%) | 2.8 | 0 | 0 | 0 | 1 | 0 | 6.3 | 0 | 0 | 0 | 2.25 | 0 | 10.2 | 0 | 0 | 0 | 3.5 | 0 |
| Sensory evaluation (10) | 7.6 | 9.0 | 9.0 | 9.0 | 8.7 | 9.0 | 6.2 | 8.7 | 8.3 | 8.2 | 8.5 | 8.7 | 3.7 | 7.9 | 7.6 | 7.5 | 8.1 | 8.3 |
| Tomato | | | | | | | | | | | | | | | | | | |
| PLW (%) | 0 | 0 | 0 | 0 | 0 | 0 | 2.5 | 0 | 0 | 0 | 0 | 0 | 0 | 7.5 | 0 | 0 | 0 | 0 |
| Sensory evaluation (10) | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 8.1 | 8.8 | 8.6 | 8.5 | 8.6 | 8.8 | 5.4 | 8.3 | 8.2 | 7.9 | 8.2 | 8.6 |
| Amaranthus | | | | | | | | | | | | | | | | | | |
| PLW (%) | 4.6 | 0 | 0 | 2.5 | 0 | 0 | 9.8 | 2 | 2 | 5.5 | 2.2 | 0 | ND | 5.5 | 5.6 | 8.9 | 5.3 | 3.4 |
| Sensory evaluation (10) | 7.1 | 9.0 | 8.5 | 7.2 | 9.0 | 9.0 | 3.8 | 7.9 | 7.3 | 6.6 | 8.5 | 8.5 | 3.8 | 6.4 | 6.4 | 4.9 | 7.2 | 7.4 |

C = Control, S = System, ND = Not determined, RH = Relative humidity

**Table 1 : Cont.....**

| Storage period, days | 4 | | | | | | 5 | | | | | | 6 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | S1 | S2 | S3 | S4 | S5 | C | S1 | S2 | S3 | S4 | S5 | C | S1 | S2 | S3 | S4 | S5 |
| Temperature(°C) | 23.5 | 19.8 | 20.4 | 21.2 | 19.7 | 18.4 | 23.6 | 19.4 | 21.1 | 21.8 | 19.8 | 18.3 | 21.6 | 18.2 | 19.4 | 20.2 | 18.8 | 17.3 |
| Relative humidity(%) | 71.3 | 98.8 | 94.6 | 96.3 | 97.6 | 98.4 | 68.7 | 97.6 | 92.2 | 90.6 | 94.1 | 96.8 | 62.5 | 98.4 | 94.3 | 93.2 | 96.4 | 98.0 |
| Vegetables | | | | | | French beans | | | | | | | | | | | | |
| PLW (%) | ND | 0 | 1.0 | 6.5 | 2.0 | 0 | ND | 1.5 | 3.5 | 7.7 | 4.6 | 1.0 | ND | 3.2 | 6.0 | 10.1 | 6.7 | 2.5 |
| Sensory Evaluation(10) | ND | 7.5 | 7.3 | 6.4 | 7.6 | 8.1 | ND | 7.0 | 6.9 | 5.7 | 7.1 | 7.7 | ND | 6.7 | 6.2 | 4.3 | 6.4 | 7.4 |
| Carrot | | | | | | | | | | | | | | | | | | |
| PLW (%) | 10.6 | 0 | 0 | 5.6 | 2.0 | 0 | ND | 1.5 | 2.0 | 7.6 | 3.9 | 1.0 | ND | 3.2 | 4.7 | 9.2 | 5.2 | 2.2 |
| Sensory Evaluation(10) | 3.1 | 7.7 | 7.7 | 7.5 | 7.8 | 8.2 | ND | 7.2 | 7.1 | 6.6 | 7.4 | 7.9 | ND | 6.8 | 6.6 | 5.5 | 6.6 | 7.4 |
| Okra | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | 1.5 | 2.5 | 4.5 | 2 | 0 | ND | 3.6 | 4.2 | 7.4 | 3.5 | 2.0 | ND | 6.2 | 6.7 | 8.6 | 5.2 | 4.5 |
| Sensory Evaluation(10) | ND | 7.2 | 6.8 | 7.5 | 7.6 | 7.6 | ND | 6.5 | 6.2 | 6.8 | 7.1 | 7.2 | ND | 5.9 | 5.3 | 5.9 | 6.2 | 6.5 |
| Tomato | | | | | | | | | | | | | | | | | | |
| PLW (%) | 10.8 | 0 | 0 | 2.6 | 0 | 0 | ND | 0 | 0 | 4.4 | 1.0 | 0 | ND | 2.0 | 2.5 | 6.3 | 2.6 | 1.0 |
| Sensory Evaluation(10) | 3.6 | 7.7 | 7.7 | 7.4 | 7.7 | 8.3 | ND | 7.25 | 7.3 | 6.9 | 7.2 | 8.0 | ND | 6.8 | 6.6 | 6.4 | 6.4 | 7.6 |
| Amaranthus | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | 8.9 | 9.9 | ND | 8.8 | 7.6 | ND | ND | ND | ND | ND | 10.1 | ND | ND | ND | ND | ND | ND |
| Sensory Evaluation(10) | ND | 4.5 | 4.4 | ND | 4.7 | 6.6 | ND | ND | ND | ND | ND | 4.7 | ND | ND | ND | ND | ND | ND |

