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Research Article

Design and Development of Energy Efficient Multi-Utility Desert Cooler

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Abstract

An evaporative cooler produces effective cooling by combining a natural process - water evaporation with a simple, reliable air-moving system Evaporative cooling is the most economical and effective means of refrigeration and air cooling since its inception particularly in the areas where climatic conditions are hot and dry. In Rajasthan (India), during summer Dry Bulb Temperature (DBT) of air may reach up to 48 ˚C while relative humidity stays below 50%. During present study efforts were made to make evaporative cooling system more versatile. In the process of study a cooler cum refrigerator has been developed which can be utilized for the purpose of air cooling, drinking water cooling viz. a viz. storing the vegetables and medicines without altering the performance of desert cooler. The energy saving by doing so is saved more than 30 W. A small size desert cooler can cool more than 24 liter water per day up to the Wet Bulb Temperature (WBT) of outside air as well as could store vegetables for more than five days.

Keywords: Desert cooler, Evaporative cooling, Humidity, Refrigeration

1. Introduction

In the North Western part of India, the humidity of air is quite low during summer season whereas dry bulb temperatures are very high. This climate is most suitable for evaporative cooling [1]. Fresh outside air is sucked through moist pads where it is cooled by evaporation of water and this cooled air circulated in a room or building by a small fan or blower. Due to vaporisation of water, the temperature may decrease upto the wet bulb temperature of air i.e. around 22 °C[2].

A simple scientific arrangement for cooling unlimited quantity of safe drinking water - naturally - with the little use of external energy source such as electricity or ice working on the principle of 'cooling by evaporation', the natural water cooler is developed by a local artisan and is made up of indigenous materials only. The water cooler is fabricated using mainly copper tubes and galvanized iron / stainless sheet. It is fitted with a standard make micro-filter for filtering solid particulate and contaminants[3]. Prajapati, Mansukhbhai from Rajkot in India, developed a water cooler made with clay and can be operated without electricity. The upper portion of the refrigerator can store about 20 liters of water, while the bottom cabinet has separate space for storing fruits, vegetables and milk. The natural cooling process inside the refrigerator can keep vegetables and fruits fresh for around 5 days, while milk can be preserved for 3 days[4].

The developed water cooler during present investigations was fabricated using mainly copper tubes and galvanized iron / stainless sheet. The water cooler is fitted with a standard make micro-filter for filtering solid particulate and contaminants. The water cooler can be connected to overhead water source and is very simple to operate and maintain.

During present study efforts have been made to utilize the cold water which is available in the cooler tank at WBT for indirect cooling of drinking water as well as vegetables and various

other eatables. The major advantage of this arrangement is to eliminate the possibility of contamination of the stored items, which are to be cooled. With practically no operation & maintenance cost, this type of coolers are ideal for use in public places such as hospitals, hotels, hostels, industries, offices, institutions etc. for providing cool & hygienically drinking water as well as eatables.

2. Experimental Setup

The conventional desert cooler used for domestic cooling purpose has been selected for the experimentation. Technical specifications of the desert cooler are given in the Table 1. The view of the developed cooler is shown in photograph. The desert cooler was connected to the insulated Galvanized Iron (GI) box developed for the present study. The schematic diagram of the experimental set up is shown in the Fig. 1

Table 1: Technical Specifications of Desert Cooler

Motor RPM	:	400
Air Delivery	:	4400 m^3/hr
Wattage	:	185 W
Maximum Current	:	0.95 amp
Fan diameter	:	457 mm
Speed Control	:	Three
Water Tank Capacity	:	51 liter
Length	:	655mm
Width	:	634 mm
Height	:	773 mm
Portability	:	Window Mountable

