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Evaporative Cooling System for Fruits and Vegetables and its Evaluation for Relative Humidity and Throttling Effect

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Abstract - *Proper storage of vegetables, fruits and food items is necessary in order to maintain their life. The shelf life of fruits and vegetables is highly dependent on the temperature factor and the relative humidity (RH) within the storage place. Cold room and refrigeration facilities are out of budget due to advance technologies and high electricity consumption. Affordable storage facility is highly useful in such conditions. The paper aims at developing low cost, small scale evaporative cooler that operates on a principle of evaporative cooling phenomenon. The developed model has box type of structure having water holding vessel at bottom side. The proposed model has cooling fan arranged for vertical orientation with certain height partial closed as well as medium height between cooling chamber and storage chamber. The fan has been operated at two speed variants namely low speed as well as high speed for getting results at different evaporation rates. Throttling vanes have been provided through the air entering chamber which significantly affects evaporation capacity of the evaporative box. In the given range of 270 minutes of operating time during two periods of day; including morning and afternoon. The relative humidity (RH) percentage increase from 26 to 60 is found through the experimentation while the temperature difference was reduced down to 8 degree of difference (*40 ^{0}C to 32 ^{0}C*) through experimentation. The performance of the developed model was found better in case of throttling with fan speed parameter that includes partial throttling at high speed and medium throttling at low speed.*

Key Words: Relative humidity, evaporative cooling, throttling effect, storage technology, shelf life.

1. INTRODUCTION

Samantha Deoraj [1] has discussed about the method is disclosed of preserving harvested vegetable which is extend life of fresh vegetable, to maintain RH, latent heat. On the principle of evaporation causes cooling effect and preventing heat from outer atmosphere to entering into the system. In this paper, the system was designed, built and tested for the storage of fruits and vegetables through an evaporative cooler. To reduce the temperature and increase in the relative humidity for the storage of produce by applying the principles of the evaporative of water the above said system is an economical and efficient method. The operating time for cooler was 180 minutes using materials like cedar, teak and coconut fibre at 4 m/s, 6 m/s and 8 m/s extraction speeds with two periods of day with morning and afternoon. [1]. In conclusion, an effective way to store fruits and vegetables using evaporative coolers through local materials like cedar shavings, teak shavings and coconut fibre. It was found that cedar shavings was the best material in terms of saturation effectiveness and lowering the ambient temperature required for storage. According to fan speed, the speed 8 m/s produced the best results [1].

Isaac F. Odesola [2] has proposed that, for the preservation of fruits and vegetables porous evaporative cooler was used. Pot-in-pot, cabinet, static, and charcoal cooling chambers are the different designs for different types of evaporative cooler was taken so the result based on the performance of the evaporative cooler have a depression in temperature in the storage chamber. Direct and indirect evaporative cooling are the two general methods were included [2].Thus prospect for use for short term preservation of vegetables and fruits soon after harvest. He conclude that the estimated rate of water loss by reducing the temperature in the storage chamber and increasing the relative humidity. During the time of the day the significant evaporative cooling temperature depression from the ambient air temperature was occurs [2].

Ndukwu MacManus [3] the author has developed, designed and evaluated an active evaporative cooler for its effectiveness in short-term storage of fruits and vegetables, when they tested to this evaporative cooling system was arranged to heat in the air is utilized to evaporate the water [3]. Thus, the ambient air of 32.80 ^{0}C temperature with 36% relative humidity should be allow to 23.20^{0}C temperature and 90.4% relative humidity cooler could drop the ambient temperature very close to its wet bulb temperature as shown as 21.96^{0}C. Resulting in a drop in the air temperature and increase in relative humidity then he conclude that from the experimental result. The relative humidity of the cooler was observed around 85.6% – 96.8% throughout the experiment, which shows the maximum possible level of saturation of air by humidification [3].

Amrat lal and D Samuel [4] the paper relates to the principle of evaporative cooling; physical phenomenon in which evaporation of a liquid, typically into surrounding air, cools an object or a liquid in contact with it. These work practices proposed that, evaporative cooling system not only lowers the air temperature surrounding the produce, but also increases the moisture content of the air [4]. According to them, evaporative cooling system is well suited where temperatures are high, humidity is low, water can be spared for this use, and air movement is available. Finally, in conclusion they established cooling is provided by the evaporative heat exchange which takes advantage of the principles of the latent heat of evaporation where tremendous heat is exchanged when water evaporates. It makes use of the free latent energy in the atmosphere [4].

