RESEARCH PAPER International Journal of Agricultural Engineering | Volume 6 | Issue 2 | October, 2013 | 403–408

Effect of evaporative cooling on storage of vegetables

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Received : 27.06.2013; **Revised :** 29.09.2013; **Accepted :** 29.10.2013

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ABSTRACT : The cooling efficiency of the evaporative cooling chamber was found to be 65.41%, 56.14% and 89.94% for month of September, October and November, respectively. The average yellowness index before and after storage of okra was 33.97 and 44.95, respectively and for snake gourd before and after storage was 40.46 and 32.17, respectively. The hardness of okra before storage was 1060g and after storage was 811.6g. The hardness for snake gourd before storage and after storage was 1626.6g and 838.3g respectively. Shelf life was increased by four days and six days of okra and snake gourd, respectively in evaporative cooling chamber as compared to ambient environment.

KEY WORDS : Evaporative cooling structure, Cooling efficiency, Shelf life, Yellowness index

HOW TO CITE THIS PAPER : Jain, S.K., Chavan, P.P. and Khedekar, V.P. (2013). Effect of evaporative cooling on storage of vegetables. *Internat. J. Agric. Engg.*, **6**(2) : 403-408.

India is a second largest producer of fruits and vegetables after China. It produces about 32 million MT of fruits and 71 million MT vegetables annually but it wastes about 35% to 40% of the produce due to improper post harvest management. Owing to lack of proper on-farm storage facilities, it is estimated that about 20% to 30% of total fruits are lost after harvesting. Keeping fruits at their lowest safe temperature will increase storage life by lowering respiration rate, and reducing water loss. Reducing the rate of water loss reduces the rate of shriveling and wilting, causes of serious postharvest losses. Maintenance of air-conditioned spaces in villages is not possible for the farmers due to high-cost, high-energy consumption and irregular supply of electricity. Therefore, low cost and zero energy consumption method of evaporative cooling chamber for storage of horticultural products is suitable. The principle of working of cool chamber is "when a particular space to be conditioned and maintained at a temperature lower than the ambient temperature surrounding the space, there should be release of some moisture from outside the body". Hence, a low cost zero energy evaporative cooling chamber was developed to store vegetables. The study was carried out with objectives, to determine the temperature and relative humidity inside and outside of the evaporative cool chamber and to test the performance of evaporative cool chamber for storage of okra (*Abelmoshus esculent)* and snake gourd (*Trichosanthes anguina)*.

Roy and Khurdiya (1986) found that the cool chambers maintain temperature between 23°C to 26.5°C and relative humidity (RH) between 94 per cent to 97 per cent as against the ambient temperature between 24.2 °C to 39.1 °C and RH 9 per cent to 36 per cent during the months of May to June. Datta (1987) found that the potential energy savings envisaged by replacing conventional refrigerated systems by evaporative systems is 75 per cent. Victor (1992) constructed a useful device for the storage of fresh vegetables by using a fired ceramic material to cool water evaporative many degrees below the ambient temperature in dry arid regions. Umbarkar *et al.* (1998) constructed an evaporative cooled structure of 2 ton capacity and found that the temperature in the chamber varied between 23°C to 26.5°C as against ambient temperature variations between 25°C to 44°C on a test day. The RH in the structure was 85 per cent to 97 per cent. Faleh Al- Sulaiman (2001) studied special test setup which is designed to evaluate the performance of three natural fibres to be used as wetted pads in evaporative cooling. The results showed that the average cooling efficiency was highest for jute at 62.1 per cent, compared to 55.1 per cent for luffa fibres, 49.9 per cent for the reference commercial pad and 38.9 per cent for date palm fibre. Anyanwu (2004) developed a porous evaporative cooler for preservation of fruits and vegetables with total storage space of 0.014 m^3, The gap between them was filled with coconut fibre. The results revealed that the cooler storage temperature depression from ambient air temperature varied over 0.1°C to 12°C. Chopra *et al.* (2004)

showed that the 'Kinnow' fruits could be stored in evaporative cooled room for 29 days against 16 days in ordinary temperature conditions. Ganesan *et al.* (2004) found that too moist or too dry cool chamber will lead unwanted growth of fungus and spoil the fruits. The shelf life of brinjal can be enhanced up to 9 days in cool chamber with addition of 100 litres of water per day as compared to 3 days at room temperature.

METHODOLOGY

The study area of evaporative cooling chamber is located in Konkan region, which is the tropical zone of Maharashtra. Climatic conditions of this region are hot and humid. The average annual rainfall of the region is in between 3500 mm to 4000 mm.

