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CONTENTS

A Review- Cold Storage System for small and marginal farmers

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ABSTRACT: Cold storage of post-harvest produce is the major requirement in agriculture processing component in the food supply chain. Cold storage systems can be a way which can provide such places to save the periodic production and it can increase the shelf life of the produce. The cold storage systems are designed to enhance the shelf life of agricultural produce and reduce the post-harvest losses while maintaining the optimum storage temperature. The modern cold storage units regulate the temperature and humidity using a variety of technologies. The use of solar energy in cold storage can be advantageous for small and marginal farmers of our country. To provide diversity of agricultural produce over a long season, small and marginal farmers need to use energy efficient cold storage techniques to reduce costs and extend the revenue period other than maintaining product quality and freshness. To overcome post-harvest storage crises of the produce of the farmer, the cold storage should be feasibly designed with optimum capacity beneficial for large access by the small holding farmers. It can be a boon to enhance quality of farm commodities as well as farmers' income. This paper entails the review of earlier developed cold storage systems used for preservation of agricultural commodities.

Key words: Cold storage systems,marginal farmers, post-harvest agricultural losses,shelf life

India produces a massive quantity of fruits and vegetables and contributes to about 11.36% and 14.04% of world's fruits and vegetables respectively on the global scale (Department of Agriculture, Cooperation and Farmer's Welfare, 2022) India has witnessed commendable growth in horticulture production over the last few years. There is however mammoth postharvest losses prior to the product can even reach the consumer. The major issue is largely attributed to the inappropriate use of cold chains in the country. Farmers being the backbone of the nation produceagricultural commodities from their field with industrious efforts, but the depravity follows them as stumbling block in getting good price of their produce.

Farmers are confronting acute constraints most dominantly in the rural areas to sell their agricultural produce in the local market at a reasonable price. Lack of transportation facility, electric supply crises, and lack of storage investment are the major challenges which hinders them in enhancing the agricultural productivity and their annual income (Dash *et al.,* 2015).The fruits and vegetables have a limited shelf-life because of their perishable nature and unfavourable storage condition. The quality and safety of fruits can be reduced due to other factors such as deterioration and spoilage (Van Rooyen, 2006). All these factors are highly reliant on temperature (Kitinoja, 2013). Indian farmers have always struggled with reducing wastage of their produce due to a variety of reasons, including the rickety market linkage and lack of facilities to store fast perishable items for any length of period.

Necessity of Cold Storage

Essentially cold storage is employed to enhance the shelf life of agricultural produce along with its smooth supply (Fig.1). The palatability, freshness and nutritive value may be changed with time interval and therefore unpreserved foods can be preserved to prevent it from getting rotten and decay and made to be obtainableall through the year. Once a crop is harvested, it is almost impossible to improve its quality. Proper storage conditions i.e.,the optimumtemperature and humidity are mandatory to lengthen storage life and maintain quality of agricultural produce. Cold storage systems are

required to preserve the perishable natured post-harvest output i.e.,fruits and vegetables need low temperatures (32 to 55°F) and high relative humidity (80 to 95 per cent) to lessen respiration and to slow down metabolic and transpiration rates (Shende, 2018).