Shengping Lyu [5] has found the first link of cold chain is precooling, which effectively inhibit the respiration and extend the preservation period of fruits and vegetables. In this paper, the precooling technologies were classified and different technologies such as cold water precooling, ice precooling, room precooling, forced-air precooling, vacuum precooling technologies and equipment were introduced. The key factor for research and development trend of precooling technology and equipment were also determined [5]. Thus, the comparison of different precooling technologies such as cold water precooling, ice water precooling, room precooling and force air precooling and vacuum precooling was compared, and the future research trends of precooling techniques were prospected. In the conclusion, to reduce energy consumption, improvement in precooling components required as well as for the research of precooling for fruit and vegetable and the development of related equipment is required. To avoid chilling injury or uncompleted precooling, develop the precise control unit which detects online parameters and for the cold chain transportation and standard specification the precooling efficiency that requires improvement in parameters [5].

2. EXPERIMENTAL AND TESTING PROCEDURE

2.1 Description of construction and operation

Components of the evaporative cooler as shown in fig.1 are an insulating box (90 cm x 70 cm x 70 cm) and vegetable basket (45 cm x 45 cm x 15 cm) as a storage chamber. Below this there is an evaporative blower fan as shown in fig.2 on water tank and at the other throttling section (40 cm x 8 cm) with a throttling vane capable of blow to air reaching maximum at blade of blower. At the base of this cooling chamber is a water storage pan with a blower at two stage partial height and medium height, which delivers water vapour to the top of the vegetable basket as a storage chamber. Throttling vent (5 cm x 1.5 cm) via. at a different two angle 45 ^{0}and 60 ^{0}. The purpose of these vent is to control the volume of blowing air. Moisten the evaporative vapour achieve an even distribution of water vapour on the surfaces of the vegetable basket. The blower to the cooling chamber creates a vacuum which removes the moisture particle from the water tank and distributes the cool moist air created through the blade of blower by throttling .The vent blower was used to ensure that all the cool air created at the cooling chamber was utilised in the cooling process which occurred in the insulating box and it prevented turbulent heat rejection from occurring. A variable speed of blower regulated the speed of air flow between low speed and high speed .The storage chamber consists of basket for storing vegetable moisture air to be created to enter the box through throttling.

Fig.-1: Evaporative cooler model

The top door of the storage box is lined with polystyrene to ensure when the door is closed and the 50 x 50 cm length and width blower is turned on there exists a vacuum.

Fig.-2: Bottom fan orientation with water reservoir

During the operation of the evaporative blower, ambient air is blown through the inlet of throttling vent and this air is cooled to water vapour particle. It is at the evaporative blower and throttle that the heat transfer takes place between the moist cool air and the ambient air. Ambient air enters the inlet through the throttle vent and exits at approximately 40 ^{0}C.

2.2 Test 1: Throttling at Partial height

In this case, the water tank kept at 8 cm below the insulating box at partial height. The water with capacity of 5 litre was filled in the water pan. The temperature of water was initially measured and noted along with the temperature of surrounding environment.

For the model development, insulating material was selected as Polystyrene (Commercial Thermocol) for box structure. The purpose behind selecting this material due to its closed cell structure and thus supports low thermal conductivity. It is highly selected for better thermal insulation. Other materials have an open cell structure and are thus unable when subject to moisture. The insulating box is placed on top of the blower to allow air to enter through het throttle, box having rectangular section.

After that the throttle vane was made up to certain degree approximately at 45 degree. The height of blower was maintained from throttle vane to blade of blower, it creates water vapour pressure on the surface of water in the tank. The basket is then been filled with the fruits and vegetables that we need to be preserve for long time. The model is been provided with vegetable basket i.e. chamber load carrying capacity upto 10 kg.

