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Evaporative Cooling Systems Using Alternative Methods for Enhancing Shelf Life of Vegetables

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Three evaporative cooling (EC) systems viz., mud pot in pot, almirah cooler, coir pith cooler were designed, developed and fabricated at Indian Institute of Horticultural Research (IIHR), Bangalore and the performance was evaluated during winter season. The almirah cooler and coir pith cooler were fabricated using MS angle 60 x 60 x 60 cm and partition was made vertically for every 15 cm height. Two water troughs were designed and made up of GI sheet, one which was kept on the top of the EC system and another at the bottom to collect the water. Different insulation materials viz., sand, jute cloth, coir pith were used to know the performance of EC systems. Temperature and relative humidity are the two major factors which have direct influence in controlling the respiration and transpiration rate of the produce, the data logger was kept both inside and also at ambient to measure the temperature and relative humidity and the data were recorded. It was found that in coir pith cooler there was considerably lower temperature (3-4 ^{0}C) with higher relative humidity (20-30%) along with this the shelf life of the vegetables increased comparatively to other EC systems. The almirah cooler with coir pith insulation system appeared as the best system and can be used to extend the shelf life of the produce.

Key words: Evaporative cooling, Relative humidity, temperature, physiological loss weight (PLW)

Fruits and vegetables constitute a commercially important and nutritionally indispensable food commodity. The post harvest losses in fruits and vegetables are due to lack of harvesting machinery, non-availability of collection centers, inadequate transportation network, lack of proper packaging material, cold storage facilities and processing centers. Storage at low temperature, after harvesting reduces the rate o respiration resulting in reducing the respiration heat, thermal composition and microbial spoilage and also helps in retention of quality and freshness if the stored material for longer period (Chopra *et al*., 2003). The farmers usually face difficulty disposing of their produce in summer when the produce spoils quickly because of the extremities in temperature coupled with low relative humidity. During that period, the power crisis often remains at its peak. For each 10 ^{0}C increment above optimum temperature the rate of spoilage increase by 2 to 3 fold (*Jimenez, 1983*).

Evaporative cooling is the low cost system reported to enhance the shelf life of fruits and vegetables by lowering the temperature and increasing the relative humidity inside the system. The cooling system reduce the temperature upto 3-4 ^{0}C during winter season and maintain a humidity above 90%. The low cost of this cooling system makes it especially suitable for short -term farm storage (Roy and Khurdiya*,* 1986*)*. The low temperature by an EC system is also beneficial for pre-cooling of horticulture produce before and during transit. EC system can be used for short term farm storage of fresh produce so that farmers can extend the shelf life of the commodities by 2 days (Maini *et al*, 1984).

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Keeping in view the present energy crisis and inadequate availability of cold storage particularly in India, attempt was made to develop different low cost cooling systems using alternative materials like river bed sand, coir pith, charcoal, wood shave, wood wool etc. which can be adopted easily by farmers without using any electrical and mechanical sources.

Materials and Methods

Raw material (Vegetables)

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

Physiological loss in weight (PLW %)

The PLW was measured to know the percent weight loss of the selected vegetables and the weight loss was kept as standard 10% then it was considered as end of the shelf life.

Mud pot in pot

$$\text{Physiological loss in weight (\%)} = \frac{\text{Initial weight - final weight}}{\text{Initial weight}} \times 100$$

In this system two mud pots were chosen 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 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). The surface of the pot cooled up slowly and the cooled air passed into the system by evaporating water and thus, maintains humidity inside the system. 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 exchange of gases takes place and thus decrease the temperature and increased the humidity inside the system. Data logger was kept inside the system to measure and record both temperature and relative humidity at every 30 min time interval. Another data logger was kept to measure and record the ambient temperature and relative humidity. 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

Almirah cooler

Structural details

Almirah cooler was 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 (top to top) was 15 cm and there were 4 number of trays in the almirah cooler.1

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 liters. The design details are shown in Fig 1.

The volume of almirah cooler was 0.21 m_3 having a storage capacity of approximately 30-45 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 gravitational pull and a flow rate of 0.212 l/min could be 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, maintained the humidity inside the system.

Coir pith cooler

A similar frame like almirah cooler was fabricated as described in above. 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 Fig 2. The operation procedure was similar to that of almirah cooler.

