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Conceptual study of Solar-Powered Evaporative Cooling Systems for the Storage of Different Perishables - A significant Appraisal

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ABSTRACT

Fruits and vegetables fall under the perishable category and are susceptible to damage, especially during hot weather. Refrigeration/cold storage facilities play a significant role in preventing microorganisms from extending the shelf life of perishables and preventing post-harvest losses. Even so, the high cost of refrigerated/cold storage and the increasing population has created opportunities to use alternative energy. Under Indian conditions, maintaining a lower temperature in an enclosed chamber has been crucial. Evaporatively cooled storage powered by renewable energy would reduce these losses after harvest if it would be powered by renewable energy. Solar energy is more attractive for evaporative cooling systems than other primary energy sources due to its renewable nature, accessible nature, and ecological safety. Renewable energy is deployed primarily to promote economic development, improve energy security and access, and mitigate climate change.

Keywords Evaporative cooling, Solar energy, Perishable, Temperature, Humidity.

INTRODUCTION

India's assorted atmosphere ensures the availability of all varieties of fresh fruits and vegetables. It ranks second in fruit and vegetable production globally, after China. India accounts for 7.39% of total global agricultural output. According to a database distributed by National Horticulture Board, during 2018-19, India produced 97.97 million tons of fruits and 183.19 million tons of vegetables (Agricultural and Processed Food Products Export Development Authority 2020). The area under cultivation of fruits stood at 9.78 Million Hectares, while vegetables were cultivated at 13.24 Million Hectares.

Fruits and vegetables fall in the perishable category susceptible to damage, especially in hot conditions and have a short shelf life. Contaminations could initiate right from harvest and continues up to its consumption. Microbial contaminations due to unhygienic conditions in transit significantly threaten health. Higher temperature increases the rate of respiration which, in turn, results in the release of moisture and weight loss of vegetables. Liberty

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Table 1. Optimum storage temperature and relative humidity of selected fruits and vegetables (Adopted from Sipho and Tilahun 2020).

Product	Optimum temperature (ºC)	Optimum relative humidity (per cent)
Broccoli	0	90-95
Cabbage	0	98-100
Lettuce	0	90-100
Carrots	0	98-100
Tomatoes	13-15	≥ 85
Guava	5-10	90
Mango	13	85-95
Potatoes	5-16	90-95
Onions	1-2	65-70
Garlic	0	65-70
Banana	13-14	90-95

et al. (2014) reported a 2-3 times increase in the deterioration rate for every 10°C rise in temperature above optimum temperature. An estimated 25 to 30% loss has been reported due to improper post-harvest operations and a lack of storage facilities (Rais and Sheoran 2015). In India, commercial processing of fruits and vegetables is 3-4% of its total production (Technology Information Forecasting and Assessment Council 2022).

The shelf life of the products varies from each other and depends on the variety of that species and pre-harvest conditions, particularly quality and maturity. The optimum storage temperature and relative humidity of different fruits and vegetables are indicated in Table 1.

Many fruits, vegetables, perishable items, and livestock items require cold storage after being harvested (Vala *et al.* 2014). By improving the storability of perishables and preventing them from microorganisms from extending their shelf life, cold storage facilities play a significant role and will decrease post-harvest losses (Patel *et al.* 2022). The storing of perishables will contribute to a continuous and regular supply chain ecosystem. Improving on-farm cold storage facilities should be combined with appropriate tactics and treatments to prevent post-harvest losses (Patel *et al.* 2022).

Refrigerated storage, which is accepted to be one of the best systems for storing fruits and vegetables in fresh form, is not only energy intensive but also includes the enormous capital cost (Vala *et al.* 2014). Refrigeration equipment uses around 15% of the world's electricity generation (Perier-Muzet *et al.* 2014). In addition, it is not suitable for rural or on-farm storage where the producer would like to store the commodities for only a few days to accumulate sufficient quantities before conveying them to the markets situated far off and in urban regions (Vala *et al.* 2014).

An alternative to maintaining a lower temperature in an enclosed chamber has been a matter of prime significance under Indian conditions. Evaporative cooling is a physical phenomenon that reduces air temperature by evaporating water. The evaporative cooling concept can be used for on-farm storage of perishables and pre-cooling of fruits and vegetables before transit and storage in cold storage. It is one of the simplest and most economical methods (Patel *et al.* 2022).