After that chamber of insulating box has been closed with lid. Initial temperature measurement and relative humidity (RH) count has been taken for the box with help of thermometer (dry-bulb temperature). The humidity ratio defines relation of the weight of water vapour to the weight of dry air. While the relation between the temperature and humidity has been calculated using the psychometric chart.

In this experimental procedure, the blower operated at two different speed mainly low and high speed.

Condition 1:

The blower has been started and kept running at low speed range; after 45 minutes temperature has been recorded and then relative humidity inside the box has been measured.

Condition 2:

The blower has been started and kept running at high speed range; after 45 minutes temperature has been recorded and then relative humidity inside the box has been measured.

The same procedure is repeated with providing different angle of throttling to the vanes.

After that throttle vane has been adjusted at an angle of 60 degree and the blower is adjusted such that the height of blower is been raised up inside the box towards upward side creating more space between vanes and the blower portion. This affects water vapour pressure on the surface of water in the water pan.

Condition 1:

The blower has been started and kept running at low speed range; after 90 minutes temperature has been recorded and then relative humidity inside the box has been measured.

Condition 2:

The blower has been started and kept running at high speed range; after 90 minutes temperature has been recorded and then relative humidity inside the box has been measured.

2.3 Test 2: Throttling at Medium height

The water tank has been kept at 12 cm below the insulating box at medium height and filled up to 8 litre of water. After that adjust blower inside the box so that throttling at medium height can occur. The measurement of the initial temperature of water and its surroundings environment has been taken. The insulating box is placed on top of the blower, to allow the air which is entering through the vanes.

After that the throttle vane was made up to certain degree approximately at 45 degree. The blower is then adjusted for the certain height so as to create water vapour pressure on the surface of water contained in the water pan. During experimentation fruits and vegetables are kept inside the vegetable basket and the lid cover of box is closed.

Condition 1:

Start the blower which is having low speed; After 45 minutes record the temperature and relative humidity of insulating box as well as fruit and vegetable.

Condition 2:

Start the blower which is having high speed; After 45 minutes record the temperature and relative humidity of insulating box as well as fruit and vegetable. Repeat the procedure as well as adjust throttle vane at angle of 60 degree. Maintain height of blower from throttle vane to blade of blower,

Condition 1:

Start the blower which is having high speed; After 90 minute record the temperature and relative humidity of insulating box as well as fruit and vegetable.

Condition 2:

Start the blower which is having low speed; After 90 minute record the temperature and relative humidity of insulating box as well as fruit and vegetable.

3. FLOW DIAGRAM FOR THROTTLING EFFECT

The shown flow diagram describes the operation of evaporative cooler and its sections across which the air flow circulates through vanes as a result of throttling effect. Throttling process involves the passage of a fluid through a vent for blowing the air. The effect is the reduction in pressure and increase in volume. In the experiment, throttling is achieved through the set of vents at the bottom of the box section through which air enters the box. Throttling vent angle is adjusted for the rate of change of speed of the air.

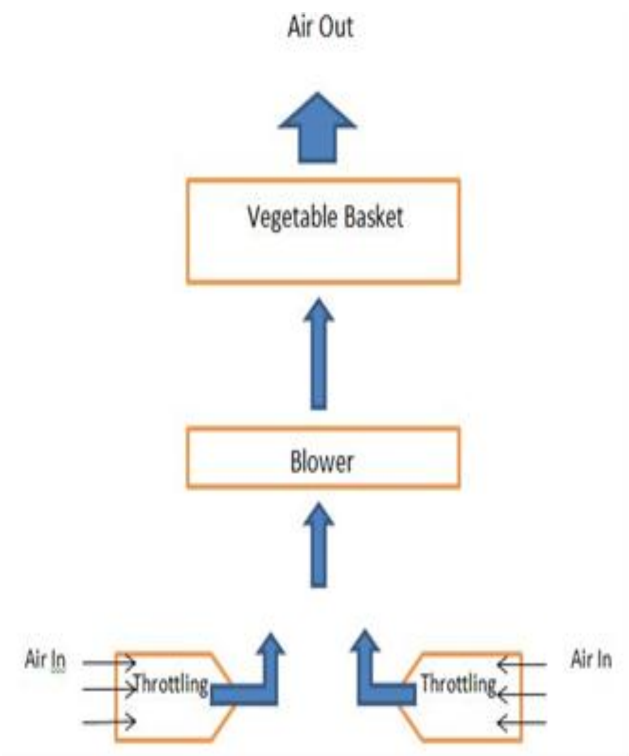

Fig.-3: Flow diagram shows throttling process

In the evaporative cooler model, when a fluid air flows through a vanes (a partially closed valve and a very narrow orifice) arranged at the bottom side of model, including certain angle, significant pressure reduction takes place. The phenomenon that creates the pressure difference among the flow termed as throttling effect.