Netlon mesh net was used for constructing outside walls of evaporative cool chamber of size 60 cm x60 cm x100 cm *i.e.* 360 litres. Thermocol sheet 6 mm thickness was used as insulator at the top and front door. The inside wall was made up of 16 gauge aluminium sheet with perforations. It traps the entry of heat inside the evaporative cooling chamber from top and front of structure. For making inner chamber air tight, slits between chamber wall and door were covered with 3 mm thick rubber gasket. The gap between inner and outside chamber walls was filled up with moss. A small tank of capacity 150 litres was placed over the cool chamber and laterals and drippers were attached to the tap of tank. The knob of tap was adjusted to release water continuously and keep the moss wet. The fresh okra and snake gourd procured from local market were kept in plastic crates. The selected samples from commodities were weighed daily for recording their weight loss and visual freshness.

The wet bulb temperature, dry bulb temperature and relative humidity of ambient and inside the evaporative cooling chamber were measured and recorded by using sensors and datalogger. The cooling efficiency was calculate by using formula given by Thakral *et al.* (2000).

$$\text{Cooling efficiency} = \frac{(T - T_1)}{(T - T_2)} \times 100$$

where, T = Ambient dry bulb temperature, °C

T_1 = Temperature of cooling chamber, °C

T_2 = Ambient wet bulb temperature, °C

Physiological loss in weight :

The PLW of vegetables was recorded daily in the morning at 08:00 am by using the electronic weighing balance. The PLW is important factor that decides the deterioration of vegetables. It is considered that if the PLW is more than 10 per cent the commodity is not suitable for market (Jain and Mukherjee, 2001).

PLW in per cent can be computed by formula:

$$PLW = \frac{W_1 - W_2}{W_1}$$

where, W_1 = initial weight of commodity

W_2 = final weight of commodity.

Change in visual quality

The changes in visual quality of vegetables stored in evaporative cooling chamber and ambient condition were observed in regard to the freshness and firmness (finger feel) as storage progressed. The rating for changes in visual quality are as follows:

Vegetables: 1: pulpy and soft; 2: fair firm; 3: firm; 4: hard.

Shelf life :

The shelf life of vegetables were determined by judging the unmarketable parameter *viz.*, shriveling, softening and rotting, which were mainly due to physiological loss in weight. Ten per cent PLW was considered as an index and point of shelf life of fruits.

Colour analysis

The colour of the samples of fruits and vegetables were analysed by using hunter's colorimeter. Three Hunter parameters namely, L (lightness), a (redness/greenness), b (yellowness/blueness) and yellowness index were measured.

Texture analyzer :

The texture analyzer was used for measurement of hardness of the bulb. Texture analyzer was equipped with a 50 kg load cell and TA3/100 probe operated at a test speed of 1 mm/s transversally to the bulb slices. Hardness is the maximum force required to break the bulb in Newton (N).

RESULTS AND DISCUSSION

The experimental findings obtained from the present study have been discussed in following heads:

Temperature and relative humidity variation :

Variation in temperature and RH of the evaporative cooling chamber and ambient were recorded during the month of September to November 2011 during no load test. The average temperature and RH during test is given in Table 1. In September the average dry bulb temperature inside the cool chamber was found to be 27.23°C while in ambient it was 30.01°C. The average RH inside evaporative cooling chamber was found to be 87.77 per cent whereas that of ambient it was 70.10 per cent. In October the average dry bulb temperature inside the cooling chamber was found to be 27.61°C while in ambient it was 30.0°C. The average RH inside evaporative cooling chamber was found to be 93.99 per cent whereas that of ambient it was 72.67 per cent. In

November the average dry bulb temperature inside the cooling chamber was found to be 28.38°C while in ambient it was 33.39°C. The average RH inside evaporative cooling chamber was found to be 78.19 per cent whereas that of ambient it was 46.33 per cent. This reduction in temperature and the increase in RH help in maintaining the freshness of commodities and improving shelf life.

Cooling efficiency :

The cooling efficiency of evaporative cooling chamber in November was 89.94 per cent. The cooling efficiency can be increased by increasing the surface area and providing

