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Review on Preservation of Post-Harvest Vegetables by Using Evaporative Cooling Method

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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 vegetables is highly dependent on temperature and humidity in 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 time slots i.e., morning and afternoon. Humidity percentage increase from 26 to 60 is found through the experimentation while the temperature difference was reduced down to 8 degrees 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.

***Keywords*: Evaporative Cooling, Fruits and Vegetables, Storage, Cold Chain**

I. INTRODUCTION

Lack of storage accommodation has been led to large number of losses to farmers throughout world and that too in developing countries like India. Thus, result in food waste and which increases cost to farmers. According to survey conducted India produces 16% of agricultural waste every year due lack of cold storage facilities [1]. The study states that use of evaporative cooling is efficient way of cooling while it comes vegetables and fruit cooling and which is way more economical for farmers. Evaporative cooling reduces the spoilage rate and also helps to improve shelf life in this case vegetables can be kept for longer period of time. Evaporative cooling system mainly based on heat and mass transfer conversion of sensible heat into latent heat. Air helps to reduces its temperature and provide sensible heat which transforms to latent heat. The concept behind this is it converts the sensible heat to latent heat with the help of unsaturated air thus led to decrease in the temperature as water gets evaporated and gives cooling effect. The sensible heat is associated with a change in temperature which do not changes the physical state of water while conversely, latent heat transfers only change the state of the water by evaporation [2]. This cooling effect has been used on various scales from small space cooling to large industrial applications [3].

In developing countries, Storage has been observed to pose a greater threat to fruits and vegetables because information on the storage temperature, humidity requirements and the length of time they can be kept without a decline in market value is either inadequate or unknown to those who need the information [4]. Spoilage of vegetables at the time of storage is depended on temperature. Lowering the temperature inside the storage is one of the ways to reduce loss. Even though too low temperature can damage the outer skin or layer of the vegetables as the vegetables leaves the area of controlled temperature spoiling process get started [5].

Most of the vegetables losses occurs after harvesting are mainly because of the lack of adequate storage facilities. Though the refrigerators are the good mean to preserve vegetables but on other hand they are expensive for small scale farmers and non eco friendly to environment. As water is used coolant in the setup so as water gets evaporated it takes energy from surrounding which leads to cooling effect. Factor that affects the evaporative cooling rate when surrounding air is more humid. As air passes through the cooling pads so the faster rate of evaporation which creates the more cooling effect in the storage. Efficiency of evaporative cooling depends on the humidity of the surrounding air [6].

The shelf life of vegetables can be increased by eliminating heat from field and cooling it as soon as possible after harvest. The finest storing temperature of vegetables is above their freezing point [7]. The problem of insufficient storage facilities for fresh vegetables later harvest leads to a reduction in the amount on the market; this also has a direct impact on the economic distribution and consumption of amount essential for human sustainability. Hence, the determination of this work is to design and construct an Evaporative Cooling System that will store fresh vegetables and increase its shelf life.

II. LITERATURE REVIEW

Yogesh Jadhav *et al.,* (2020) [8] For preserving shelf life of vegetables, the appropriate storage and temperature are necessary. Using cold storage nowadays is not affordable due to electric consumption and other things. The paper aims at developing a low-cost, small-scale cooler that functions on principle of indirect evaporative cooling. The model which is developed having the water-holding vessel at the bottom. The final model consists of a cooling fan arranged for vertical orientation with height, partial closed and medium highs between the cooling chamber and storage chamber.

The fan is operating with low as well as high speed. In the given range of 270 minutes of operating time during two periods of the day including morning and afternoon humidity increase from 26 to 60 if found through experimentation and temperature reduced down to 8 degrees of difference. In this paper investigation model of the evaporative cooler has been carried out for the effectiveness and preservation capability. The selected material for this experiment was found suitable for evaporative cooling. Also, the insulation properties of the used materials are highly effective.

M. K Ghosal *et al.,* (2019) [9] The green vegetable highly perishable and need storage for mentioning the shelf life of the vegetables. The importance of such type of vegetables nowadays increasing due to vitamins and other things. The farmers move away from growing the vegetables because of less profit. To overcome this problem the evaporative cooling is the best idea. Once the vegetables are cut, they can be sited in this system to maintain their shelf life. It is found that it could be stored for 4 days in the marketable form in the cooling chamber under coastal conditions to one day in room state during the summer season. The loss of mass of the stored food items indicates that moisture loss from it. Any storage mother for vegetables should aim at minimizing the moisture. So, in the rural areas, there must be a technology that can store the food products for at least 6 to 7 days.

