SOLAR POWERED EVAPORATIVE COOLING SYSTEM

ABHISHEK[1],ABHINANDAN.KV[1],CHETAN.C[1],AKHILESH.R[1],PRAVEEN MATH[2]

[1]UG Scholars, School of Mechanical Engineering, REVA University, Bangalore

[2]Assistant Professor, School of Mechanical Engineering, REVA University, Bangalore

Abstract: A solar powered evaporative cooling system of 0.14m^3 capacities is designed and constructed to increase the shelf life of stored vegetables. A suction fan of 12V and a water pump of 6V were powered through a solar panel of 12V with a battery of 12V and 7.5AH used to store charge and maintain the systems operation. The evaporative cooler was tested and evaluated using vegetables. The equipment operates on the principle of evaporative cooling and increasing the relative humidity in the preservation chamber. And provides an efficient storage conditions for vegetables. There was considerable effect on physiological loss in weight of different vegetables kept either inside or outside cooling chamber.

IndexTerms **– Relative humidity, Cooling pad, Evaporative cooling, Enthalpy**

I. INTRODUCTION

Evaporative cooling is the process by which the temperature of a substance is reduced due to the cooling effect from the evaporation of water. The conversion of sensible heat to latent heat causes a decrease in the ambient temperature as water evaporated provide useful cooling. This cooling effect has been used on various scales from small space cooling to large industrial applications. Several researches have been done on various forms of design of evaporative coolers. A solar powered evaporative cooling storage system (SPECSS) was developed to improve the shelf life of fruits and vegetables for small-holder farmers. Erratic power supply and inadequate facilities hinder storage of perishable crops, leading to postharvest losses.

This study was designed to develop a solar powered evaporative cooling system for the storage of perishable crops. Extending produce quality for longer periods makes the solar powered evaporative cooling system suitable for use in rural communities where there is no electricity. To overcome the above problems and design the most economical storage system for the small farmers and to increase the shelf life of fruits and vegetables. The system consists of two jute pad on left and right side through which the water flows from reservoir. The suction fan is present at the back side due to which vacuum will be created inside the chamber and heat will be removed from the system.

India is the second largest producer of fruits and vegetables in the world after Brazil and China respectively. Production of fruits and vegetables account for 209.72 million tonnes (MT) of which 73.53 MT & 136.19 MT are fruits & vegetables respectively. Storage of fresh horticultural produce after harvest is one of the most pressing problems of a tropical country like India.

Due to their high moisture content, fruits and vegetables have very short life and are liable to spoil. Moreover, they are living entities and carry out transpiration, respiration and ripening even after harvest. Metabolism in fresh horticultural produce continues even after harvest and the deterioration rate increases due to ripening, senescence and unfavourable environmental factors. Hence, preserving these types of foods in their fresh form demands that the chemical, bio-chemical and physiological changes are restricted to a minimum by close control of space temperature and humidity.

Therefore, there is a need to evolve a marketing system where benefit is prevailed to both growers and consumers. The fruits and vegetables, being perishable, need immediate post harvest attention to reduce the microbial load and increase their shelf life, which can be achieved by storing them at low temperature and high relative humidity conditions. These conditions are usually achieved in cold storages.

II. LITERATURE SURVEY

Giabaklou and Ballinger (1996) have attempted to study the effectiveness of a passive evaporative cooling system employing natural ventilation. The front faces of a building are provided with water guide filaments, where in water flows from the top to bottom by gravity. The incoming air gets cooled and goes inside the building. Such a system is found to reduce the temperature of incoming air by 9.9 C^o, averaged over a day. He has extended the study the using Fanged PMV (PredictedMean Vote) methodology. It shows that such a system can improve PMV significantly when the number of air changes per hour is higher.

Kant and Mullick (2003) have studied on thermal comfort in a room with exposed roof using evaporative cooling system. Hourly values of temperature and humidity are computed and compared with the values that are obtained during unexposed condition. The levels of thermal sensation, which can be obtained with a direct evaporative cooler, are computed.