Selection of the best low cost cooling system

The three different low cost cooling systems were selected viz., mudpot in pot storage system, almirah cooler and coir pith cooler were tested for performance using three vegetables French bean, carrot, amaranthus. The selected systems were tested during winter season to assess the best cooling system.

Operation of almirah and coirpith cooler

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

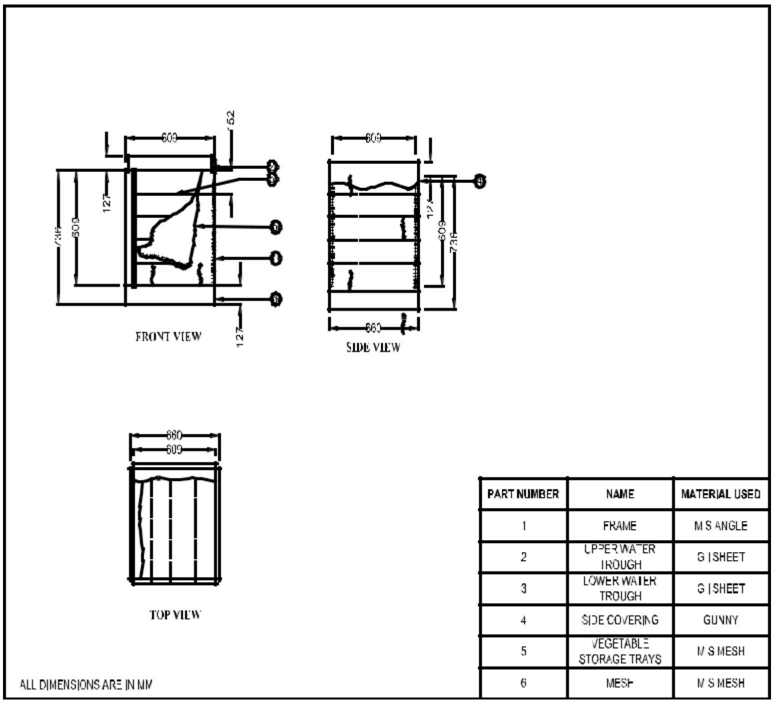
5A data logger was kept inside the system to measure and record both temperature and relative humidity (RH) for every 30 min time interval. Another data logger was kept outside to measure and record the ambient temperature and humidity. Weight of the vegetables was measured every day. The data were recorded 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.

Results and Discussion

Cooling Standardization of low cost cooling system

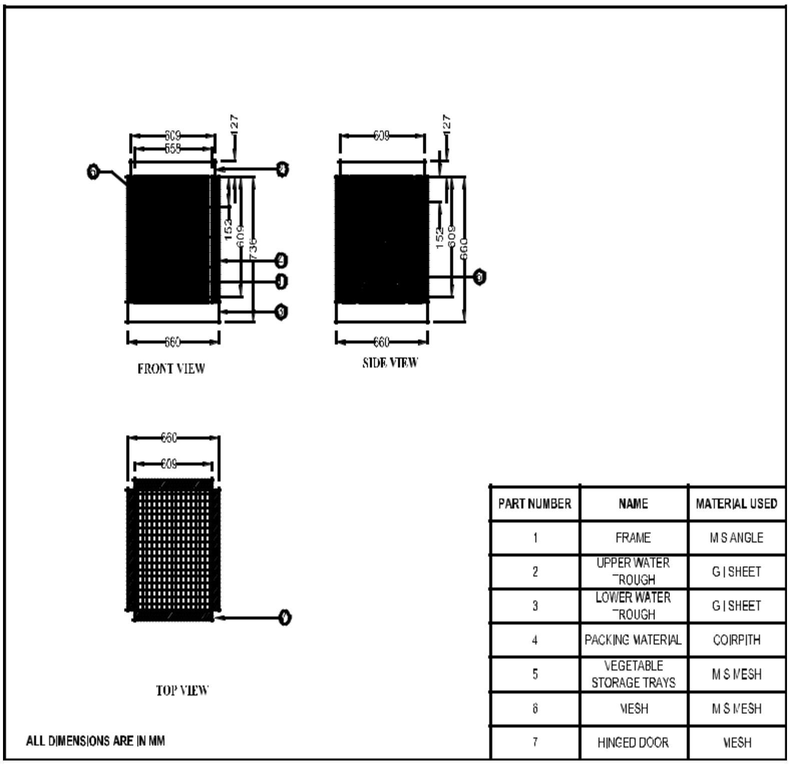
The various low cost cooling sytems were developed and were evaluated viz., mud pot in pot, almirah cooler and charcoal to know their performance during winter season. The evaluation was made by keeping 1kg of fresh vegetables (French beans, carrot and amaranth) in different EC systems and also for control to know the shelf life of the vegetables and their freshness till the end of their shelf life. The coirpith cooler maintained good freshness and keeping quality with minimum loss in weight as compared to other EC system. Thus, the coirpith cooler appeared as the best EC system.