The recent development in evaporative cooling unit requires electric energy to run its electrical accessories like a fan, pump, peltier module. Utilizing solar power energy with a low-cost evaporative cooling unit can minimize the post-harvest losses of horticulture produces and give a perfect solution to mobile vendors and farmers (Patel *et al.* 2022).

Energy demand

The world's energy demand is increasing significantly because of population growth and industrial evolution. Considering energy sources is therefore very important as they play a crucial role in satisfying the need of the world and living population. The ecosystem is polluted heavily because of the emission of various gases generated from the burning of fossil fuel which is available and commonly used for satisfying the energy demand of the world.

The increasing expense and inaccessibility of electricity for mobile vendors and small-scale farmers have put them under increased pressure. Energy availability is crucial for vendors and farmers who want to expand their agricultural exercises. The energy use structure in agriculture has changed significantly, with a critical shift from the animal and human force towards machine power, electricity and renewable energy sources, mainly solar energy (Mansuri 2015). In this circumstance, vendors/farmers may be keen to adopt farming systems that are not reliant on fossil fuels but instead get their energy from renewable sources.

Renewable energy sources (RES), used to produce energy from natural processes, meet the ever-increasing energy requirements worldwide, replacing conventional energy sources. Conventional energy sources are finite and under depletion. On the contrary, renewable energy sources constantly appear in the natural environment. The main forms of RES are solar, wind, hydroelectric, geothermal, and biomass. Many countries worldwide have adopted the application of RES to become energy independent (Gareiou *et al.* 2021).

Therefore, the high-energy demands on existing power sources and global warming threats provide the impetus for research towards technological alternatives. Solar energy is most suitable for adapting to cooling methods for fresh produce since it is available throughout the year (Dash *et al.* 2018).

Solar energy

Solar energy, being renewable, free and ecologically safe, is more attractive for man's use than other primary energy resources such as fossil fuels or nuclear energy. It is harvested from the sun, usually through PVs, which are arrays of cells containing appropriate material, such as silicon, that converts solar radiation into electricity through the PV phenomenon (Itskos *et al.* 2016).

Solar energy is the most abundant energy source of renewable energy and the sun emits it at the rate of 3.8×10^{23} kW, out of which approximately 1.8×10^{14} kW is intercepted by the earth (Panwar *et al.* 2013). Studies revealed that global energy demand could be fulfilled by using solar energy satisfactorily as it is abundant in nature and a freely available energy source with no cost. It is a promising energy source globally because it is not exhaustible, giving solid and increasing output efficiencies to other energy sources.

A solar system can effectively be used for villages, industrial operations and homes since it is easily affordable and applicable. The use of this technology in a proper way would be the best option for the future world to avoid unwanted consequences arising from the energy crisis. Many researches are now undertaken to increase the efficiency of the solar industry for making the future world productive in terms of energy utilization.

Evaporative cooling system

An evaporative cooling storage structure is a double-wall structure with space between the walls filled with porous water-absorbing materials called pads. These pads are kept constantly wet. When unsaturated air passes through a wet pad, a transfer of mass and heat takes place and the energy for the evaporation process. Evaporative cooling is an adiabatic process occurring at constant enthalpy (Banyat and Bunjerd 2013). This is the most economical way of reducing the temperature by humidifying the air. It has many advantages over a refrigeration system, as it does not use refrigerant, so it is friendly to the environment (reduces CO_2 emission). It does not make noise as there is no moving part. It does not use electricity,

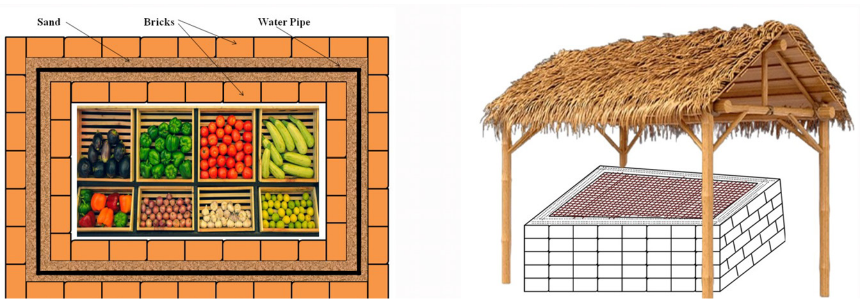

Fig. 1. Zero energy cool chamber.

Table 2. Comparative storage study of fruits and vegetables in Zero energy cool chamber (ZECC) and ambient condition (Kale *et al.* 2016).