C = control, S = System, ND = not determined, RH = Relative humidity

**Table 1 : Cont.....**

| Storage period, days | 7 | | | | | | 8 | | | | | | 9 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | S1 | S2 | S3 | S4 | S5 | C | S1 | S2 | S3 | S4 | S5 | C | S1 | S2 | S3 | S4 | S5 |
| Temperature(°C) | 23.5 | 19.8 | 20.3 | 21.4 | 19.5 | 17.8 | 22.9 | 19.7 | 20.7 | 20.3 | 19.5 | 18.1 | 23.9 | 18.3 | 20.3 | 20.7 | 17.7 | 16.3 |
| Relative humidity(%) | 69.2 | 96.8 | 93.5 | 92.7 | 97.4 | 96.4 | 68.4 | 97.4 | 94.6 | 92.1 | 95.3 | 97.8 | 66.7 | 98.4 | 94.6 | 90.5 | 95.2 | 97.7 |
| French beans | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | 5.6 | 8.2 | ND | 8.5 | 3.7 | ND | 7.4 | 10.8 | ND | 10.7 | 6 | ND | 8.6 | ND | ND | ND | 7.2 |
| Sensory Evaluation(10) | ND | 6.2 | 5.4 | ND | 5.6 | 6.9 | ND | 5.9 | 4.1 | ND | 4.0 | 6.5 | ND | 5.2 | ND | ND | ND | 5.7 |
| Carrot | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | 5.6 | 7.8 | 10.7 | 7.6 | 3.5 | ND | 7.2 | 10.5 | ND | 8.6 | 4.8 | ND | 9.0 | 7.3 | 10.8 | 10.3 | 6.2 |
| Sensory Evaluation(10) | ND | 6.4 | 6.3 | 4.3 | 5.6 | 7.0 | ND | 5.9 | 5.8 | ND | 5.2 | 6.5 | ND | 5.3 | 5.4 | ND | 4.3 | 6.2 |
| Okra | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | 9.8 | 10.2 | 10.2 | 7.7 | 6.2 | ND | ND | ND | ND | 7.9 | 7.7 | ND | ND | ND | ND | ND | 9.5 |
| Sensory Evaluation(10) | ND | 4.1 | 4.2 | 4.4 | 5.2 | 5.8 | ND | ND | ND | ND | 3.9 | 5.3 | ND | ND | ND | ND | ND | 4.1 |
| Tomato | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | 4.2 | 4.3 | 7.6 | 4.2 | 2.7 | ND | 5.4 | 5.7 | 10.3 | 6 | 4.5 | ND | 6.6 | 8.4 | ND | 7.4 | 5.9 |
| Sensory Evaluation(10) | ND | 6.5 | 6.2 | 5.6 | 6.1 | 7.2 | ND | 6.2 | 5.7 | 4.2 | 5.6 | 6.6 | ND | 5.9 | 5.2 | ND | 5.1 | 6.2 |
| Amaranthus | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Sensory Evaluation(10) | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |

Where, C = control, S = System, ND = not determined, RH = Relative humidity

Similarly, during summer season (March-May), the maximum drop in temperature and increase in relative humidity was observed in almirah cooler with charcoal insulation with 8.86 °C and 53.55%, respectively. The lowest was observed in almirah cooler with 3.72 °C and 38.66%, respectively and the values are presented (Table 2). As air flow through the pads heat was transferred from the dry air stream to the fluids in the wet pads. The air while passing through the moist materials/insulating materials would pick up humidity from the insulating material and eventually cool down and add more moisture to the chamber (Getinet, *et al.,* 2011). This might be due to the good water holding capacity and optimum