Kittas et al (2003) have investigated the temperature and humidity gradients during summer in a greenhouse equipped with a ventilated cooling-pad system and half shade plastic roof. The cooling performance up to 80 % is reported. The temperature of the greenhouse is lowered by 10 C^o than the outside air.

Taufiq et al (2007) have conducted an energy analysis of evaporative cooling for reducing energy use in a building. A correlation has-been developed between relative humidity and energy efficiency, and between ambient temperature and energy efficiency. The results of the study revealed that when relative humidity is increased, energy use also increases. The study concluded that the evaporative cooling is a feasible technology that can reduce mechanical cooling and energy requirement.

Shukla et al (2008) have done an experimental study in a cascade green house with inner thermal curtain. About 5-8 Cº reduction in the temperature of greenhouse is reported during hot summer in Delhi. Energy saving aspects are attempted by **Al-Azzawi and Almuhtadi (2009)** using of newly designed automated solar powered evaporative cooler. **Naticchia et al(2010)** have used a new novel technique, water evaporative wall, which reduces the conduction heat gain across the walls. The experiments have shown to reduce the summer overall heat load considerably.

He and Hoyano (2010) have studied the cooling effects of passive evaporative cooling wall constructed of porous ceramic materials. Experimental results showed that the cooling efficiency reached a maximum of 0.7 during sunny daytime periods. A higher cooling efficiency is obtained under windy conditions where wind at a speed of 1-3 m/s is continuously blowing. **Heidarinejad et al (2010)** have investigated a hybrid system of nocturnal radiative cooling and direct evaporative cooling and up to 13.5 º c Reduction in indoor temperature is reported.

Datta et al (1987) have experimentally studied an 8.5 ton indirect-direct evaporative cooling system and reported that such a system 14provides a relief cooling rather than comfort cooling. The room could be maintained at 4-5 Cº above the inlet wet bulb temperature using such a cooler. A facility of using indirect direct evaporative cooling for residential use in arid regions of Israel is attempted by **Navon and Arkin (1994)**. Such a systemic shown to provide higher level of thermal comfort where external humidity is around 80 %.

III. OBJECTIVES

In the light of above facts, solar energy can be a decent alternative and efficient energy source that can substitute the non-renewable sources with greater reliability. Considering the specifics the present research work for developing solar energy powered rural storage structure for fruits and vegetables is undertaken with the following objectives:

1. To design and fabricate a solar powered evaporative cooled storage structure.
2. To evaluate the performance of storage structure for storing fruits and vegetables.
3. It not only reduces the storage temperature but also increases the relative humidity of the storage which is essential for maintaining the freshness of the commodities.

IV. METHODOLOGY

4.1 Formulation and presentation of problem

The previously designed system was electric powered system and there was a no water collector. Hence there was a loss of water which used to be continuously drained out of the system and resulted in the wastage of water. Since the system was electrically powered it cannot run all the time and there was loss of cooling. This project attempts in making a solar powered evaporative cooling system which is affordable.