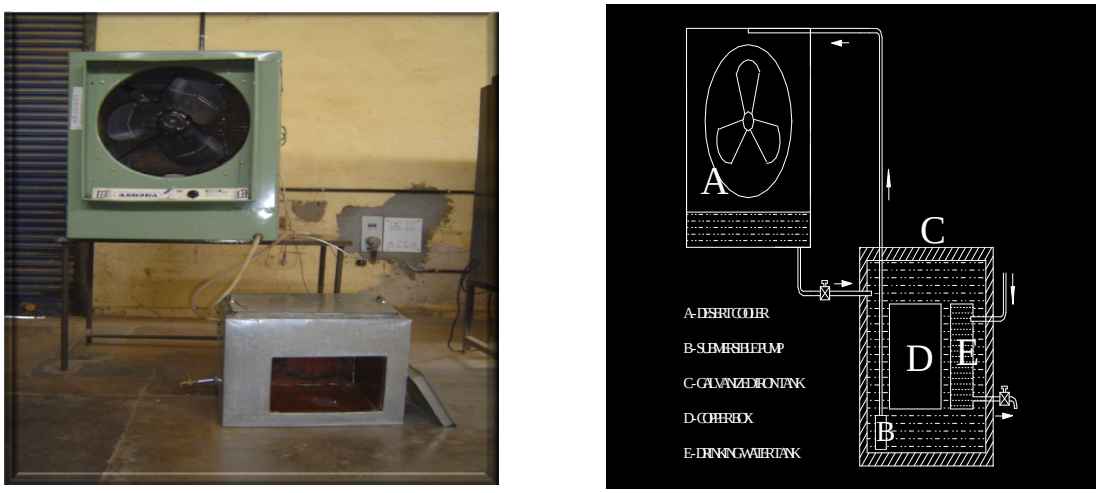

Fig. 1: Photograph of Maru Cooler and Schematic Diagram of the Experimental Set up

Box is made of double layered Galvanized Iron (GI) sheet (24 SWG). Between the two layers (10 cm apart) of G.I. sheets, thermocol is provided as an insulator to reduce heat transfer from cold water to outside air. Same thickness of thermocol has been selected which is generally used in ice boxes. Two separate copper boxes were fitted inside the GI box to accommodate drinking water as well as food items like milk, vegetables etc. Out of two copper boxes, one is used for storage of drinking water having inlet connection for hot water supply and outlet connection for getting cold drinking water. Brass fits are used in inlet and outlet port and box is sealed so that there will be no contamination in drinking water. Seven liters water can be stored in this copper box for drinking purpose. Second copper box is used for storage of food items like milk, vegetables etc. for more than three days.

3. Performance Study of Existing Cooler

To test the utility of the developed water cooler cum storage, exhaustive experimental work has been done. To see the performance of desert cooler various experiments are conducted on existing desert cooler. The velocity of incoming air was measured with the help of anemometer. Temperature and humidity of incoming air to the cooler as well as out coming air were measured. On the basis of observations effectiveness of the cooler were calculated. The observations and results are shown in Table 2.

Table 2: Observations and Performance of Desert Cooler

Sr. No.	Time in min.	Air Temperature in °C		% Relative Humidity (RH)		Water Temp °C	WBT in °C (T_b)	Effectiveness %
		Outside Air Temp. (T_1)	Temp. after cooler (T_2)	Outside Air	After cooler			
1.	15	36.5	25.7	19	58	21.2	20.0	65.4
2.	15	36.0	25.8	20	54	20.8	20.0	63.75
3.	27	38.6	26.8	17	51	20.5	20.3	68.3
4.	25	37.5	25.8	18	55	20.0	20.0	68.57

Effectiveness[5,6] of the cooler is defined as the ratio of actual temperature drop of air to maximum possible temperature drop.

Effectiveness= $(T_1-T_2)/(T_1-T_b)$

Where T_1= Temperature of outside air in ^{0}C

T_2= Temperature of air coming out from the cooler in ^{0}C

It is clear from the results indicated in Table 2 that water temperature of cooler tank almost reaches to WBT of ambient air. Also we got an average effectiveness of desert cooler equal to 66.5%.

4. Performance of desert cooler with attachment

After attaching the G.I. box with desert cooler investigations were made as in the case of desert cooler. Observations and results are depicted in the Table 3.