**Table1: Cont......**

| Storage period, days | 10 | | | | | | 11 | | | | | | 12 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | S1 | S2 | S3 | S4 | S5 | C | S1 | S2 | S3 | S4 | S5 | C | S1 | S2 | S3 | S4 | S5 |
| Temperature($^{0}$C) | 18.5 | 15.6 | 16.2 | 17 | 15.9 | 15 | 23.9 | 19.7 | 20.4 | 21.6 | 20.1 | 17.6 | 23.1 | 17.7 | 20.4 | 19.5 | 17.4 | 16.3 |
| Relative humidity(%) | 74.3 | 95.6 | 93.2 | 91.8 | 94.3 | 96.7 | 61.2 | 97.4 | 94.3 | 92.6 | 95.4 | 97.8 | 68.8 | 96.6 | 92.4 | 89.4 | 94.2 | 96.9 |
| French beans | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | 10.5 | ND | ND | ND | 8.6 | ND | ND | ND | ND | ND | 10.2 | ND | ND | ND | ND | ND | ND |
| Sensory Evaluation(10) | ND | 3.4 | ND | ND | 5.3 | ND | ND | ND | ND | ND | ND | 3.9 | ND | ND | ND | ND | ND | ND |
| Carrot | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | 10.4 | ND | ND | ND | 7.5 | ND | ND | ND | ND | ND | 8.6 | ND | ND | ND | ND | ND | 10.9 |
| Sensory Evaluation(10) | ND | 3.9 | 3.8 | ND | ND | ND | ND | ND | ND | ND | ND | 5.3 | ND | ND | ND | ND | ND | 4.2 |
| Okra | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Sensory Evaluation(10) | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Tomato | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | 8 | 10.5 | ND | 10.3 | 7 | ND | 10.3 | ND | ND | ND | 8.5 | ND | ND | ND | ND | ND | 10.2 |
| Sensory Evaluation(10) | ND | 5.5 | 3.8 | ND | 4.2 | 5.8 | ND | 4.2 | ND | ND | ND | 5.2 | ND | ND | ND | ND | ND | 4.3 |
| Amaranthus | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Sensory Evaluation(10) | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |

Where, C = control, S = System, ND = not determined, RH = Relative humidity

**Table 2: Determination of the shelf life of vegetables in different evaporative cooling systems during summer season**

| Storage period, days | 1 | | | | | | 2 | | | | | | 3 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | S1 | S2 | S3 | S4 | S5 | C | S1 | S2 | S3 | S4 | S5 | C | S1 | S2 | S3 | S4 | S5 |
| Temperature($^{0}$C) | 30.1 | 23.8 | 25.3 | 25.8 | 23.2 | 20.4 | 28.7 | 22.6 | 23.2 | 23.8 | 21.4 | 19.1 | 29.4 | 22.4 | 22.8 | 25.2 | 21.2 | 19.5 |
| Relative humidity (%) | 42 | 94.5 | 90.2 | 89.6 | 92.6 | 94.6 | 32.1 | 93.4 | 86.5 | 85.2 | 94.2 | 95.7 | 36.5 | 92.4 | 89.3 | 85.6 | 93.2 | 94.1 |
| French beans | | | | | | | | | | | | | | | | | | |
| PLW (%) | 3.9 | 0 | 0 | 0 | 0 | 0 | 8.6 | 0 | 0 | 1 | 0 | 0 | ND | 0 | 0 | 3.2 | 0 | 0 |
| Sensory Evaluation(10) | 8 | 9 | 9 | 9 | 9 | 9 | 6.5 | 8.4 | 8.3 | 8.2 | 8.6 | 8.8 | 4 | 7.7 | 7.6 | 7.4 | 8.2 | 8.5 |
| Carrot | | | | | | | | | | | | | | | | | | |
| PLW (%) | 2.5 | 0 | 0 | 0 | 0 | 0 | 6.8 | 0 | 0 | 0 | 0 | 0 | 10.4 | 0 | 2 | 0 | 0 | 0 |
| Sensory Evaluation(10) | 7.5 | 9 | 9 | 9 | 9 | 9 | 5.8 | 8.2 | 8.4 | 8.3 | 8.5 | 8.8 | 3.9 | 7.3 | 7.7 | 7.4 | 7.8 | 8.6 |
| Okra | | | | | | | | | | | | | | | | | | |
| PLW (%) | 4.5 | 0 | 0 | 0 | 0 | 0 | 8.8 | 0 | 1.5 | 0 | 0 | 0 | ND | 0 | 2.7 | 0 | 0 | 0 |
| Sensory Evaluation(10) | 6.9 | 9 | 9 | 9 | 9 | 9 | 4.3 | 8.2 | 8.2 | 8.6 | 8.3 | 8.8 | ND | 7.4 | 7.1 | 7.8 | 7.7 | 8.7 |
| Tomato | | | | | | | | | | | | | | | | | | |
| PLW (%) | 0 | 0 | 0 | 0 | 0 | 0 | 3.5 | 0 | 0 | 0 | 0 | 0 | 7.4 | 0 | 0 | 0 | 0 | 0 |
| Sensory Evaluation(10) | 8.5 | 9 | 9 | 9 | 9 | 9 | 7.4 | 8.6 | 8.6 | 8.5 | 8.4 | 8.8 | 6.1 | 7.8 | 8.1 | 7.7 | 8 | 8.4 |
| Amaranthus | | | | | | | | | | | | | | | | | | |
| PLW (%) | 4.5 | 2.5 | 1.5 | 2 | 0 | 0 | 8.8 | 6 | 4.2 | 3.8 | 3.5 | 2 | ND | 9.4 | 8.7 | 8.5 | 7.5 | 4.5 |
| Sensory Evaluation(10) | 6.5 | 8.1 | 8.2 | 7.8 | 8.3 | 9 | 3.5 | 6.4 | 6.6 | 6.2 | 6.7 | 8.6 | ND | 4.2 | 4.1 | 3.9 | 5.8 | 7.4 |