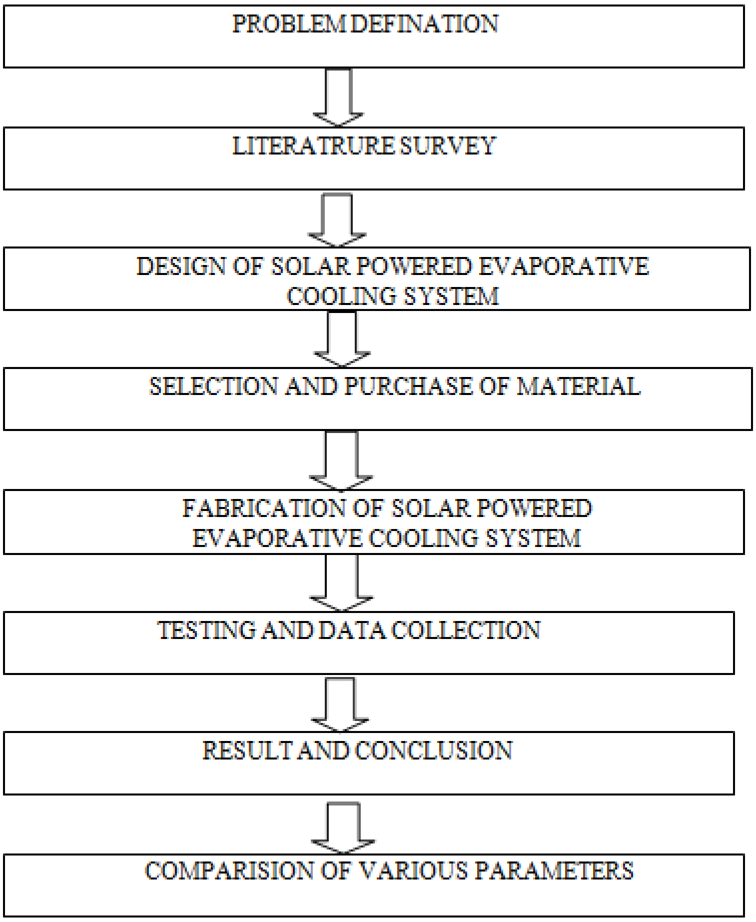

Figure: Methodology flowchart

4.2 Materials used

Table1: Material specification of components used

Sl no	Particulars	Specifications
1	Efficiency (%)	75-80
2	DC Suction fan	12V
3	Speed	1800 RPM
4	DC Pump	6V
5	Lead Acid Battery	12V 7AH
6	Solar Panel	12V
7	Reservoir	11liters
8	Jute Pad	0.6mm

V.CALCULATIONS

Theoretical:

Design Criteria of the Cooling System

The storage system is rectangular in shape, and the design specifications for the system as well as the reservoir seat were done are as follows:

1. Design of Front and Rear Sides of the Storage System

Height of the Front and Rear Sides- H=0.7m, Length, L=0.4m

Area= H x L= 0.7 x 0.4=0.28m^2

2. Design of Left and Right hand sides of storage system (Pad area)

Length of left side of storage system- H=0.7m, Breadth, B=0.5m

Area= H x B=0.7 x 0.5=0.35m^2

3. Design of top of storage system

Length of top of storage system- L=0.5m, Breadth, B=0.4m

Area= L x B= 0.5 x 0.4=0.2m^2

4. Design of reservoir seat

Length of reservoir seal- L=0.5m, Breadth, B=0.3m

Area= L x B= 0.5 x 0.3=0.15m^2

5. Volume of the storage system (Inner Volume)

Length of the storage system- L=0.4m, Breadth, B=0.5m, Height, H=0.7m

Volume= L x B x H=0.4 x0.5 x 0.7=0.14m^3

6. Volume of reservoir

Height of reservoir- H=0.3m, Radius, r=0.11m

Volume= π x r^2x H=3.14x $(0.11)^2$ x 0.3=0.0113m=11litres

7. Selection of Battery

Type: Lead Acid Battery

Specification: 12V, 7.5AH

8. Selection of Pump

Type: DC Pump

Specification: 6V

9. Selection of Suction Fan

Type: DC Fan

Specification: 12V

V. RESULTS AND DISCUSSIONS

The temperature difference inside the evaporative cooling system was calculated for a period of 5 Days With vegetables of same quantity kept under ambient condition. The temperature and relative humidity of both the system and ambient condition were monitored throughout the experiment and the freshness of vegetables was checked with those kept in ambient temperature for a period of 5 days. The table below shows the experiment carried out for a period of 5 days and was temperatures were tabulated.