Table 3: Performance of Desert Cooler with Attachment

Sr. No	Air temperature ^{0}C		Relative humidity (RH)		WBT	Effectiveness
	Ambient	After cooler	Ambient	From cooler		
1.	39.1	28	23%	58%	22.3	66.07%
2.	39.4	28	22%	56%	22	65.5%
3.	40	29	22%	56%	23	64.7%

Average effectiveness is found to be 65.42 %. There is no significant difference is obtained with unloaded condition. Drinking water was the main objective behind designing the present cooling system. Performance of the cooler was taken with drinking water in the G.I. box as well as without attaching the G.I. box with the existing cooler. The cooling curve is shown in Fig. 2. The outside conditions during experiments were observed to be hot and dry (40 deg. C DBT and 17% R.H.). At these conditions, temperature, almost WBT (21.2 ^{0}C) has been obtained only in 25 minutes without attachment in contrary to 52 minutes when it is connected to the G.I. box having cooling water as well as drinking water in it. For circulating the cooling water in desert cooler without attachment conventional pump was kept in position whereas in the case of attachment another pump mounted in the G.I. box was in operation. The lag of 27 minutes was due to the load of additional cooling water as well as drinking water. It can be concluded that performance of the desert cooler is affected in terms of time lag but not in terms of minimum temperature obtained by it. As indicated in Fig. 3, the temperature of cooling water in desert cooler as well as in G.I. container reaches to its WBT almost at the same time i.e. 52 minutes after the start of cooler.

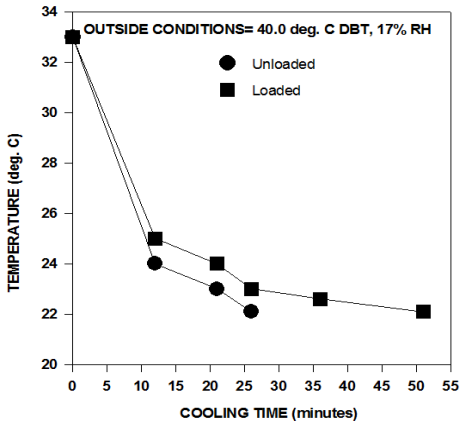

Fig. 2 Cooling Time for Water in Desert Cooler with and Without Attachement

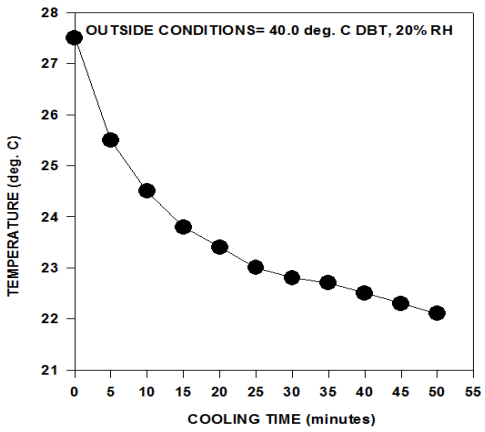

Fig. 3 Cooling Time for Water in G.I. Container

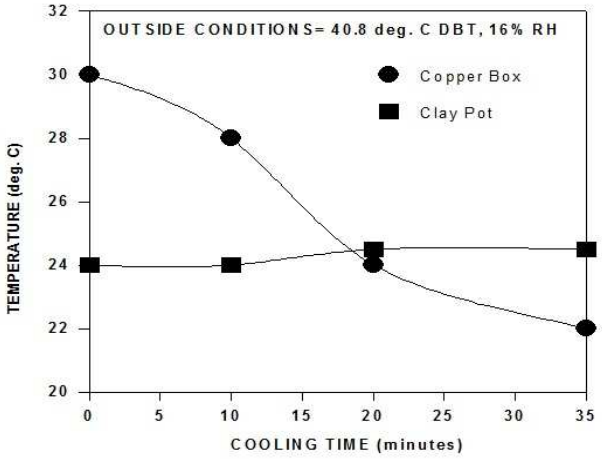

Fig. 4 Comparison of Cooling of Drinking Water in Copper Box and Clay Pot

5. Performance of Desert Cooler with Drinking Water

For domestic use, it is observed that the requirement of drinking water is not continuous. Fig. 4 shows the change in drinking water temperature with time. The cooling water attains its minimum temperature in around 30 to 35 minutes, which is ½ to 1 degree C more than the temperature of water in G.I. container.

Comparison of drinking water obtained through the conventional clay pot in Rajasthan is also made and concluded that the temperature of water is significantly lower in the case of copper box.