Crop	ZECC Shelf life (days)	ZECC PLW* (per cent)	Ambient Shelf life (days)	Ambient PLW* (per cent)
Fruits				
Aonla	18	1.72	9	8.70
Banana	20	2.50	14	4.80
Grape	70	10.20	27	4.94
Guava	15	4.00	10	13.63
Kinnow	60	15.3	14	16.10
Lime	25	6	11	25
Mango	9	5	6	15
Sapota	14	9.46	10	20.87
Vegetables				
Amaranth	3	10.98	<1	49.82
Okra	6	5.00	1	14.00
Pointed gourd	5	3.89	2	32.86
Carrot	12	9.00	5	29.00
Potato	97	7.67	46	19.00
Mint	3	18.6	1	58.5
Turnip	10	3.4	5	16.0
Peas	10	9.2	5	29.8
Cauliflower	12	3.4	7	16.9

*Physiological loss in weight.

i.e., it saves energy. It does not require a high initial investment and operational cost is negligible. It can be quickly and easily installed as this is simple in design. Its maintenance is easy (Fig. 1). It can be constructed with locally available materials in a remote area and most important, it is eco-friendly as it does not need chlorofluorocarbons.

Many scientists carried out studies for its efficacy for increasing the shelf-life of fruits and vegetables, namely, tomato, potato, mango, grapes, orange, sapota, banana, plums, aonla, bitter gourd, brinjal, cucumber, chilli, ladies finger, beet, peas, carrot, radish and leafy vegetables (Singh *et al.* 2017, Dash *et al.* 2018). Table 2 presents shelf life and Physiological Loss in Weight (PLW) of selected fruits and vegetables in ECC and ambient storage as reported by various researchers.

Challenges associated with evaporative cooling technologies

Despite having numerous advantages (low initial and operational costs, environmentally friendly, no noise, no need of electricity, built from locally available materials, preservation of nutritional values, extension of shelf life with less PLW), this technology (Amer *et al.* 2015), ECC has not been adopted by the farmers for the on-farm storage of the horticultural commodities. Evaporative cooling systems must offer storage conditions that fulfil the farmers' demands. Variations in the need for improved farm storage can arise due to seasonal growing and harvest cycles, production surpluses relative to local demand, and climate variations (Verploegen *et al.* 2018). If these criteria cannot be met, then the ECCs may not provide sufficient benefits to justify their use. It is also challenging for potential farmers to construct, operate, and handle the structures. These challenges include the selection of construction sites, construction materials and availability of continuous water supply, perishable varieties, and the environment (Patel *et al.* 2022).

Future perspective

To overcome these challenges, ECC should be required to modify with green energy or other appropriate technologies to increase their adoption. Few alterations/modifications in ECC may prevent food loss, increase access to fresh produce, and create opportunities for additional income for farmers.

The adaptability of low-cost fixed evaporative cooling storage structures may be enhanced if it will made portable. A large portion of the horticultural production is in the rural areas, where there is little or no electricity supply and stability, as well as a limited number of cold-chain alternatives (Espedalen 2019). In off-grid areas where electricity is intermittent or prohibitively expensive, some green solar energy may be coupled easily to run a pump for water distribution of ECC. This will offer rural farmers access to a cold chain they would not otherwise have access to.

Recent developments in evaporative cooling using solar energy

The use of solar energy for evaporative cooling in all cases has been limited to buildings and this provides an opportunity for the extension of the same principles to the preservation of fresh produce. Evaporative

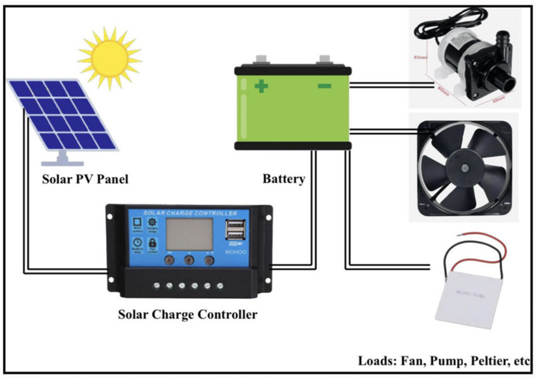

Fig. 2. Layout of solar PV system.

cooling technology, if used with forced air, requires lower energy to operate water pumps and fans while it is effective in providing cold and humid air to the storage chamber. The use of renewable solar energy for cooling and refrigerated storage applications has promising outlooks, as indicated by the investigations of many potential technologies such as solar, electric and thermal refrigeration. However, engineering design, especially to convert solar energy into electrical energy and the storage of this energy in a battery to run the technologies during the night, remains one of the important research and development areas that need attention. Hence, an integrated evaporative cooling and renewable energy approach as a power source could be highly suitable for small-scale farmers and vendors (Fig. 2). This will play a pivotal role in ensuring food security at the household level and reliable family sustenance through income obtained from sales (Sen and Bhattacharyya 2014).

