Design and Construction of An Evaporative Cooling System for The Storage of Fresh Vegitables

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Abstract- *A solar powered evaporative cooling system of 0.6 m3 capacity was designed and constructed to increase the shelf life of stored vegetables. The evaporative cooler was tested and evaluated using tomato and other vegetables. The equipment operates on the principle of evaporative cooling and increasing the relative humidity (RH) in the preservation chamber. The storage system was made up of aluminum sheets of 1mm thick while a side of the system is made of jute pad which get moist by water flowing through a series of perforated pipe from the reservoir located at the top of the storage system.*

The water flows with the influence of gravity. The RH and weight loss of tomato was statistically analyzed using student T – test and the result revealed that there was significant difference in using the evaporative cooling system for storing tomatoes as compared to ambient condition. The average cooling efficiency was found to be 83%. The temperature in the system dropped drastically when compared to the ambient condition which ranges from 6 to 10°C and the relative humidity in the cooling chamber increased considerably to 85%. However, the testing of the evaporative cooling system shows that the tomatoes can be stored for an average of five (5) days with negligible changes in weight, color, firmness and rotting as compared to ambient condition which started rotting after three (3) days. Hence, it is on this note that farmers, house holders and tomatoes processing factories should adopt the use such evaporative cooling system for the storing of fresh tomatoes as this increases the shelf life of tomatoes.

Keywords- Evaporative cooling, Storage, Relative humidity, weight loss.

I. INTRODUCTION

India is the second largest producer of fruits and vegetables in the world after Brazil and China respectively. 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.

Due to the short shelf life of these crops, it is estimated that about 30 to 35% of India's total fruits and vegetables production is lost during harvest, storage, grading, transport, packaging and distribution in a year which reduces the growers share. Hence, there is a need for maximum commercial utilisation of fruits and vegetables. 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.

In order to extend the shelf life of fruits and vegetables, they need to be properly stored. Proper storage means controlling both the temperature and relative humidity of the storage area. The essence of storage is of great importance because not all the harvested vegetables or crops in general will be used immediately after harvest so, measures of preserving the vegetables before it exceeds its shelf life is of great importance.

Vegetables should be consumed in the fresh state because they are usually perishable. In their fresh form most fruits and vegetables contain 80% water with some varieties such as cucumber, lettuce and melons containing about 95% When vegetables are harvested the moisture in them reduces partly due to respiration that occurs and since there is no replenishment and loss to the atmosphere.

II. LITERATURE SURVEY

Refrigerated cold storage is considered to be the best for storage of fruits and vegetables. But this method is not only energy intensive, but also involves large initial capital investment. Besides, it is not suitable for on-farm storage in the rural areas. Considering, the acute energy shortage in rural areas, there is better scope for adoption of small capacity, low cost, on-farm scientific storage structure like Zero Energy Cool Chamber (ZECC) developed at IARI, New Delhi by **Roy and Khurdiya** 1986 based on the principle of evaporative cooling.

In 1985 Construction of various evaporative systems was done by **Rusten** using available materials as absorbent. Materials used include canvas, jute curtains and clay blocks. Mechanical fans were used in some of the designs which drew air through a continuously wetted pad.

The process of evaporative cooling is an adiabatic exchange of heat when ambient air passes through a saturated surface to obtain low temperature and high humidity, which is desirable to extend the storage life of fruits and vegetables **Das and Chandra (2001)**. Storage of horticultural products inside the cool chamber has showed reduction in physiological loss in weight, optimum colour, better firmness and extended shelf life by 1–2 weeks in other parts of the country. Cool chambers are effective in maintaining the fruit acceptability for a longer period and minimizing the weight loss during storage (1990).

Wasker et al. (1999) reported slower rate of change of physico-chemical constituents in fruits stored in cool chamber. Weight loss of fresh tomato has been reported to be primarily due to transportation and respiration and limited shelf-life and losses in quality have been identified as the major problems faced in the marketing of fresh tomatoes (Bhowmic and Pan 1992). Zero energy cool chambers along with packaging materials, ventilation and anti- fungal treatments can help in minimizing the losses of ascorbic acid in the stored lemon fruits to some extent compared to the storage under ambient conditions of storage

In 1999 **Sanni** did a research on the development of evaporative cooling system on the storage of vegetable crops .The major development was implemented by adding a regulated fan speed, water flow rate and wetted-thickness. This was possible as a result of varying temperature and relative humidity within the facility.