As throttling occurs at the bottom end and the air flow occurs upwards. The aid fir the circulation of the air is given by the blower located inside the evaporative cooler. Blower enables flow of air through the vegetable basket designed to hold vegetables and fruits need to be stored for long time. The air escapes through the opening provided at the top end of the box structure.

3.1 Observation Table

Table -1: Thermometric Property

Sr. No.	Thermometric Properties	Values
1	Ambient Air Temperature (T_a)(^{0}C)	40
2	Initial water Temperature (T_w) (^{0}C)	27
3	Cropped vegetable Temperature (^{0}C)	30
4	RH of Room (%)	25
5	Atmospheric Pressure on Water surface (N/m^2)	1.013
6	Partial Vapour Pressure (N/m^2)	0.5833
7	Temperature Difference (^{0}C)	5
8	Initial value of RH into the box (%)	25
9	Final Value of RH into the box (%)	60
10	Heat Transfer Rate of Insulated box (W/m2k)	0.163
11	Area of Insulated box (m2)	25.2

Table-2:Experimental value for relative humidity (RH)

Duration of Testing (minutes)	Relative Humidity (RH) (%)			
	Throttling at Partial height		Throttling at Medium height	
	Speed of Blower			
	Low	High	Low	High
0	25	25	30	32
45	28	30	32	31
90	30	32	33	32
135	45	44	38	35
180	46	48	45	38
225	48	49	48	42
270	51	52	52	44

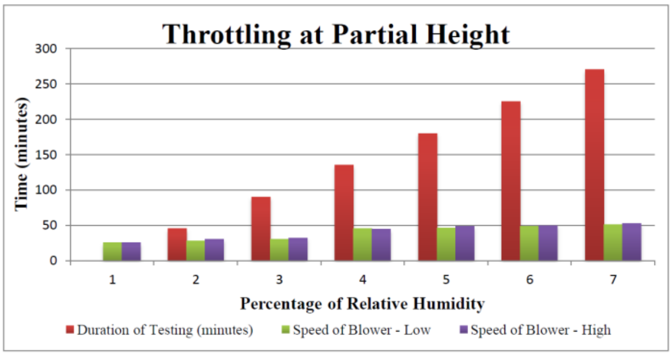

Chart-1: Percentage of Relative humidity against time (Throttling at partial height)

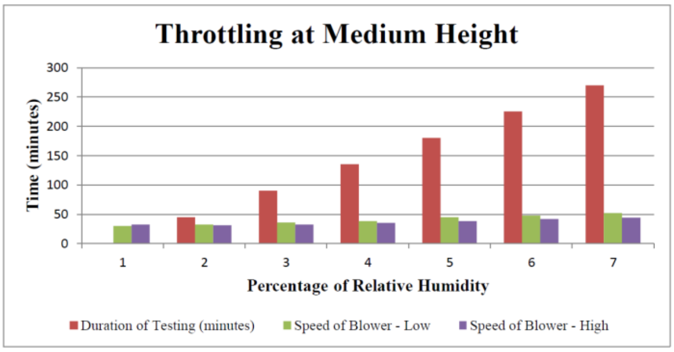

Chart-2: Percentage of Relative humidity against time (Throttling at medium height)

Experiment was conducted under ambient temperature and relative humidity at dry climate in summer. The relative humidity of the test period are summarized with experimental procedure. Even the collected data shown in table 2 and plotted a chart 1 and 2 shown with throttling at partial as well as medium height. Partial pressure of vapor is considered along with the effect of temperature and pressure associated with the conditions. The results of the throttling occurred at the event of medium height experiment is derived and shown in the graph 2. Also relative humidity has been observed as slightly varied to certain amount of its previous value.