Table 1 : Daily maximum temperature and relative humidity during no load test

Day	Inside the ECC	Ambient		Avg. inside	Avg. ambient	RH
	db (°C)	db (°C)	wb (°C)	RH (%)	RH(%)	Diff
September						
1	27.0	30.1	25	84.4	65.9	18.5
2	27.4	29.3	25.2	84.8	67.6	17.2
3	27.3	29.1	25.3	84.8	73.9	10.9
4	27.5	30.5	25.6	83	70.6	12.4
5	27.7	31.4	25.9	89.9	71.3	18.6
6	26.9	28.9	25.1	86.5	73.3	13.2
7	28.4	30.7	25.4	85.3	66.8	18.5
8	27.1	30.4	26.5	88.3	65.2	23.1
9	25.9	29.1	26.8	92.1	68.5	23.6
10	27.1	29.7	26.1	91.9	75.8	16.1
Average	27.23	30.01	25.76	87.77	70.10	17.67
Cooling efficiency = 65.41 per cent						
October						
1	27.7	30.1	25.7	94.7	73	21.7
2	26.8	29.8	25.6	94.2	69.7	24.5
3	26.1	29.5	25.4	94	70.3	23.7
4	28.7	30.5	24.3	90.5	65.6	24.9
5	27.9	30.1	26.2	95.3	70.8	24.5
6	27.9	30.1	25.6	94.2	71.5	22.7
7	28.1	30.2	26.7	93.3	74.6	18.7
8	28.9	30.3	26.9	95.4	75	20.4
9	26.8	29.5	25.8	93.2	76.7	16.5
10	27.2	29.3	25.7	95.1	79.5	15.6
Average	27.61	29.94	25.79	93.99	72.67	21.32
Cooling efficiency = 56.14 per cent						
November						
1	27.1	34.5	26.8	63.2	41.3	21.9
2	29	35.1	28.4	84.4	40.8	43.6
3	30.5	33.5	29.5	82.4	60.2	22.2
4	29	34.1	28.4	84.4	40.8	43.6
5	28.2	33.9	27.2	88.8	43.8	45
6	30.8	33.3	29	82.3	61.9	20.4
7	26	30.1	25.4	84.4	40.8	43.6
8	28.7	32	27.9	83.2	52.5	30.7
9	27.3	33.7	26.3	64.4	40.6	23.8
10	27.2	33.7	29.3	64.4	40.6	23.8
Average	28.38	33.39	27.82	78.19	46.33	31.86
Cooling efficiency = 89.94 per cent						

better aeration, which improves the performance of evaporative cooling chamber.

Cooling efficiency in month of September and October was less as compared to November because in the month of September and October it was raining intermittently.

Physiological loss of weight (PLW) :

Higher temperature increase causes difference in the vapour pressure between the vegetables and the surrounding. This difference induces the faster moisture transfer from commodities to the surrounding air, which ultimately causes the higher rate of PLW. The loss in weight of the vegetables in the evaporative cooling chambers as well as in the ambient storage observed during study is presented through Table 2 and 3. In case of okra *(Abelmoschus esculents)* the ambient samples shrinked after four day whereas inside cooling chamber samples have less weight loss but shrinked after seven day. The PLW of okra samples kept inside cooling chamber ranged from 0.55 per cent to 2.31 per cent after one day whereas in case of ambient samples it ranged from 4.74 per cent to 17.35 per cent. The PLW of snakegourd samples kept inside cooling chamber ranged from 0.14 per cent to 0.29 per cent after one day whereas in case of ambient samples it ranges from 0.40 per cent to 7.71 per cent. The shelf life of okra for ambient and cool chamber ended on 3rd and 9th day, respectively. The shelf life of snakegourd for ambient and cool chamber ended on 5th and 13th day, respectively.

Table 2 : Average physiological weight loss (in %) for okra

Days	Inside cooling chamber									
	OKI1	OKI2	OKI3	OKI4	OKI5	OKI6	OKI7	OKI8	OKI9	OKI10
1	1.15	0.78	1.49	1.79	2.31	2.56	0.55	1.59	1.19	1.33
2	4.02	3.10	2.99	3.13	4.17	3.85	1.64	4.76	1.79	3.54
3	6.32	4.65	4.48	4.91	6.94	4.49	2.73	5.56	3.57	5.31
4	8.62	6.98	8.21	7.14	8.80	5.77	6.01	7.14	5.36	7.08
5	9.20	8.91	8.96	8.48	9.72	7.69	8.20	7.94	6.55	7.96
6	9.20	9.30	8.96	8.93	9.72	8.33	8.74	8.73	8.33	8.85
7	10.34	9.69	9.70	9.37	10.19	8.97	9.29	9.52	8.93	9.29
8	10.92	10.08	9.70	10.27	10.19	9.62	9.84	9.52	9.52	9.73
9	11.49	10.47	10.45	10.71	10.65	10.26	10.38	10.32	10.12	10.18
	Outside cooling chamber									
Days	OKO1	OKO2	OKO3	OKO4	OKO5	OKO6	OKO7	OKO8	OKO9	OKO10
1	8.05	4.74	5.00	6.25	3.85	11.59	8.33	8.06	17.35	10.94
2	11.49	6.84	10.00	11.88	12.09	19.57	20.83	12.90	21.43	17.71
3	13.79	11.05	12.50	13.75	12.64	22.46	26.04	14.52	27.55	20.83