Evaporative Cooling System: Evaporative cooling is a physical phenomenon in which the heat is removed from an object by the evaporation of a liquid coolant. Evaporation of water produces a considerable cooling effect. Thus faster the evaporation the greater is the cooling. Evaporative coolers provide cool air by forcing hot dry air over a wetted pad. The water in the pad evaporates, removing heat from the air while adding moisture.

The efficiency of an evaporative cooler depends on the humidity and temperature of the surrounding air. When the temperatures are the same, no net evaporation of water in air occurs, thus there is no cooling effect. In the extreme case of air that is totally saturated with water, no evaporation can take place and no cooling occurs.

The evaporatively cooled storage structures work on the principle of adiabatic cooling caused by evaporation of water, made to drip over the bricks or cooler pads. Generally, an evaporative cooler is made of a porous material that is fed with water. Hot dry air is drawn over the material. The water evaporates into the air raising its humidity and at the same time reducing the temperature of the air.

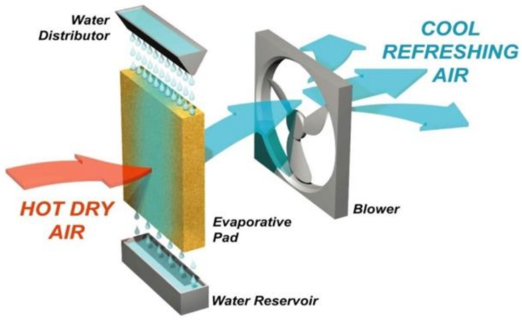

Fig.1: Evaporative cooling principle

III. METHODOLOGY

The design of the evaporative cooler is based on the principle of evaporation which causes a cooling effect to its

Fig.2: Experimental Setup

surrounding. The system is an enclosed system and air is allowed to pass only through the pad also a suction fan centrally located which draws in air through the pad.

Water drips into the jute pad at a constant rate through a water distribution system. As the

water drips into the pad the suction fan draws warm air through the wetted pad. During this process the warm air which is the sensible heat passes through the wetted pad which is now changed to latent heat due to the evaporation that has occurred as a result of the water being evaporation which causes the cooling within the enclosure

The materials used are cheap and readily available. As show in Figure the evaporative cooler in this study consist of

1. Suction fan
2. Pad end
3. Water reservoir
4. Pipe network

The pad was installed on both sides of the cabin and the suction fan was centrally located at the opposite side of the main entrance of the cooler. The pipe network is connected to the water tank. The pipe network allows the dripping of the water into the pipe to the pad. Excess water is drained provided with a reservoir at the bottom of the system.

The water distribution network consist of pipe network an overhead tank of about 25 litres and a bottom channel to take the excess water. The pipe network consists of a valve which was used to regulate the flow rate. The figure below shows the outline of piping network.

The water is being pumped by gravity as the stand used is 2.75m in height compared to the height of the cooler which is of 1.90m. The horizontal pipes which are layed on the region of the 2×2 steel constitutes of holes which allows water to drip into the pad and at the end of the pad is a stopper which prevent the water to be wasted. Figure shows the overhead tank with the discharge pipe at one side of the storage cabin

PAD ENDS:

The pad is held in place by a Steel metallic frame work and a wire mesh which covers both sides of the steel frame. A rectangular large hole which allows air movement into the pad constitutes the cross-section of the wire mesh. A thickness of 60mm was used based on the experiment carried out by Dvizama (2000) where it was disclosed that this gives the highest efficiency. Figure below shows the isometric and side view of the rectangular framework for the pad material.

Fig 5. Side view of the rectangular framework for the pad material

FAN POSITION:

A negative pressure is needed to be created inside the cabin which is a function of the pad and the fan and when this happens air at a higher pressure rushes into the system through the pad. For proper air circulation, the fan was located at the central position directly opposite the door which is air tight which now allows air to drawn from the pad area which in turn draws the cool air and expel the humidified air out. An exhaust fan of 1400rpm is used for the circulation of air inside the system.

Fig. 6: Fan position

The fan requirement for an evaporative is listed below

a) Exhaust fans should have freely operating pressure on their exhaust side to prevent unwanted air exchange when fans are not operating.
b) Fans should be tested and rated according to air movement and control association. Guard fans to prevent accidents.
c) Pad should cool air to within 2c of the wet bulb temperature at a pressure loss not exceeding 0.015kPa
d) Vertical pads must be well mounted and secured to prevent sagging .Pads should be easy to install and replace.
e) As water evaporates the salt concentration is increased. In area than have water with high minerals content a bleed off system is necessary to prevent mineral precipitation in the pad.