Table 3 shows the temperature difference across all the testing duration while throttling at partial height as well as throttling at medium height. Saturation vapor pressure depends on temperature. There is no effect of total pressure and there is no difference between the situation in an open space and that in a closed container.

Temperature variation seen across chart 3 and chart 4 the different test procedures including partial height and medium height with variable blower speed. The relative humidity (RH) percentage increase from 25 to 52 is found through the experimentation while the temperature difference was reduced down to 6 degree of difference (40 ^{0}C to 34 ^{0}C) through experimentation.

Table- 3. Experimental value for temperature differences

Duration of Testing (minutes)	Temperature Differences (^{0} C)			
	Throttling at Partial height		Throttling at Medium height	
	Speed of Blower			
	Low	High	Low	High
0	40	40	39	39
45	38	39	39	38
90	37	39	38	38
135	37	38	36	37
180	35	36	35	35
225	35	35	35	34
270	36	35	34	34

While the considerable time period of 270 minutes was utilized for reading all the values evaluated under experiment.

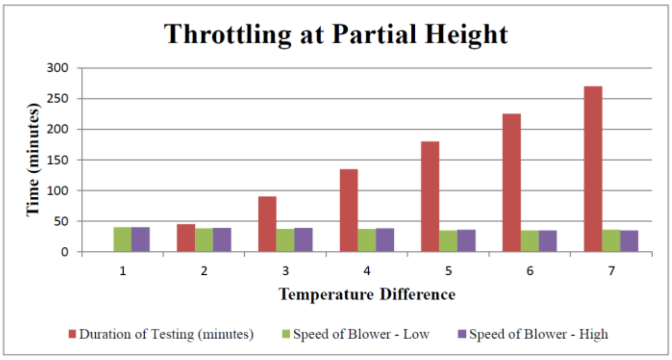

Chart-3: Temperature difference against time (Throttling at partial height)

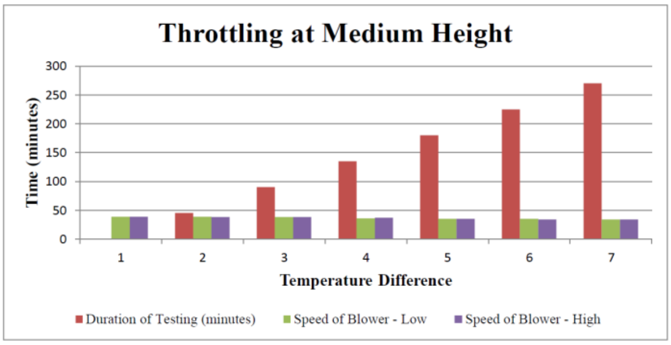

Chart-4: Temperature difference against time (Throttling at medium height)

It indicated in the chart 3 and 4 of temperature difference derived from the table 3. The partial pressure of vapour is equal to the saturation pressure and its value depends on temperature difference.

4. CONCLUSIONS

In this paper, investigation on the developed model of evaporative cooler has been carried out for its effectiveness and preservation capability. Fruits and vegetables are preserved for longer period and tested under evaporative cooling effect and ambient conditions as stated in the experiment. The selected material in the model development i.e. Polystyrene (Commercial Thermocol) was found suitable for the evaporative cooler. Even the insulation properties of the used materials are highly desirable for the application of evaporative cooling effect.

The effect of significant change in the blower height has been studied under the effect of evaporation. The results shows in table no.2 which states the relative humidity during the testing slightly changes from low speed of blower to high speed of blower. In conclusion, the high speed of blower at partial height gives more relative humidity, about 52%. Based on the accuracy results the life of fruits and vegetables has long in terms of more relative humidity. In the second phenomena, the low speed of blower gives more relative humidity as compared to high speed, about 52%.

So, from the above experimental study, we conclude that eevaporative cooling and lowering the ambient temperature required for storage. The blower speed was low at medium level of throttling it produced the best results, when the blower speed was low at medium level throttling the relative humidity was more than the partial height of blower. An effective way of storing fruits and vegetables using evaporative cooling method as cost saving option for domestic as well as agricultural purpose.

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