It is required to develop simple, energy-efficient and economical cooling system that ensure fast cooling through efficient geometry and environmentally friendly construction. These considerations form the foundation for conceptualizing a portable cooling system based on renewable energy for fruits and vegetables (Espedalen 2019).

An evaporatively cooled cart for mobile retail vending of fruits and vegetables having a capacity of 200 kg fruits and vegetables will be a good alternative. It should provide a temperature reduction of the storage chamber by 15-25°C and an increase in relative humidity by 40 to 60% which enhanced the storage life of fresh fruits and vegetables by up to five days.

Anon (2014) developed an evaporatively cooled cart for mobile retail vending of fruits and vegetables. With additional storage space of 0.25 m^3 below the main platform of the cart, an effective and uniform evaporative cooling arrangement with forced air circulation by direct current (DC) fans. Lighting facility is provided through DC LED powered by solar photo voltaic (SPV) Panel of 100 W equipped with a portable energy bank of 7 Ah charge controller. The temperature of the storage chamber was decreased by 5-8°C and an increase in relative humidity was by 15 to 30%.

Islam and Morimoto (2015) constructed a zero-energy cool chamber consisting of two cooling systems, a solar-driven adsorption refrigerator and an evaporative cooling system. They reported it as low-cost and eco-friendly cooling storage for storing fruit with moderate respiration rates. The solar-driven adsorption refrigerator, consisting of a solar collector containing activated carbon as an adsorbent, a condenser and an evaporator, cool water by evaporating methanol and adsorbing it on activated carbon and then making ice. The ice was then used to cool the storage space. The combined use of two cooling systems reduced the average inside temperature of the ZECC to 12.07°C when an average outside temperature of 31.5°C and extended the shelf life of tomatoes from 7 to 23 days.

Mansuri (2015) evaluated the performance of a solar power-operated evaporatively cooled storage structure with three different pad materials (wood wool, Khas and CELdek) and four distinctive pad areas (2.25 m^2, 4.5 m^2, 6.75 m^2 and 9 m^2) in no-load conditions. There was a significant difference in cooling efficiency between pad materials and distinctive areas. The average air-cooling efficiency was highest for CELdek (78.67%), compared to 73.82 % for wood wool and 70.75% for khas when used in ECSS.

Olosunde *et al.* (2016) developed a solar-powered evaporative cooling storage system having solar panels (182 W), suction fan (24 W) and a water pump (18 W), with a battery (130 Ah). An ambient average temperature was 33°C and 38% RH. The temperature depression varied from 8 to 15°C and relative humidity was 74 to 96%, respectively. The shelf life of tomatoes, mangoes, bananas and carrots stored inside the chamber were 21, 14, 17 and 28 days, respectively, compared to 6, 5, 5 and 8 days in the ambient storage.

Samuel *et al.* (2016) developed a solar-powered vending cart and reported the maximum and minimum temperature drop ranged between 8.1°C and 11.2°C, and the relative humidity was increased up to 15% and 25% in June. The requirement for water varied between 16.5 and 20.0 liter/day. The shelf life of vegetables increased considerably.

Zakari *et al*. (2016) developed a hand-operated pushcart to store tomatoes. The average cooling efficiency was 83% and lowered temperature of the system by 6 to 10°C, whereas the relative humidity of the cooling chamber increased to 85%. The tomatoes could be stored for five days with minor changes in weight, color, firmness, and rotting compared to ambient conditions where they started to deteriorate after three days.

Bokade *et al.* (2017) constructed zero-energy cool chamber with two cooling systems: A solar-powered adsorption refrigerator and an evaporative cooling. The average inner temperature of these cooling systems was 12.07°C, compared to an average outer temperature of 31.5°C, and the shelf life of tomatoes increased from 7 to 16 days.

Zhang *et al.* (2017) developed a solar-assisted combined cooling, heating and power system. The system energy efficiency was about 37% and fossil fuel saving was 30.4%, with a solar thermal share of 26%. The system showed 33 per cent reduction in carbon dioxide gas emission occurred compared to the conventional system without solar powered.