The pipe network is connected to the water tank. The pipe network allows the dripping of the water into the pipe to the pad. Excess water is drained provided with a reservoir at the bottom of the system. Figure below shows a water reservoir which helps to drain the water which is coming out of the evaporative pad.

IV. RESULTS AND DISCUSSIONS

The evaporative cooler was tested without been loaded with the food materials. The temperature and the relative humidity were determined. Both the temperature of the cooler and the atmospheric air were determined.

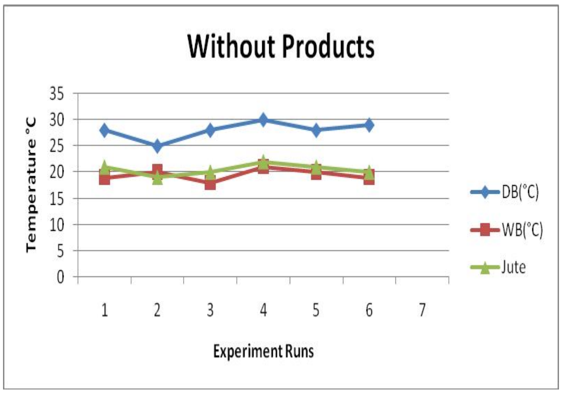

Fig: Temperature comparison

India is the fruit and vegetable basket of the world. Approximately 23–35% of the horticulture produce goes waste due to improper post-harvest operations and due to lack of enough storage facilities. Evaporative cooling system has a very large potential to propitiate thermal comfort. Nowadays, evaporative cooled storage system is increasingly being used for on-farm storage of fruits and vegetables. Evaporative cooling system not only lowers the air temperature surrounding the produce, it also increases the moisture content of the air. This helps prevent the drying amount of the produce, therefore extends the shelf life of horticultural produce.

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. There are many different styles of evaporative coolers. The design depends on the materials available and the users requirements. It is most suitable for the short term storage of vegetables and fruits soon after harvest. 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.

Based on this study, which was to provide an alternative source of storage for vegetables using a double-sided padded evaporative cooler it can be deduced that the evaporative cooler can be used as a temporary means of storage of vegetables.

The jute bag was used in the construction (fan and pad system). Cooled dry air is passed into the storage chamber were the vegetables are stored. The assumption is based that the dry cool air will reduce or totally remove the effects of the heat load of the store thereby providing a favourable condition for the preservation of the vegetables. The average drop in the temperature during the no-load test is about 8.5°C.

The cooling efficiency of the cooler was estimated both on load and a no-load condition. The efficiency of the cooler during the no-load test was averagely 85.5%. The products to be stored was divided into two for both the cooler and the ambient in other to deduce the effects of the advantage of the cooler using physical phenomenon like the weight, colour etc.

The percentage weight loss of the vegetables was much in the ambient compared to those stored in the cooler. The colour changes noticed in the vegetables stored in the ambient was greater compared to the ones stored in the cooler. The change in the firmness of the vegetable stored in the cooler was negligible when been compared to the ones stored in the ambient.

V. CONCLUSIONS

The economics of using evaporative cooling are surprising to most people. An 85% reduction in energy used compared to a conventional air conditioning unit seems too good to be true. Compared to air-conditioning which uses mechanical refrigeration, the operating cost of heat evaporative exchanging are 90% less than air conditioning. There are, now a days in operation, more than 20 millions of residential evaporative cooling in all world, saving approximately 60 millions of petroleum's drum and avoiding the emission of 27 billions of CO2 pound yearly. In the USA, only the fair of residential evaporative cooling moves US$ 180 millions in the year, with more than 4 millions of units installed.

The cost per unit of equipment is between US $35 for simple direct system and US$ 2,000 for completely systems with ducts, and the average cost between US$ 300 and US$ 700. The direct settling reduce the operation costs between 25% and 40% when it is compared with costs of mechanical refrigeration only, to produce the same cooling effects. A direct/indirect system accounts for saving between 40% and 50% energy in moderately wet areas. On farm evaporative cool storage was found to be technically feasible at reducing potato storage losses by as much as 50% over farmer's methods. However, the additional cost of ECS may be too high to encourage widespread adaptation.

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