K.V Vala *et al.,* (2014) [10], researchers showed different materials for the improving efficiency of evaporative cooling storage. The evaporative cooling storage largely depends on the operating parameters. In the paper, researchers are identified different types of parameters for improving the efficiency of evaporative cooling storage over mechanical refrigeration. They introduce different types of materials at low cost, easily available, and cheaper. The researchers analysed different structural parameters like wood bricks, mild steel, aluminium for the wall of the evaporative storage structure. For the top of evaporative storage use lightweight, cheaper, and easily available material like jute bags, plywood, gunny bag, asbestos sheet, etc. Also, they define different types of pad material namely brickbats, clay, wood saving, sand, PVC sponge, wheat straw, sawdust, coconut coir, rice husk, cotton fibre, greenhouse shedding net, and jute. This is more economical, low cost of construction, negligible operational cost, and has other advantages over mechanical refrigeration.

Danyal Rehman *et al.,* (2020) [11] This research paper is all about evaporative vegetable cooling storage. In this article, the two main technologies were highlighted. Interestingly, these two systems do not use any fuel or refrigerant for providing refrigeration, which results in to decrease in energy requirements as compare to standard refrigeration systems also it has low cost and massive water saving. Although the evaporative cooling system performs finest in hot and arid region like Africa, most of the people stay in undeveloped areas is partial or high-priced access to electricity. These vegetable storages help to save vegetable from food loss especially after harvesting the produce. The major difference between these two is earlier uses pot in outer surface and latter uses plastic dish as the outer surface.

These two evaporative coolers were tested in Mali and the result shows pot-in-pot and pot-in-dish devices consume 1.96 and 2.85 L/day of water, respectively. The devices were designed in straight cylindrical shape but in Mali, the pots were seen not perfectly cylinder. The various equations for mass balance, energy balance, evaporative model, capillary action model, etc. have been elaborated. This article concludes that the Mean absolute error of pot-in-dish is higher than the pot-in-pot which means cooling of pot-in-dish is lower than the pot-in-pot.

P. K Sharma *et al.,* (2016) [12] authors have developed a solar evaporative cool storage structure under economical material. They are designed for the storage of fresh vegetables and fruits using solar energy. In the setup, they are used wood wool and khaskhas (Vetiveria Zizanoides) mat for taken as a cooling pad in an evaporative cooling storage structure. Also, they installed a Solar Photovoltaic system to operate the exhaust fan (48W), water pump (40W). The Solar photovoltaic system consists of 4 solar panels (100Wp/12V each) for converting DC supply to AC supply, they use a solar inverter (24V/1400VA).

The solar photovoltaic system produces 400 W average power in 6 light hours. When solar evaporative cold storage structure works consuming 2.212 kWh. This is only 92.61% energy consumption of the solar photovoltaic system. Would be this result photovoltaic system is suitable for cover the load demand without using energy from the electric grid. This concept is useful for an off-grid population in India.

Ajay Kale *et al.*, (2014) [13] The present work is about Evaporative coolers for vegetable preservation structure is grounded on the value that once moist but unsaturated air comes in contact with a cooling pad temperature is higher than the dew point temperature of the air, some water from the cooling pad surface evaporates into the air. Evaporative cooling storage is an efficient and cost-effective means for dropping the temperature and increasing the relative moistness.

Numerous vegetables need a high humidity (≥ 70%) with unconditionally no exposure to direct heat or sunlight. Here the experiments are directed on natural and forced updraft evaporative coolers. Coolers are made of a G.I sheet of 0.5 mm thick. PUF is used as lagging and it is located between the G.I sheets in compelled state to avoid air gap between the G.I sheet and foam. The system is a surrounded system and the air is permissible to pass only through the plate covering water. During this procedure, the warm air will come in contact with a relatively large surface of the water. The result shows the fact that keeping a low temperature of 15°C +/- 2°C and RH 70 – 80% will improve the shelf life of vegetables for all seasons.

Hafiz M. U. Raza *et al.*, (2021) [14] highlighted over the various evaporative cooling techniques which are used for agriculture storage and livestock air conditioning in Pakistan. In this article, three main evaporative cooling techniques were observed and collected the data of those systems. These structures are direct evaporative cooling and indirect evaporative cooling and M- cycle evaporative cooling.