Table 3 : Average physiological weight loss (in per cent) for snake gourd

Days	Inside cooling chamber					Outside cooling chamber				
	SGI1	SGI2	SGI3	SGI4	SGI5	SGO1	SGO2	SGO3	SGO4	SGO5
1	0.21	0.14	0.29	0.14	0.15	0.40	7.71	0.86	1.45	0.99
2	0.32	0.59	1.14	1.05	0.83	1.44	13.80	7.07	2.17	1.71
3	5.02	1.64	2.14	1.33	2.03	3.52	14.06	7.07	8.55	2.83
4	5.02	3.09	2.71	1.75	3.17	5.12	14.17	11.29	10.58	8.43
5	5.87	4.55	4.00	2.59	4.97	7.12	16.67	14.00	15.51	12.84
6	7.79	4.82	5.43	3.07	6.41					
7	9.23	7.23	6.14	6.22	8.21					
8	9.61	9.05	8.29	7.69	9.57					
9	9.77	9.23	8.57	9.08	9.72					
10	9.87	9.36	8.86	9.64	9.80					
11	9.98	9.55	9.57	9.92	9.95					
12	10.09	9.95	10.71	10.20	10.02					
13	10.19	13.14	12.86	11.39	11.76					

Change in visual quality :

Vegetables were stored in the evaporative cooling chamber and ambient environment. The changes in the visual quality as the storage progressed were observed by finger feel. It was observed from Table 4 that the quality attribute in regard to the softness and firmness (finger feel) was higher when stored in the evaporative cooling chamber while in the ambient condition. In case of okra ambient samples became soft after third days where as the inside cooling chamber samples remained fresh up to ten days. In case of snake gourd ambient samples shrinks after six days and inside cooling chamber samples were fresh on fifteen days.

Shelf-life :

It was found that the shelf life of the commodities stored in evaporative cooling chamber was enhanced by 4 to 6 days over the ambient storage with respect to physiological loss in weight. In case of okra the ambient samples shrinked after four day whereas inside evaporative cooling chamber samples shrinked after ten days. In case of snake gourd the ambient samples got ripen after five days whereas inside evaporative cooling chamber got ripen after fifteen days.

Colour analysis :

Degree of lightness to darkness of the samples was represented by "L" value, redness to blueness by "a" value and yellowness to whiteness by "b" value on hunter scale. For okra the yellowness index before and after storage changed from 33.97 to 44.95. For snake gourd the yellowness index before and after storage changed from 40.46 to 32.17. The data are represented in Table 5. It showed that the colour before and after storage of okra turned darker while that of snake gourd turned lighter.

Texture analyzer :

As revealed (Table 5) that the average hardness of fresh okra before storage was 1060 g while after storage it was 811.6 g. Similarly, the average hardness of fresh snake gourd before storage was 1626.6 g while after storage it was 838.3 g. The reduction in hardness was due to reason that after storage period the vegetables become soft and pulpy.

Table 4 : Changes in visual quality of vegetables during storage by finger feel

Sr. No.	Product	Storage condition	Days of storage															Remark
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1.	Okra	Inside ECC	4	4	4	4	4	3	3	2	2	2	1					Fungal attack on 11th day
		Ambient	4	4	1	1												Fungal attack on 4th
2.	Snake	Inside ECC	4	4	4	4	4	4	4	3	3	3	3	3	2	1	1	After 10 days rotting starts
	Gourd	Ambient	4	4	3	3	2	1										Becomes yellowish and Shrinkage after 6th day

1: Pulpy and soft; 2: Fair firm; 3: Firm; 4: Hard

Table 5 : Color and texture analysis of the okra and snake gourd

Sr. No.	Sample		Yellowness index	Load target, g
1.	Before storage of okra		34.31	1210
			34.23	1095
			33.38	875
		Average:	33.97	1060
	After storage of okra		45.31	860
			45.23	800
			44.31	775
		Average:	44.95	811.6
2.	Before snake gourd		40.80	1755
			40.29	1630
			40.29	1495
		Average:	40.46	1626.6
	After snake gourd		32.37	890
			32.17	910
			31.97	715
		Average:	32.17	838.3

Conclusion :

– Shelf life was increased by four days and six days of okra and snake gourd in evaporative cooling chamber as compared to ambient environment.

– Cooling efficiency of evaporative cooling chamber was higher in month of November as compared to September and October**.**

– After storage the yellowness index of okra increased while that of snake gourd decreased. The hardness of the okra and snake gourd decreases after storage as they become soft and pulpy.

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