Potdukhe *et al.* (2018) converted solar powered three-wheeled peddle rickshaw having photovoltaic module of 50 W/24 V power source, an exhaust fan (DC, 12 V, 0.7 A, 8.4 W) and a submersible water pump (DC, 18W, 12V). The pad material was perforated paper and utilized spatial cross-connecting technology to improve cooling effectiveness. It reduced the temperature to 15 to 16°C than the ambient condition and increased the storage life of perishables by 3 to 4 days.

Shuaibu *et al.* (2019) developed a solar-powered evaporative cooler using galvanized iron, thin wooden strips, a car radiator fan, and a submersible water pump and humidity and temperature control unit was integrated to control the water supply for regulating the room's humidity. The energy consumption of this air cooler for 6 h was measure 0.054 kWh. It was found that this technology was cheaper and efficiently improved indoor air quality.

Ogumo *et al.* (2020) fabricated a solar-powered cooling system and freshly harvested French beans were stored under conventional field shed conditions. A solar-powered prototype cooler, with weight and temperature measurement at 2 h interval and later packed in modified, atmosphere packaging bags. The bags were stored for 7 days in a cold room. Significant differences ($p \leq 0.05$) in weight loss between produce stored in the conventional shed and those in the solar cooler prototype were observed. The weight of French beans was reduced by 5 and 2.8% after 7 h under a conventional field shed and a fabricated solar cooler, respectively.

Biswas and Kandasami (2021) fabricated a solar thermoelectric cooler (STEC) using solar energy and evaluated its cooling performance. The STEC is comprised of a thermoelectric module (TEM), an inner and outer heat sink-fan fixed in the cooler box wall, and a photovoltaic (PV) panel connected with the device through a battery and PV charge controller. The effect of varying input electric current on the cold side temperature of TEM, cooling capacity, power consumption and coefficient-of-performance (COP) were investigated. The results showed that the cold side temperature decreased to 5±0.2ºC in 120 and 180 min for without and with product load (0.5 kg fish fillets), respectively. The cooling capacity, power consumption and COP of the STEC were 23.8 W, 53.5 W and 0.44, respectively, at the input electric current of 3.5 A. The battery power was utilized to drive STEC for 5-6 h after sunset.

CONCLUSION

Most of the postharvest losses incurred in fruits and vegetables in developing countries are due to a lack of storage facilities. In developed countries, effective storage systems for preserving fruits and vegetables are usually designed and constructed. However, these systems are too expensive, not readily available, or inappropriate for the needs of the local farmers or vendors. Hence, there is a shift in accentuation in cold storage to other alternative storage systems. Under Indian conditions, maintaining a lower temperature in an enclosed chamber has been crucial. Evaporatively cooled storage is the process by which the temperature of a substance is reduced due to the cooling effect from the evaporation of water. Nevertheless, challenges to its adoption can be mitigated by making transit storage facilities powered by renewable energy, which would be renewable, free and ecologically safe, is found to be more attractive for evaporative cooling systems to lower these postharvest losses.

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REFERENCES

Agricultural and Processed Food Products Export Development Authority (2020).

Amer O, Boukhanouf R, Ibrahim G (2015) A review of evaporative cooling Technologies. *Int J Environ Sci Develop* 6(5): 111-117.

Anon N (2014) PhD thesis. Submitted to Indian Agricultural Research Institute, New Delhi on Development of Solar Powered Evaporatively Cooled Cart for Mobile Retail Vending of Fruits and Vegetables.

Banyat N, Bunjerd P (2013) Performance Study of Cooling Pads. *In Adv Materials Res* 66 (4) : 931-935.

Biswas O, Kandasamy P (2021) Development and Experimental Investigation of Portable Solar-Powered Thermoelectric Cooler for Preservation of Perishable Foods. *Int J Renewable Energy Res* 11(3): 1292-1303.

Bokade S, Varghe P, Ghumde A (2017) Fabrication and experimental study of new zero energy cooling chamber with a solar-Driven adsorption refrigerator. *Int J Engg Develop Res* 5(7): 4-11.

Dash K, Bakhara K, Pal S, Panda K (2018) Portable evaporative cooled storage chamber for horticultural produce. *J Agric Engg* 46 (5): 118-125.

Espedalen H (2019) Master thesis. Submitted to NTNU on Conceptual Study of a Portable Cooling System based on Renewable Energy for Use on Fruits and Vegetables.