Table 01: Temperature and Relative humidity of Day 1

SL.NO	TIME	TEMPERATURE(C)		RELATIVE HUMIDITY (%)	
		Outside condition	Inside condition	Outside condition	Inside condition
1	10.00AM	28.0	24.0	44	48
2	11.00AM	30.0	23.4	43	50
3	12.00PM	31.2	22.8	48	51
4	1.00PM	31.6	22.0	47	51
5	2.00PM	32.1	21.9	43	51
6	3.00PM	33.1	21.0	46	52
7	4.00PM	30.4	20.1	47	52

Table 02: Temperature and Relative humidity of Day2

SL.NO	TIME	TEMPERATURE(C)		RELATIVE HUMIDITY (%)	
		Outside condition	Inside condition	Outside condition	Inside condition
1	10.00AM	29.0	25.5	46	46
2	11.00AM	30.0	24.8	44	47
3	12.00PM	31.5	23.0	48	50
4	1.00PM	32.0	22.1	47	51
5	2.00PM	32.5	21.5	42	51
6	3.00PM	33.0	21.1	45	52
7	4.00PM	31.1	20.0	46	52

Table 03: Temperature and Relative humidity of Day 3

SL.NO	TIME	TEMPERATURE(C)		RELATIVE HUMIDITY (%)	
		Outside condition	Inside condition	Outside condition	Inside condition
1	10.00AM	27.0	24.0	45	48
2	11.00AM	30.0	23.8	44	50
3	12.00PM	32.0	22.4	47	51
4	1.00PM	33.0	21.8	41	51
5	2.00PM	32.8	21.0	42	52

6	3.00PM	31.5	20.8	46	52
7	4.00PM	30	20.1	44	53

Table 04: Temperature and Relative humidity of Day 4

SL.NO	TIME	TEMPERATURE(C)		RELATIVE HUMIDITY (%)	
		Outside condition	Inside condition	Outside condition	Inside condition
1	10.00AM	28.8	25.4	46	45
2	11.00AM	30.0	24.3	44	46
3	12.00PM	32.0	23.5	48	49
4	1.00PM	32.5	22.4	42	50
5	2.00PM	33.0	21.8	45	51
6	3.00PM	32.8	20.9	46	52
7	4.00PM	29.8	20.3	45	52

Table 05: Temperature and Relative humidity of Day5

SL.NO	TIME	TEMPERATURE(C)		RELATIVE HUMIDITY (%)	
		Outside condition	Inside condition	Outside condition	Inside condition
1	10.00AM	27.5	25.8	45	47
2	11.00AM	29	25.3	43	46
3	12.00PM	30	25	44	46
4	1.00PM	31.6	24.8	44	48
5	2.00PM	32.1	20.2	48	51
6	3.00PM	33.4	21	43	51
7	4.00PM	30.4	20.6	47	50

The above Tables shows the temperature and relative humidity of 5 days for different intervals of time of both Ambient and Inside of cooling system and the temperature drop and the increase in relative humidity was observed .For every day there was certain amount of decrease in temperature and relative humidity which is shown in the table .

GRAPHS:

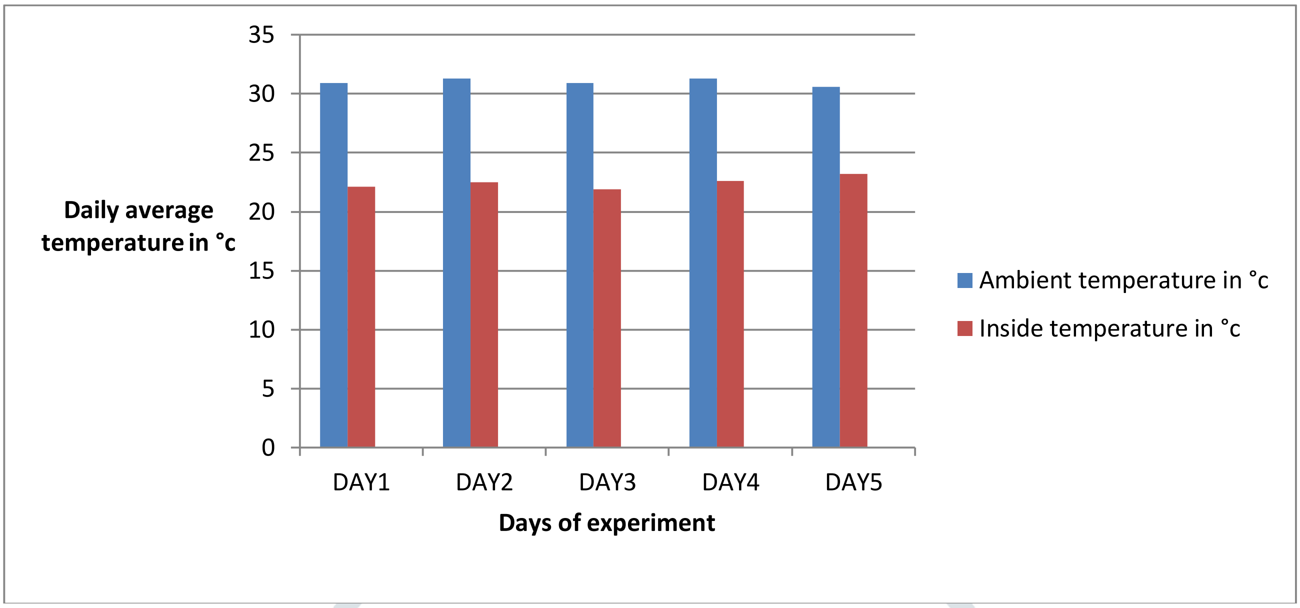

Fig1:Average temperature for both ambient and cooling system

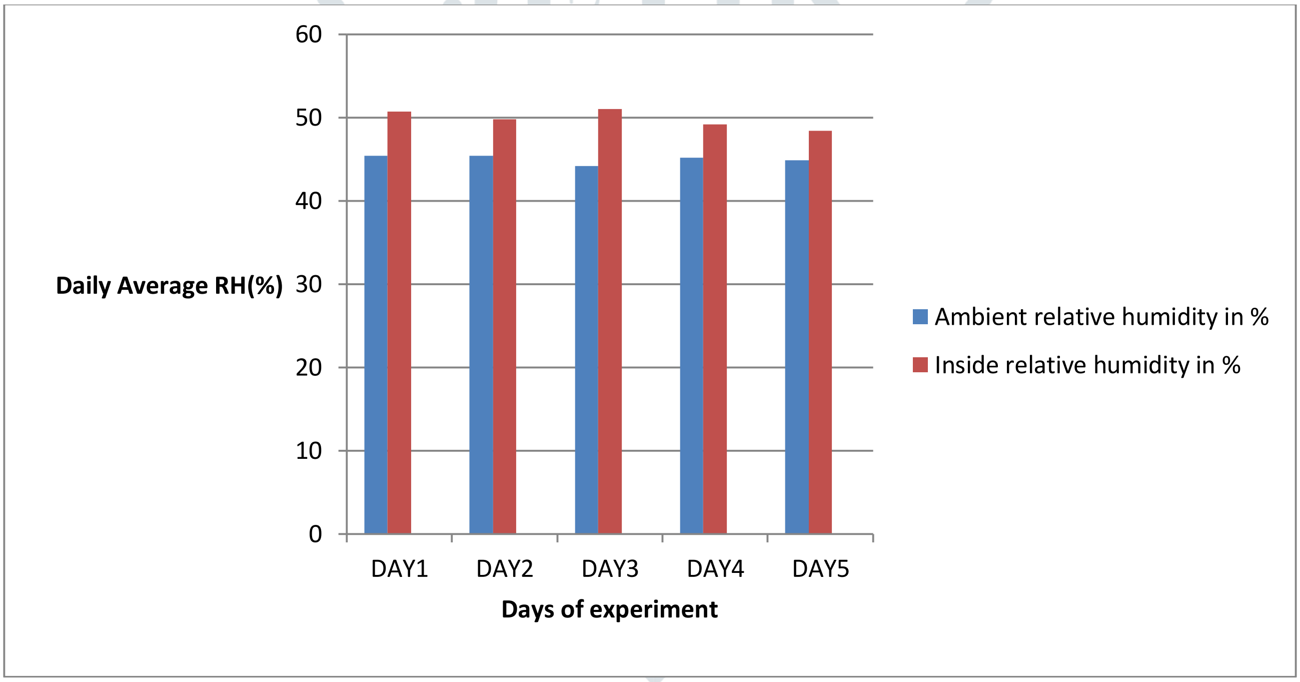

Fig2:Daily average relative humidity for both ambient and cooling system

The results of the experiment are shown in the above graphs. The average cooler temperature in morning, afternoon, and in the
The results of the experiment are shown in the above graphs. The average cooler temperature in morning, afternoon, and in the evening were measured for a period of 5 days and was found to be 22.1°c,22.5°c,21.9°c,22.6°c,23.2°c. While relative humidity were 50.7%, 49.8%, 51% 49.2%, 48.4% respectively. From the temperature drop of 12°c was recorded and there was increase in relative humidity. The fruits and vegetables were kept inside the cooler and they were observed. Daily records of the observation on condition of fruits and vegetables in cooler and the one which kept at room temperature where and recorded compared and several remarks were observed**.**

VI. CONCLUSIONS

The solar powered evaporative cooling system is designed and constructed for preservation of fruits and vegetables. An evaporative cooling system works on the principle such that the warm air from ambient atmosphere is cooled and humidified by passing through jute fibres. The evaporative cooling system operates by solar energy as a power source in which cool air passes through chamber were vegetables and fruits are stored. The testing of evaporative cooling system was carried out for a period of 5 days the average drop in temperature was recorded up to 12⁰c. The changes observed in the vegetables were greater than the one which are stored in the system. However the testing of evaporative cooling system shows that the vegetables can be stored for 5 days without rotting compared to that of ambient. Hence, it is concluded that farmers, house holders, ware houses should adopt the use of solar powered evaporative cooling system for preserving vegetables and fruits which increases the shelf life of fruits and vegetables.

VIII. REFERENCES