Where, C = control, S = System, ND = not determined, RH = Relative humidity

**Table 2 : Cont......**

| Storage period, days | 4 | | | | | | 5 | | | | | | 6 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | S1 | S2 | S3 | S4 | S5 | C | S1 | S2 | S3 | S4 | S5 | C | S1 | S2 | S3 | S4 | S5 |
| Temperature($^{0}$C) | 27.1 | 23.2 | 24.3 | 24.7 | 22.3 | 18.9 | 27.6 | 22.8 | 23 | 23.6 | 22.1 | 18.6 | 29.2 | 23.6 | 24.4 | 26.2 | 22.8 | 20.1 |
| Relative humidity(%) | 32.6 | 92.3 | 90.1 | 88.5 | 92.4 | 94.6 | 38.6 | 93.2 | 88.4 | 85.3 | 92.7 | 95.2 | 40.5 | 91.1 | 88.7 | 84.3 | 93.4 | 94.6 |
| French beans | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | 4.5 | 4.7 | 4.6 | 1.8 | 1 | ND | 6.2 | 7.6 | 7.2 | 2.7 | 2.5 | ND | 9.8 | 10.4 | 8.6 | 4.6 | 4.2 |
| Sensory Evaluation(10) | ND | 6.4 | 6.8 | 6.7 | 7.7 | 7.9 | ND | 5.5 | 5.6 | 6.2 | 7.2 | 7.4 | ND | 4.1 | 4.3 | 5.4 | 6.5 | 6.9 |
| Carrot | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | 3.6 | 4.5 | 2 | 0 | 0 | ND | 6.7 | 7.2 | 3.5 | 2.4 | 2.1 | ND | 8.5 | 8.4 | 5.8 | 4.2 | 4.6 |
| Sensory Evaluation(10) | ND | 6.7 | 7.1 | 7.2 | 7.3 | 8.2 | ND | 6.3 | 6.5 | 6.7 | 6.8 | 7.8 | ND | 5.4 | 6.1 | 6.2 | 6.2 | 6.9 |
| Okra | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | 2.2 | 5.6 | 2.4 | 2 | 2.2 | ND | 4.6 | 8.2 | 4.4 | 4.3 | 3.7 | ND | 7.7 | 10.5 | 7.9 | 7.8 | 6.3 |
| Sensory Evaluation(10) | ND | 6.9 | 6.4 | 7 | 7.1 | 8 | ND | 6.3 | 5.5 | 6.4 | 6.6 | 7.4 | ND | 5.4 | 4.2 | 5.5 | 5.5 | 6.8 |
| Tomato | | | | | | | | | | | | | | | | | | |
| PLW (%) | 10.6 | 0 | 1.5 | 2 | 0 | 0 | ND | 2.5 | 3.4 | 3.6 | 0 | 0 | ND | 5.2 | 6.7 | 6.8 | 1.9 | 0 |
| Sensory Evaluation(10) | 3.2 | 7.5 | 7.4 | 7.1 | 7.6 | 8.3 | ND | 7 | 6.8 | 6.6 | 7.2 | 8 | ND | 6.5 | 6.2 | 6 | 6.7 | 7.7 |
| Amaranthus | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | ND | ND | ND | 10.2 | 6.7 | ND | ND | ND | ND | ND | 10.3 | ND | ND | ND | ND | ND | ND |
| Sensory Evaluation(10) | ND | ND | ND | ND | 3.8 | 6.2 | ND | ND | ND | ND | ND | 4.8 | ND | ND | ND | ND | ND | ND |