The mean daily temperature and relative humidity both inside the coirpith cooler and ambient were



PART NUMBER	NAME	MATERIAL USED
1	FRAME	M S ANGLE
2	UPPER WATER TROUGH	G I SHEET
3	LOWER WATER TROUGH	G I SHEET
4	SIDE COVERING	GUNNY
5	VEGETABLE STORAGE TRAYS	M S MESH
6	MESH	M S MESH

Fig. 1. Almirah cooler



PART NUMBER	NAME	MATERIAL USED
1	FRAME	M S ANGLE
2	UPPER WATER TROUGH	G I SHEET
3	LOWER WATER TROUGH	G I SHEET
4	PACKING MATERIAL	COIRPITH
5	VEGETABLE STORAGE TRAYS	M S MESH
6	MESH	M S MESH
7	HINGED DOOR	MESH

Fig. 2. Coirpith cooler

measured and recorded. It was observed that the mean maximum temperature and relative humidity under ambient were 26$_0$C and 63% humidity respectively. Similarly, the maximum temperature and humidity inside the EC system were 20$_0$C and 97%, respectively. Hence, around 4-5$_0$C decrease in temperature and 30- 35% increase in RH were observed in the system in comparison to ambient. Similarly the temperature and RH values of other vegetables are presented (Table 1) and are similar to findings of (Rusten and Eric, 2009 and Nadre, *et al.,* 1999).

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

Storage period, days	1				2				3				4			
	C	S1	S2	S3	C	S1	S2	S3	C	S1	S2	S3	C	S1	S2	S3
Temperature($_{0}$C)	23.2	20.1	21	19.2	22.4	20.2	20.8	19.6	24.5	21.6	22	20.2	23.5	19.8	20.4	19.4
Humidity (%)	62.4	92.1	93.4	95.3	66.5	92.3	90.1	95.8	64.1	93.7	93.1	96.8	63.6	95.6	92.3	97.5
Vegetables								French beans								
PLW (%)	3.8	0	0	0	7.2	0	0	0	10.8	0	0	0	ND	0	2.2	0
Sensory Evaluation (10)	7.9	9	9	9	6.4	9	8.6	9	3.8	8.2	6.7	8.6	ND	7.8	6.3	8.3
								Carrot								
PLW (%)	1.5	0	0	0	4	0	0	0	7.8	0	0	0	10.6	0	2.5	0
Sensory Evaluation (10)	8	9	8.8	9	6.8	8.6	8.3	8.7	5.6	8.2	7.8	8.4	3.8	7.7	7.2	7.9
								Amaranth								
PLW (%)	4.6	0	0	0	9.8	2.8	5.1	1.5	ND	5.1	10.2	4.5	ND	9.6	ND	7.4
Sensory Evaluation (10)	7.1	8.5	8.2	9	4.2	7.8	7.2	8.2	ND	6.6	6	7.5	ND	4.2	3.9	6.7
Storage period, days	5				6				7				8			
	C	S1	S2	S3	C	S1	S2	S3	C	S1	S2	S3	C	S1	S2	S3
Temperature(0C)	24.6	20.3	21.3	19.2	23.8	20.2	20.8	18.7	24.5	21.5	22	20.2	25.2	20.2	21.3	19.5
Humidity (%)	61.6	91.4	89.4	95.3	66.8	94.5	91.2	95.4	66.3	93.8	91.5	96.8	61.8	95.3	92.7	97.5
Vegetables								French beans								
PLW (%)	ND	1.5	4.2	0	ND	3.4	6.2	1.2	ND	5.2	7.5	2.6	ND	6.5	8.8	4.1
Sensory Evaluation (10)	ND	7.2	5.6	7.6	ND	6.6	5.2	6.8	ND	5.9	4.5	6.2	ND	5.2	3.9	5.6
								Carrot								
PLW (%)	ND	1.5	3.8	0	ND	2.9	4.9	1.4	ND	4.2	5.8	2.5	ND	5.5	7.2	3.6
Sensory Evaluation (10)	ND	7.1	6.5	7.4	ND	6.4	5.8	7.1	ND	5.8	5.2	6.6	ND	5.1	4.5	6.2
								Amaranth								
PLW (%)	ND	ND	ND	9.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sensory Evaluation (10)	ND	ND	ND	4.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Storage period, days	9				10				11				12			
	C	S1	S2	S3	C	S1	S2	S3	C	S1	S2	S3	C	S1	S2	S3
Temperature($_{0}$C)	24.7	20.1	21.6	19.4	25.8	20.4	21.3	19.4	24.8	21.5	22	19.2	24.9	20	20.7	19.4
Humidity (%)	65.6	93.2	90.3	96.7	61.3	94.4	92.2	97.6	60.2	94.2	92.1	95.9	62.4	95.6	92.4	97.5
Vegetables								French beans								
PLW (%)	ND	7.5	ND	6	ND	10.2	ND	7.2	ND	ND	ND	8.5	ND	ND	ND	10.1
Sensory Evaluation (10)	ND	4.4	ND	5.1	ND	ND	ND	5.6	ND	ND	ND	4.6	ND	ND	ND	ND
								Carrot								
PLW (%)	ND	6.5	7.7	4.7	ND	7.2	9.8	6.4	ND	9.2	ND	7.6	ND	ND	ND	9.6
Sensory Evaluation (10)	ND	4.6	4	5.8	ND	4.2	ND	5.3	ND	ND	ND	4.6	ND	ND	ND	4.2
								Amaranth								
PLW (%)	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