Research pertaining to the cold storage systems

The paper concisely and succinctly reviews the results obtained by various researchers in field of solar-operated portable cold storage for small and marginal farmers. Bahadori (1984) firstly studied and deliberated the natural cooling system and its viability for long-term storing of coolness. For the purpose of long-term usage of coolness, probable materials and process for storage employed were rocks, groundwater, ice production etc. The study evaluated coolness utilization factor (15) which is defined as the ratio of coolness delivered to building in summer to the energy consumed by pumps, fans, etc. and coefficient of performance (3) for conventional refrigeration system.The study by Kattakayan and Srinivasan(2000) focused on the evaluation of performance of domestic refrigerator deploying the inverters, battery bank and PV panels. It also ascertained that the thermal performance characteristic of the refrigerator. It was deduced that the heating of compressor was least at a particular voltage which was set to the nominal voltage at the site.More modifications were studied by Dai *et al.* (2002) which employed solar powered solid adsorption desiccant cooling system for grain storage. The study agglomerates the technologies of solar adsorption refrigeration and rotary desiccant dehumidification and compared with the earlier solid adsorption refrigeration system. The findings concluded that the coefficient of performance of the system was >0.4 whereas the outlet temperature was <20°C and therefore, the new hybrid system performed better compared to conventional system under typical condition.Krishnakumar(2002) designed a cold storage for fruits and vegetable considering several parameters including heat transfer through buildings, walls, floor and respiration load. Xihong *et al.* (2003) contemplated comprehensively the portable mini cold storage system made from new type foamedpolyethylenein addition to its effect on fruit quality i.e., kiwi. It was investigated that new type foamed polyethylene possessed better quality than fruit kept in existing control structure post 86 days storage, with firmness of 14.5 kg/cm^2. Certain refinements in the design was conducted by Anyanwy (2004) where the study focuses on design and assessment of the performance of storage system employed with porus evaporative cooler for efficient preservation of agricultural commodities. The evaporative cooler incorporates cuboid shaped porous clay container positioned inside another clay container and had a total storage space of 0.014 m^3. The findings reflected theperformance of experimental evaporative cooler was investigated to be substantially affected by seasonal weather conditions. It was concluded that overall depression of cooler storage chamber temperature from the ambient air temperature was upto 12°C while the ambient air temperatures varied from 22–38°C.

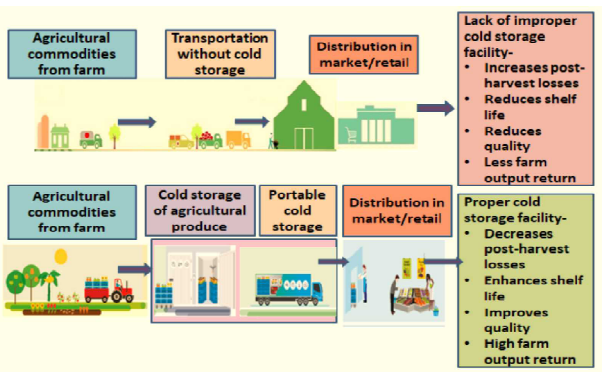

Fig. 1:**A view of importance of cold storage systems in preserving the post-harvest agricultural produce**

Jany *et al.* (2008) evaluated the effect of storage condition on shelf life and quality of winter vegetables at room temperature for 8 days, at refrigerated (4°C) temperature for 12 days and at freezing temperature (-18°C) for 90 days. The findings assessed pH values post storage, and it was evaluated as 3.85 at room temperature, whereas, it was 3.86 in refrigerated condition (without blanching) and was 5.08 in freezing condition. It was concluded that the rate of weight loss increases as the time progresses in all conditions. The quality of vegetables stored in freezing condition persisted

better even after 3 months of storage. More refinements were seen in the research conducted by Xing *et al.* (2011). It evaluated the performance of portable mini cold storage made from soft foam polyethylene (PE) and considering its significant effect on the quality of Fuji apples. The study revealed that soft foamed PE insulation material had a good potential to prepare mini store room for preservation of fruits. The study concluded that the use of foamed PE material yielded excellent thermal insulation performance and improves the preservation quality of fruits stored in storage system.

Aktacir (2011) evaluated the performance of multipurpose refrigerator system driven by PV panel. The performance of photovoltaic refrigerator system was independent of local electricity grid and the capacity. Sinha and Karale (2013) studied and compared solar-operated refrigeration system with various cooling thermal energy storage systems viz. cooling thermal energy storage (CTES), chilled water storage (CWS) and ice thermal storage (ITS). The results of the study reflected that solar electric method was the most favourable and effective method for solar refrigeration compared to other methods. Based on storage volume capability, the ITS had advantage over other methods. However, it has relatively lower COP than other techniques.Ndukwu and Manuwa (2014) utilized the application of evaporative cooling for preservation of fresh agriculture harvest. The research entails the constraints and prospects of marketing and commercialization of evaporative cooler in selected developed countries. The study investigated thatthe various evaporative cooler exhibitedfavourable operation of system on climatic adjustment during dry season when the relative humidity is low in the tropical countries.