Where, C = control, S = System, ND = not determined, RH = Relative humidity

moisture holding of the insulation material (Charcoal), which kept the fairly high RH and reduced temperature prevailing inside the cool chamber as compared to room temperature. (Emanuel, *et al.,* 2010; Ganesan, *et al.,* 2004).

**Sensory evaluation**

The sensory evaluation was carried out using a set procedure and the results are presented (Table 1 and 2). As, the sensory score reading goes below 4 then it is said to be not fit for human consumption/lost its market value (Bhowmik and Pan 1992). The sensory scores at the end of their shelf life during

**Table 2 : Cont......**

| Storage period, days | 7 | | | | | | 8 | | | | | | 9 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | S1 | S2 | S3 | S4 | S5 | C | S1 | S2 | S3 | S4 | S5 | C | S1 | S2 | S3 | S4 | S5 |
| Temperature($^0$C) | 26.5 | 22.1 | 22.8 | 23.5 | 21.6 | 19.8 | 27.4 | 22.6 | 23.1 | 23.8 | 21.5 | 19.6 | 28.4 | 23.6 | 24 | 24.5 | 22.6 | 19.7 |
| Relative humidity(%) | 44.5 | 92.4 | 90.1 | 85.4 | 91.6 | 93.5 | 42.8 | 92.7 | 90.2 | 85.7 | 92.4 | 93.8 | 40.3 | 94.3 | 88.5 | 83.2 | 93.6 | 96.2 |
| French beans | | | | | | | | | | | | | | | | | | |
| PLW | ND | ND | ND | 10.4 | 6.8 | 6.5 | ND | ND | ND | ND | 8.3 | 7.4 | ND | ND | ND | ND | 10.1 | 8.5 |
| Sensory Evaluation(10) | ND | ND | ND | 4.2 | 6.1 | 6.4 | ND | ND | ND | ND | 5.3 | 5.8 | ND | ND | ND | ND | 3.8 | 5.2 |
| Carrot | | | | | | | | | | | | | | | | | | |
| PLW (%) | 10.6 | ND | 9.4 | 7.2 | 6.9 | 4.7 | ND | ND | 10.6 | 9.8 | 8.5 | 6 | ND | ND | ND | ND | 10.4 | 7.1 |
| Sensory Evaluation(10) | 3.8 | ND | 5.3 | 5.5 | 5.7 | 6.8 | ND | ND | 3.8 | 4.1 | 5.2 | 6.4 | ND | ND | ND | ND | 4.2 | 6 |
| Okra | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | 9.8 | ND | 10.2 | 9.8 | 7.9 | ND | ND | ND | ND | ND | 10.4 | ND | ND | ND | ND | ND | ND |
| Sensory Evaluation(10) | ND | 3.8 | ND | 3.9 | 4.2 | 5.6 | ND | ND | ND | ND | ND | 4.5 | ND | ND | ND | ND | ND | ND |
| Tomato | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | 7.2 | 8.6 | 8.8 | 2.7 | 1 | ND | 8.8 | 10.5 | 10.8 | 5.8 | 3.5 | ND | 10.6 | ND | ND | 8 | 5.2 |
| Sensory Evaluation(10) | ND | 6.5 | 5.3 | 5.1 | 6.2 | 7.4 | ND | 5.4 | 3.3 | 3.1 | 5.6 | 7.1 | ND | 3.8 | ND | ND | 5.1 | 6.6 |
| Amaranthus | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Sensory Evaluation(10) | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |

Where, C = control, S = System, ND = not determined, RH = Relative humidity

**Table 2 : Continue..**

| No of days | 10 | | | | | | 11 | | | | | | 12 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | S1 | S2 | S3 | S4 | S5 | C | S1 | S2 | S3 | S4 | S5 | C | S1 | S2 | S3 | S4 | S5 |
| Temperature($^0$C) | 27.1 | 23.2 | 23.8 | 24.1 | 22.6 | 19.4 | 28.3 | 21.6 | 22.4 | 24.1 | 21 | 18.6 | 30.5 | 24.6 | 25.1 | 26.3 | 23.4 | 20.2 |
| Relative humidity(%) | 44.2 | 93.4 | 90.6 | 86.1 | 94.2 | 96.7 | 48.6 | 92.5 | 91.0 | 86.4 | 93.5 | 94.7 | 43.2 | 92.4 | 93.2 | 84.8 | 94.6 | 95.3 |
| Vegetables | | | | | French beans | | | | | | | | | | | | | |
| PLW (%) | ND | ND | ND | ND | ND | 10.6 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Sensory Evaluation(10) | ND | ND | ND | ND | ND | 4.2 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Carrot | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | ND | ND | ND | ND | 8.6 | ND | ND | ND | ND | ND | 10.4 | ND | ND | ND | ND | ND | ND |
| Sensory Evaluation(10) | ND | ND | ND | ND | ND | 5.4 | ND | ND | ND | ND | ND | 4.4 | ND | ND | ND | ND | ND | ND |
| Okra | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Sensory Evaluation(10) | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Tomato | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | ND | ND | ND | 10.7 | 6.6 | ND | ND | ND | ND | ND | 7.5 | ND | ND | ND | ND | ND | 9.8 |
| Sensory Evaluation(10) | ND | ND | ND | ND | 4 | 6.2 | ND | ND | ND | ND | ND | 5.8 | ND | ND | ND | ND | ND | 4.4 |
| Amaranthus | | | | | | | | | | | | | | | | | | |
| PLW (%) | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Sensory Evaluation(10) | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |

Where, C = control, S = System, ND = not determined, RH = Relative humidity

**Table 3 : Performance evaluation of low cost cooling system during summer and winter**

| t-test | Between S and W (control) | Between S and W (systems) | Between C and S (summer) | Between C and S (winter) | t-table | t-table1% |
|---|---|---|---|---|---|---|
| French Beans | 0 $^{NS}$ | 0.535 $^{NS}$ | 3.762** | 8.968** | 2.306 | 3.355 |
| Carrot | 0.660 $^{NS}$ | 0.558 $^{NS}$ | 4.603** | 5.198** | - | - |
| Okra | 0.341 $^{NS}$ | 0.478 $^{NS}$ | 3.545** | 4.652** | - | - |
| Tomato | 0.321 $^{NS}$ | 0.486 $^{NS}$ | 5.074** | 5.355** | - | - |
| Amaranthus | 4.391 $^{NS}$ | 0.552 $^{NS}$ | 3.782** | 1.387 | - | - |

S and W = Summer and Winter, C and S = Control and System, ** - Significant at 1% level, NS - Non Significant

**Table 4 : Standardization of evaporative cooling system**

| Anova | | | | | | overall system means | |
|---|---|---|---|---|---|---|---|
| Source | DF | SS | MSS | F | F-TABLE | S1 | 7.4 |
| System | 4 | 72.58 | 18.145 | 17.70244 | 3.006917 | S2 | 7.0 |
| Season | 1 | 7.22 | 7.22 | 7.043902 | 4.493998 | S3 | 6.4 |
| Vegetables | 4 | 211.58 | 52.895 | 51.60488 | 3.006917 | S4 | 7.8 |

Cd = 1.987632 , Sem+ = 0.357946

winter season for selected vegetables *viz*., French beans, carrot, okra tomato and amaranth under ambient were found to be 3.8, 3.1, 3.7, 3.6 and 3.8, for 3, 4, 3, 4 and 2 days, respectively. The almirah cooler with charcoal insulation retained best score of 3.9, 4.2, 4.1, 4.3 and 4.7 for 11, 12, 9, 12 and 5 days, respectively and was followed by almirah cooler with coirpith