Where, C-Control, S1-Mud pot in pot, S2-Almirah cooler, S3-Coirpith cooler, PLW-physiological loss in weight, ND-not determined

It was observed from (Table 1). The percent PLW for french beans, carrot and amaranth after two to four days of storage period under ambient condition was 10.8% after 3 days, 10.6% after 4 days and 9.8% after 2 days, respectively. The percent PLW of French beans, carrot and amaranth stored inside the standardized EC system (coirpith cooler) was 10.1% after 12 days, 9.6% after 12 days and 9.2 % after 5 days. Hence, it was found that french beans kept inside the system could be stored safely for about 12 days compared to only 2-3 days under ambient condition similarly for carrot it was 12 days compared to 4 days and for amaranth 5 days as compared to 2 days. Thus, the shelf life of beans could be increased by about 9 days, carrot by 8 days and 3 days compared to ambient during winter season, if it was kept inside standardized EC system (coir pith cooler) and the results were similar to findings of (Chakravorthy, 1994, Roy and Khurdiya, 1982, Pal and Roy 1988 and Goswami*, et al.,* 2008)

The sensory evaluation was carried out based on visual quality for French beans, carrot and amaranth through 9 point hedonic scale. It was observed that French beans, carrot and amaranth stored under ambient condition lost quality after 3, 4 and 2 days respectively. The sensory evaluation was carried out regularly at the end of storage period and the hedonic scale reading of french beans, carrot and amaranth was found to be 3.8 for 3 days, 3.8 for 3 days and 4.2 for 5 days respectively under ambient. But it was showed that the hedonic scale reading for french beans, carrot and amaranth was 4.6 after 11 days, 4.2 after 12 days and 4.3 after 5 days respectively then it was considered as it has lost its consumer acceptability and the findings were similar to findings of (Bhowmik and Pan 1992).

Conclusion

The evaluation has been made by using different alternative evaporative cooling systems and also standardization has been made based on the shelf life obtained by different vegetables. The shelf life can be increased by using locally available materials based on evaporative cooling principle. The vegetables which are kept outside the EC system has 2-3 days of shelf life and it lacks consumer acceptability. The vegetables which are kept inside the system increased the shelf life to more than 2-3 folds by maintaining the freshness, keeping quality and consumer acceptability. So, these kind of EC systems can be evaluated by using different locally available materials and should be standardized and popularized.

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