1. Bhatnagar DK, Pandita ML, Shrivastava VK (1990) Effect of packaging materials and storage conditions on fruit acceptability and weight loss of tomato. National Workshop on Post-Harvest Management of Fruits and Vegetables, March 14–16, Nagpur, India.

2. Chopra S, Baboo B, Alesksha, Kudo SK, Oberoi HS (2003) an effective on farm storage structure for tomatoes. Proceedings of the International Seminar on Downsizing Technology for Rural Development held at RRL, Bhubaneswar, Orissa, India, October 7–9, pp 591–598.

3. Choudhury (2005) recent developments in reducing postharvest losses in the Asia-pacific region. Postharvest Management of Fruit and Vegetables in the Asia-Pacific Region. Reports of the APO seminar on Reduction of Postharvest Losses of Fruit and Vegetables held in India, 5–11 October 2004 and Marketing and Food Safety: Challenges in Postharvest Management of Agricultural/Horticultural Products in Islamic Republic of Iran, 23–28 July 2005.

4. Chouksey RG (1985) Design of passive ventilated and evaporative cooled storage structures for potato and other semi perishables. In: Proc. Silver jubilee convention of ISAE held at Bhopal, India, October 29–31, pp 45–51.

5. Dadhich SM, Dadhich H, Verma RC. Comparative study on storage of fruits and vegetables in evaporative cool chamber and in ambient. Int J Food Eng. 2008; 4(1):1–11.

6. Fuglie K, Khatana V, Ilangantileke S, Singh JP, Kumar D, Scott GJ (1997) economics of potato storage in India. Social Science Department Working Paper No.1997–5. Int potato centre(CPI), Lima, Peru.

7. Ganesan M, Balasubramanian K, Bhavani RV. Studies on the application of different levels of water on Zero energy cool chamber with reference to the shelf-life of brinjal. J Indian Inst Sci. 2004; 84:107–111.

8. Jain D. Development and testing of two-stage evaporative cooler. Build Environ. 2007; 42(7):2549– 2554. Doi: 10.1016/j.buildenv.2006.07.034.

9. Mordi JI, Olorunda AO. Effect of evaporative cooler environment on the visual qualities and storage life of fresh tomatoes. J Food Sci Technol. 2003; 40(6):587–591.