**Table 5 : Rank distribution for different evaporative cooling systems**

| Sl. No. | System | Rank |
|---|---|---|
| 1 | S1 (Mud pot in pot) | 3 |
| 2 | S2 (Almirah cooler) | 4 |
| 3 | S3 (Mud pot with Ventilation holes) | 5 |
| 4 | S4 (Coir pith cooler) | 2 |
| 5 | S5 (Charcoal cooler) | 1 |

insulation. The least was observed in case of Almirah cooler. Similarly during summer season the sensory scores at the end of their shelf life under ambient were found to be 4.5, 3.9, 4.3, 3.2 and 3.5 for 2, 3, 2, 4 and 2 days, respectively. The almirah cooler with charcoal insulation retained best sensory scores of 4.2, 4.4, 4.5, 4.4 and 4.8 for 10, 11, 8, 12, 5 days, respectively and are followed by almirah cooler with coirpith insulation. This might be due to good water holding capacity of the charcoal, along with this, the change in temperature and relative humidity plays a major role in maintaining the sensory scores for longer duration. The least was observed in case of almirah cooler. The results were similar to the findings of (Murugan *et al.,* 2011; Ngangbam and Eloni 2014).

**Shelf life of vegetables**

The shelf life of the vegetables were determined based on the physiological loss in weight of the vegetables. As the loss in weight of the vegetables reach 10% or beyond that then it is considered as the vegetable has lost its keeping quality (Mishra, *et al.,* 2009). The almirah cooler with charcoal insulation were found to maintain the longer shelf life with minimum loss in weight of the vegetables. The PLW of the vegetables at the end of their shelf life during winter was found to be 10.2, 10.9, 9.5, 10.2 and 10.1% for 11, 12, 9, 12 and 5 days, respectively as compared to only 10.8, 10.6, 10.2, 10.8 and 9.8% for 3, 4, 3, 4 and 2 days, respectively followed by almirah cooler with coirpith insulation. The least was observed in case of almirah cooler and the data are presented (Table 1).

Similarly during summer season, the PLW of the vegetables kept under almirah cooler with charcoal insulation was found to be 10.6, 10.4, 10.4, 9.8 and 10.3 for 10, 11, 8, 12 and 5 days, as compared to only 8.6, 10.4, 8.8, 10.6 and 8.8% for 2, 3, 2, 4 and 2 days respectively followed by almirah cooler with coirpith insulation. The least was observed in case of almirah cooler and the data are presented (Table 2). This might be due to reduction in the temperature and increase in the relative humidity inside the EC system this is in comparision with the findings of (Chakravorthy *et al.*, 1994; Pal, *et al.,* 1991; Taye, *et al.*, 2011; Singh and Satapathy, 2006; Goswami, *et al.,* 2008; Dash *et al.,* 2006, Ganesan, *et al.*, 2004) and vegetables were firm and attractive even at the end of their shelf life compared to those stored at room temperature. Several workers reported that the cool chamber-stored fruits and vegetables look and taste better than the ones stored at room temperature.

**Performance evaluation of summer and winter season**

The performance evaluation of the different cooling systems *viz*., mud pot in pot, almirah cooler, mud pot with ventilation holes, coirpith cooler and charcoal cooler were carried out during winter and summer season and were tested statistically.

**Standardization of low cost cooling system**

The various low cost cooling systems were developed and were evaluated to know their performance in two different seasons and were presented (Tables 3 and 4). The evaluation were made by keeping 1kg of fresh vegetables (beans, carrot, okra, tomato and amaranthus) in different EC systems and also in the control to know the shelf life of vegetables and their freshness at the final day.

The results with respect to different seasons and different systems were evaluated based on the shelf life of the vegetables for summer and winter seasons. The results for summer and winter seasons were compared by using paired t-test and the results were presented (Table 5). The control and EC systems values both in summer and winter seasons indicated that there was a significant difference at 1% level and summer and winter values indicated that there was no significant difference between summer and winter both for control and the systems.

The best system was analyzed by drawing one way Anova keeping in view the shelf life results of different systems in different seasons (summer and winter seasons) compared to all the other EC systems, it was observed that the vegetables stored in charcoal cooler system has the longest shelf life and the results were presented (Table 5).

Ranks were allocated to different low cost cooling systems based on their overall system means and the results were presented (Table 5). It was observed that the S5 system (charcoal cooler) ranked first among the systems followed by S4 (coir pith cooler), S1 (mud pot in pot storage system), S2 (almirah cooler) and S3 (mud pot with ventilation holes)**.**

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