These collected data were later compared with the application of air conditioning of agriculture storage and livestock. As per the study, Pakistan has an agricultural economy and produces nearly 12 million tons of fruits and vegetables per year. About 35% of this agricultural production is lost due to post-harvest losses. In this decade, the optimal storage and hygienic handling of agricultural produce are very important as per bio safety standards in international markets. In Pakistan and other developing countries, it has been seen that research on agriculture storage is being neglected because of the high operating costs of modern AC storage.

Timothy Adekanye (2019) [15], author has been studied & carried out an experiment on evaporative cooling system for the storage of vegetables. The principle of an evaporative cooling system is the change of delicate heat to latent heat outdoor air which is dry and warm is enforced through the holes of the pad material that is wetted by water that is discharged and circulated by the upper water tank or coolant reservoir.

The air passing through the wet cooling pad is drawn by a suction fan from the environment. The sensible heat is warm and dry air from the ambient that passes through the wet cooling pads and finally changes to latent heat because of the incidence of evaporation which grades in the cooling of chamber. The cooler was made in a rectangular shape to create a broader surface for the circulation of air. Galvanized sheet metal was used on the external wall & the outer wall was painted silver colour to progress reflection and decrease the rate of heat fascination. Experimental shows that an active evaporative cooling device was made-up to evaluate with tomatoes and sweet orange. The cooler dropped the temperature of the ambient of 29.5-degree Celsius C to 22.8 degrees Celsius & increased umidity from 64.69% to 95.70%. The cooler was able to store already ripen red tomatoes without deteriorating for seven days. This shows that this technology is worth accepting to reduce the rate of post-harvest losses in vegetables and also improving the profitable values of agricultural produce.

III. FACTORS AFFECTING EVAPORATIVE COOLING

There are various factors that do disturb shelf life of vegetables which would lead to their spoilage.

1. Warmness or coldness of a substance is known as the temperature. Temperatures play vital role in maintaining the agricultural products FAO, (1998) when products are exposed to extreme temperature thus lead to damage of products eventually increases their level of respiration. And study states that agricultural products vary their level of respiration. As an outcome unwarranted temperature will rise the proportion of natural food enzyme reactions and the reactions of other food residents.

2. The volume of moister in the air as the percentage of the maximum amount that air is capable of holding at definite temperature is known as Humidity. Humidity has a huge effect on the deterioration of vegetables because its dependent on moisture content in the surrounding atmosphere.

IV. METHODS OF EVAPORATIVE COOLING

Evaporative cooling has divided into two different methods i.e., direct evaporative cooling and indirect evaporative cooling.

A. Direct Evaporative Cooling

Direct evaporative cooling encompasses movement of air through a wet cooling pad and hence cooling effect occurs. Cool humid air is passed directly to the targeted cooling area. Dissimilarity to this method is indirect evaporative cooling where the usage of heat exchanger is done which take the cool and moist air created by evaporative cooling to reduce the temperature of the drier air. This cool and dry air is used to cool the storage area.

In direct evaporative cooling practice of wet bulb is done where the continuous temperature and enthalpy remains unaffected dry bulb temperature drops while relative humidity and specific humidity rises [16]. Direct evaporative cooling is the eco friendly way of cooling which is cost efficient and natural cooling is done without using any harmful chemicals or refrigerants this direct evaporative cooling can also be carried in many ways such as earthen pots, or by using fabric and spraying water on it, also by using canvas material as the warm dry air passed through it water get cool and thus cooling effect is achieved.

Fig. 1 Direct Evaporative cooling [17]

Limitations: The temperature dewdrop is usually only a minor portion of the entire evaporative reduction that is possible. This is mostly due to a huge quantity of water that has to be cooled by a comparatively small evaporation surface. Only a few matters can be accommodated in big water containers.

B. Indirect Evaporative Cooling

Direct evaporative cooling generates the high humidity which is unwanted for some applications.

Whereas indirect evaporative cooling is the solution for this problem which uses the cool and moist air generated by evaporation to cool drier air. Thus, results cold air is used to cool the cooling storage area. This transfer of cooling is by mean of heat exchanger [18]. In indirect evaporative cooling system cooling is carried out by using water pump and forced air which is flowed by axial fans limitation of indirect evaporative cooling can't be used in all environmental conditions and desired temperature can't be achieved with this system with traditional mechanical cooling system [19]. The benefit of indirect evaporative cooling system for increasing the comfort level of quarters lies in the comparatively small acquisition or structure prices and the relatively little operation costs compared to convection air conditioning [18].