6. Experiments on Vegetables

Various experiments are conducted in front copper container by putting vegetables inside it. Cooling curves of various vegetables are drawn to see the time taken by the device to cool vegetables up to the copper box temperature. For this purpose thermocouples are attached to vegetables. Some vegetables like tomato have larger size so the thermocouple is inserted up to the core. The preserved vegetables are shown in photograph. The Figure 5 shows the cooling curves for different vegetables. The cooling rate of coriander and cucumber is found to be same whereas the rate of cooling of ladyfinger is different and lower than both the vegetables due to its density. Further, all the vegetables could achieve the temperature of cooling water in around 23-25 minutes.

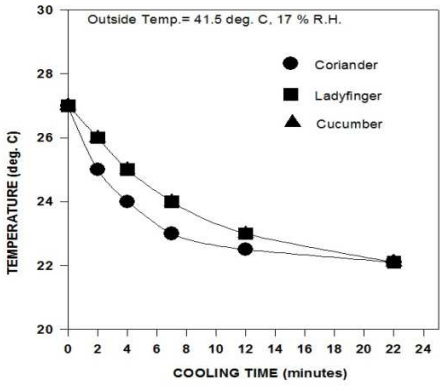

Fig. 5 Cooling Curves for Different Vegetables

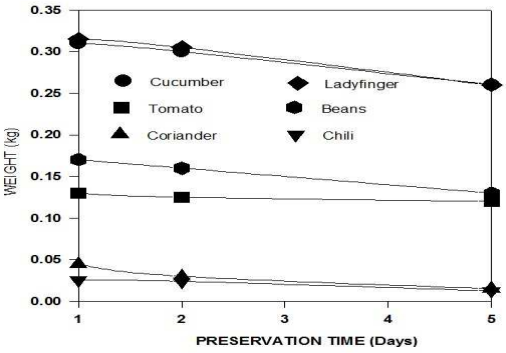

Fig. 6 Weight Loss of Preserved Vegetables

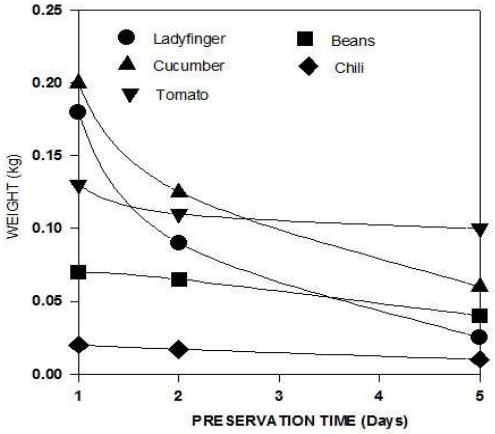

Fig. 7 Weight Loss of Un-preserved Vegetables

Fig 8 Preservation of Different Vegetables

The weights loss of six different vegetables was measured after 2 days and 5 days in container as shown in Fig. 6. Curves are plotted for weight loss v/s time. These weight losses are compared with the weight losses of vegetables in environment. These curves show that there is enormous difference in weight losses of the two. The vegetables lying outside lose weight rapidly as compared to the vegetables kept inside the copper container. Weight loss of chili and coriander is found to be very little whereas cucumber and ladyfinger losses weight rapidly. For the purpose of comparison, weight losses of unpreserved vegetables are indicated in Fig. 7. The observations reveals that the vegetables lying outside losses weight so rapidly that they are not usable after only one day but vegetables lying inside the copper container were good enough to eat even after 5 days. This shows the usefulness of this device to store vegetables

6. Conclusions

On the basis of present study, following salient conclusions are drawn

1. The developed cooler can be used for the purpose of storage of vegetables, bakery products, chocolates, medicines etc. including drinking water. The main medicines which can be stored in the temperature range of 22 - 27 ^{0}C: Propecia is the medicine used to treat male pattern hair loss in men only [7] .
2. Average effectiveness is found to be **65.42 %** which is comparable with unloaded condition.
3. In unloaded condition, WBT (21.2 deg. C) has been obtained only in 25 minutes contrary to 52 minutes when it is connected to the G.I. box having cooling water as well as drinking water in it.
4. Developed cooler performs better over its nearest rival i.e. clay pot which is most popular in desert areas for cooling the drinking water.
5. Vegetables can be stored up to five days without any decay in their properties.
6. Around 30W energy can be saved by using the developed attachment with the conventional desert cooler without affecting the performance of the cooler

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