Qdah (2015) evaluated the performance of solar powered air conditioning under climatic condition prevailing in Al Madinah Al Munawwarah, Saudi Arabia. The COP for the system was investigated to be with a good agreement with traditional storage system.Varkute *et al.*(2016) designed and fabricated Peltier operated portable air cooling system with dehumidifier for achieving both sensible cooling and dehumidification. The air cooling unit provides cooling upto 26°C and better results were attained employing cold water.Samuel *et al.*(2016) developed a solar operated evaporative cooled, vegetable portable cart for storage of fruits and vegetables and its performance was evaluated during summer season. The study revealed that the minimum and maximum drop in temperature ranged between 8.1°C and 11.2°C, whereas, relative humidity was increased up to 15% and 25% inside the vending cart chamber in June. It was concluded that the freshness, quality and shelf- life of vegetables increased considerably during post storage in the cart. The study by Warke and Deshmukh (2017) ascertained the performance of two different cellulose cooling pad (5090 and 7090) in sub sonic wind tunnel made from corrugated papers. Pressure drop, humidity variation, and effectiveness were also evaluated for inlet air velocities. The results indicated that overall pressure drop increases by increasing the thickness and inlet air velocity in both types of pads. On the other hand, humidity variation and effectiveness decreases by increasing inlet air velocity. Kesavan (2018) reckoned the performance of evaporative cooler employing luffa fiber material and zizanoiddes in hot and humid region.

The performance parameters include cooling efficiency, pressure drop and air velocity. The result contemplated that average cooling efficiency was highest for zizanoiddes (88%) compared to (77%) for luffa. While, at the same time, the velocity as well as pressure drop was significantly higher for luffa matched to zizanoiddes materials pad. Several modifications were incorporated including use of solar applications by Setiwan *et al.* (2018) who feasibly designed and developed inflated portable cold storage house equipped with solar cell as facilities for supporting the fisheries marketing and production. The developed structure can be built and applied in a residential location/specific housing easily, safely quickly and lightly (0.55mm PVC tarpaulin). This development support fisheries production and meet the requirement of strength, speed and comfort. The findings of Kayode *et al.* (2019) involved design and fabrication of the

conventional prototype solar powered mobile cold room for the storage of agricultural commodities i.e.,fruits and vegetables mounted in the tricycle. Mishra *et al.* (2020) designed a cost-effective and smart PV cold storage system deployinga domestic split air conditioner. The cold storage was equipped with IoT-based sensors for remote monitoring and controlling of humidity and temperaturein addition to tracking of the stored items. The study employed microcontroller and multiple sensors to monitor and maintain the anticipated temperature and relative humidity. The average recorded temperature and relative humidity of the designed cold storage chamber was assessed as 6.88 (±0.7)^{0}C and 95 (±1) % respectively. Singh and Chourasia (2021) studied the thermal effects of desiccant cooling in cold storage using CFD analysis. The desiccant material employed in the study decreases the humidity by a significant value. The study indicated that post using desiccant material, the obtained humidity was ascertained as 58.5% in CFD analysis and substantially reduced the temperature to a difference of 5ºC. Saxena A. (2022) designed and modified solar-operated portable cold storage of 2 tons capacity for small and marginal farmers, which can be used to store the farmers' produce for some time. The study concluded that the developed cold storage was best suited for effective storage of 2 tons of produce at storage temperature of around 12ºC.

CONCLUSION

It was concluded from the review that numerous research studies were carried out on solar refrigeration system but no studies were conducted on solar AC for effective storage of the farmers' agricultural produce. The study indicated that there is still inadequacy of studies on the portable storage system primarily focuses on small and marginal farmers.The cold storage system should be feasibly designed with viably economical so that large number of post-harvest agricultural commodities from small farmers' fields can be preserved with high quality and shelf life. Capacity of the cold storage should be optimum enough so as to cater the management of agricultural products. Cost economics should also be considered in its design so that it can be made affordable and reasonable for the marginal farmers to access its functionality. Government intervention is indispensable for the development of flexible, reliable and affordable cold chains to meet the demands of the farmers.

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