Evaporation not only reduces the air temperature encompassing the turn out, it will increase the wetness of air. Thus, helps to avoid drying of vegetables and eventually increase its shell life. Reduction of spoilage rate of vegetables is due to change in the state of cooling which minimizes the loss. Evaporative cooling is kind of traditional cooling method which is alternative for refrigeration and air conditioning. The use of electricity, harmful chemicals and refrigerants is done in this system to achieve desired cooling effect on other these technologies are so far harmful for the environment which led to increase global warming.

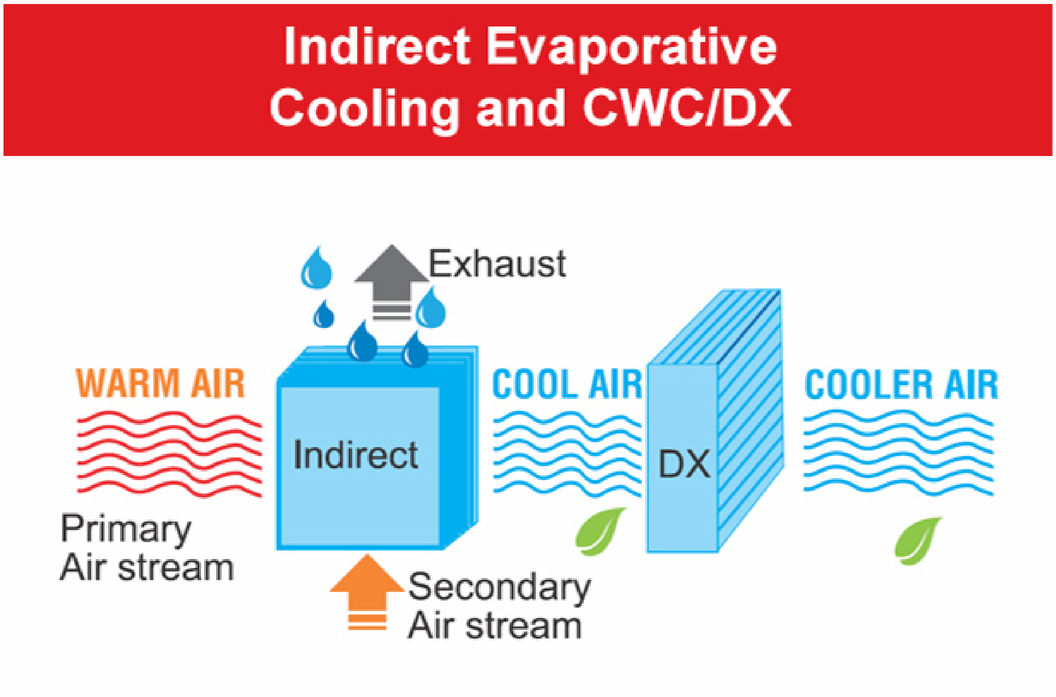

Fig. 2 Indirect Evaporative Cooling [17]

The major benefit of evaporative cooling systems is that it's totally eco-friendly no any use of chemical is done here and which is cost effective and easy to maintain and required very less maintenance. The environmental circumstances are favorable, evaporative cooling should be considered as a practical substitute to these extra complex and expensive commercial systems [19]. The main gain of evaporative cooling over cooling methods that includes commercial refrigeration is its low cost, less than $2. For example, an evaporative cooling system developed in the United States to cool fresh produce was able to produce 14 energy units of cooling while using only one energy units of electricity [20].

V. CONCLUSION

Evaporative cooling system has a completely huge capacity to appease thermal comfort. Nowadays, evaporative cooled garage system is more and more getting used for on-farm garage of culmination and veggies. Evaporative cooling system now no longer best lowers the air temperature surrounding the produce it moreover will rise the moisture amount of the air. This facilitates save you the drying amount of the produce, consequently increases the shelf life of agricultural produce. Evaporative cooling system is correctly desirable where temperature is high, humidity is low, water may be spared for this use, and air wave is present. There are many different kinds of evaporative coolers. The layout relies upon at the substances to be had and the clients' necessities. It is maximum suitable for the fast time span garage of veggies and conclusion quickly after harvest. Zero Energy Cool Chamber will be used positively for short-length garage of culmination and veggies even in mountainous region. It now no longer bests decrease the garage temperature though additionally will increase the comparative humidity of the garage that's important for preserving the freshness of commodities.

REFERENCES

[1] [Online]. Available: https://www.financialexpress.com/economy/india-wastes-up-to-16-of-its-agricultural-produce-fruits-vegetables-squandered-the-most/1661671/.