Gareiou Z, Drimili E, Zervas E (2021) Public acceptance of renewable Energy surces. *In Low Carbon Energy Technologies Sustain Energy Systems* 12(3): 309-327.

Islam P, Morimoto T (2015) Evaluation of a new heat transfer and evaporative design for a zero energy storage structure. *Solar Energy* 118(1): 469-484.

Itskos G, Nikolopoulos N, Kourkoumpas D, Koutsianos A, Violidakis I, Drosatos P, Grammelis P (2016) Energy and the environment. *Environ Develop* 6(2): 363-452.

Kale J, Nath P, Jalgaonkar R, Mahawar K (2016) Low cost storage Structures for fruits and vegetables handling in Indian Conditions. *Ind J Hortic* 6(10): 376-379.

Liberty T, Agidi G, Okonkwo I (2014) Predicting storability of fruits and vegetables in passive evaporative cooling structures. Int J Scientific Engg Technol 3 (5): 518-523.

Mansuri S (2015) Development of Solar Powered evaporative Cooled Rural Storage structure for fruits and vegetables. MTech thesis. Submitted to the Faculty of Post-Graduate School, Indian Agricultural Research Institute, New Delhi.

Ogumo O, Kunyanga N, Kimenju J, Okoth M (2020) Performance of a fabricated solar-powered vapour compression cooler in maintaining post-harvest quality of French Beans in Kenya. *Afr J Food Sci* 14(7): 192-200.

Olosunde A, Aremu K, Okoko P (2016) Computer Simulation of Evaporative Cooling Storage System Performance. *Agricult Engg Int CIGR J* 18(2): 280-292.

Panwar N, Kaushik S, Kothari S (2013) Role of Renewable Energy Sources in Environmental Protection: A Review. *Renew Sustain Energy Rev* 15(4): 1513-1524.

Patel P, Jain S, Lakhawat S, Wadhawan N (2022) A low-cost storage for horticulture commodities for enhancing farmer's income: An overview on evaporative cooling. *J Food Process Engg* 45(10): e14134.

Perier-Muzet M, Bedecarrats P, Stouffs P, Castaing-Lasvignottes J (2014) Design and dynamic behavior of a cold storage system combined with a solar powered thermoacoustic refrigerator. *Appl Thermal Engg* 68(1): 115-124.

Potdukhe P, Mantriwar I, Punekar N (2018) Solar assisted vegetable cart. *Int Res J Engg Technol* 5(2): 14-22.

Rais M, Sheoran A (2015) Scope of supply chain management in fruits and vegetables in India. *J Food Proc Technol* 6(3): 112-118.

Samuel K, Sharma K, Sinha J (2016) Solar-powered evaporatively cooled vegetable vending cart. *Curr Sci* 111(2): 2020-2025.

Sen R, Bhattacharyya C (2014) Off-grid electricity generation with renewable energy technologies in India: An application of HOMER. *Renewable Energy* 62(4): 388-398.

Shuaibu M, Musa M, Nawawi Y, Ahmad U, Mohammad A, Adamu S, Ibrahim P (2019) Design and construction of a solar powered evaporative air cooler. *Global Scientific J* 7(3): 930-937.

Singh K, Poonia S, Santra P, Mishra D (2017) Design, development and performance evaluation of low cost zero energy improved passive cool chamber for enhancing shelf-life of vegetables. *Int J Bio-Resour Stress Manag* 5(1): 116-121.

Sipho S, Tilahun W (2020) Potential Causes of Postharvest Losses, low-cost cooling technology for fresh produce farmers in sub-Sahara Africa. *Afr J Agricult Res* 16(5): 553-566.

Technology Information Forecasting and Assessment Council (2022).

Vala V, Saiyed F, Joshi C (2014) Evaporative cooled storage structures: An Indian Scenario. *Trends Post Harvest Technol* 2(3): 22-32.

Verploegen E, Rinker P, Ognakossan K (2018) Producing and using Evaporative Cooling Chambers and Clay Pot Coolers. Copyright © Massachusetts Institute of Technology.

Zakari D, Abubakar S, Muhammad B, Abubakar S (2016) Design and construction of an evaporative cooling system for the storage of fresh tomato. *ARPN J Engg Appl Sci* 11(4): 2340-2348.

Zhang N, Wang Z, Han W (2017) Analysis of a solar assisted combined cooling, heating and power (SCCHP) system. *Energy Procedia* 142(5): 55-62.