[2] J. T. Liberty, W. I. Okonkwo and E. A. Echiegu, "Evaporative Cooling: A Postharvest Technology for Fruits and Vegetables Preservation," *International Journal of Scientific & Engineering Research*, Vol. 4, No. 8, pp. 2257- 2266, August-2013.

[3] J. T. Liberty, B. O. Ugwuishiwua, S. A. Pukumab and C. E. Odoc, "Principles and Application of Evaporative Cooling Systems for Fruits and Vegetables Preservation," *International Journal of Current Engineering and Technology*, 2013.

[4] FAO, "General Post Harvest Handling Practices in Southern Nigeria; A Manual for Sustainable Agriculture," *Food and Agricultural Organization*, Rome, 2003.

[5] D. M. Bastrash, *Properties of Fruits and Vegetables*, A Manual for Horticulture Crops, 3rd Edition Series No. 8, 1998. [Online]. Available: www.cabastrtactslus.org/abstracts.

[6] N. Nobel, "Evaporative Cooling, practical action technology, challenging poverty," Bourton, UK, 2003. [Online]. Available: www.practicalaction.org.

[7] FAO, The optimum storage temperature of most fruits and vegetables is above their freezing point, 1995.

[8] Y. S. Jadhav, P. S. Patil and S. S. Marathe, "Evaporative Cooling System for Fruits and Vegetables and its Evaluation for Relative Humidity and Throttling Effect", *International Research Journal of Engineering and Technology (IRJET)*, Vol. 07, No. 06, June 2020.

[9] M. K. Ghosal, S. Titikshya, and G. M. Mohapatra, "Studies on Short-Term Storage of Leafy Vegetable (Spinach) in Zero Energy Cool Chamber with Gravity Fed Micro-Dripper Watering System," *South Asian Research Journal of Agriculture and Fisheries*, Vol. 1, No. 3, 2019.

[10] K. V. Vala, F. Saiyed and D. C. Joshi, "Evaporative cooled storage structures: an Indian Scenario," *Trends in post-harvest Technology*, Vol. 2, No. 3, pp. 22-32, 2014.

[11] D. Rehman, E. McGarrigle, L. Glicksman and E. Verploegen, "A heat and mass transport model of clay pot evaporative coolers for vegetable storage," *International Journal of Heat and Mass Transfer*, Vol. 162, pp. 120-270, 2020.

[12] S. M. Mansuri, P. K. Sharma and D.V.K. Samuel, "Solar powered evaporative cooled storage structure for storage of fruits and vegetables," *The Indian Journal of Agricultural Sciences,* Vol. 86, No. 7, 2016.

[13] A. Kale and K. Sundaram, "Experimental Evaporative Coolers for Vegetable Preservation," In Conference Proceeding, 3rd International Conference on Innovative Approach in Applied Physical, Mathematical/Statistical, Chemical Sciences and Emerging Energy Technology for Sustainable Development, pp. 106-111, 2014.

[14] H. M. Raza, M. Sultan, M. Bahrami and A. A. Khan, "Experimental investigation of evaporative cooling systems for agricultural storage and livestock air-conditioning in Pakistan," *Building Simulation*, Vol. 14, No. 3, pp. 617-631,Tsinghua University Press, June 2021.

[15] T. A. Adekanye and K. O. Babaremu, "Evaluation of an active evaporative cooling device for storage of fruits and vegetables," *Agricultural Engineering International: CIGR Journal*, Vol. 21, No. 1, pp. 203-208, 2019.

[16] F. A. Babarinsa, "Collection of Simple Evaporative Coolers for Low Cost preservation of Fruits and Vegetables," *In A paper presented at Nigeria and Stored Product Research Institute and In-house Review Meeting*. 1986.

[17] [Online]. Available: https://www.ategroup.com/hmx/why-evaporative.

[18] Singh, Mastiner and K. G. Naranyahgkeda, "Investigation and development of indirect evaporative cooling using plastic heat exchanger," *Mech Eng Bull*, Vol. 14, No. 7, pp. 61-65, 1999.

[19] F. A. Babarinsa, "A Jacketed Chamber Evaporative Cooler," *A Design presented to the Nigeria Stored product Research Institute In-house Review Meeting: Port-Harcourt, Nigeria*, 2000.

[20] K. B. Hutchison and C. Roger, "Inexpensive Evaporative Coolers for Short-term Storage of Food and Vegetables," *A design study report. Mechanical Engineering Department, University of Texas at Arlington*, 2000.