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Walk-in size charcoal cool room for small-scale cool storage in Semera, Ethiopia. (Source: Lisa Kitinoja).

FEED THE FUTURE
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EVAPORATIVE COOLING AND COOL STORAGE TECHNOLOGIES FOR HORTICULTURAL CROPS

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Introduction

Horticulture crops are a good source to ensure nutritional security, and they also play a significant role in income generation by providing opportunity for a range of small business activities (Demmler, 2020). However, nutrient levels of fresh fruit and vegetables begin to decline gradually once harvested, due to their high water content (about 90%), contributing to deterioration and decay. Deterioration of fresh produce starts from the moment it is harvested and continues until it reaches the final consumer. While the optimal storage conditions vary for different fresh produce, many fruits and vegetables are best stored in a cool and humid environment to prevent rot and dehydration (McGregor 1989). The storage conditions and temperature management along the supply chain play a key role in preventing postharvest losses, and the cold chain management should start right from the time the produce is harvested.

MarGEn conducted a Commodity System Assessment Methodology (CSAM) study in Ethiopia, Rwanda, Senegal, and Nepal for the Feed the Future Business Drivers for Food Safety (BD4FS)[1] from September to December 2020 to identify critical postharvest issues in the selected horticulture crops and the potential business opportunities for micro, small, and medium scale enterprises (MSMEs). Most techniques for cooling and storing fruits and vegetables rely on electricity – which is unavailable or unaffordable in most of the rural areas in developing nations – limiting access to effective and affordable postharvest storage options. The evaporative cooling devices that are the subject of this article function without the use of electricity and so are well suited for regions without electricity access or where electricity-dependent cooling and storage technologies are not affordable. The effective and affordable cooling and storage technologies have the potential to prevent food loss, increase access to fresh produce, and create opportunities for additional income generation in off-grid areas and where electricity is intermittent or prohibitively expensive (Basediya et al., 2011).

Evaporative cooling systems

Evaporative cooling occurs by the removal of heat through evaporation of water from the surface of the storage device. The evaporative cooling effect causes a decrease in temperature and an increase in the relative humidity inside the storage device, creating conditions that increase the shelf life of many fruits and vegetables (Kitinoja and Thompson, 2010). Water has to be added at regular intervals to maintain the cooling effect. The watering frequency required can vary from several times a day to only a few times a week, depending on the storage device's material and design as well as the weather conditions. The rate of evaporation of water is highly dependent on ambient humidity. When the ambient humidity is higher, there is a less significant reduction of the interior temperature. Evaporative cooling storage rooms are commonly used for bulk storage of tropical and subtropical crops (such as sweet potatoes) or as small-scale cool chambers for the temporary storage of fruits and vegetables in tropical regions.

Different low-cost self-constructible designs of small-scale, evaporative-cooled pre-cooling and storage units were reviewed by Kitinoja and Thompson (2010). The evaporation of water in these cooling units can be achieved either by passively or actively using a fan. In the present article, some popular passive evaporative cooling storage units to reduce postharvest losses are discussed.

Zero Energy Cooling Chamber (ZECC)

A ZECC is a low-cost passive cooling chamber constructed from locally available materials including bricks, sand, wood, straw, gunny or burlap sack, and twine. The brick ZECC was originally developed in India in the early 1980s (Roy and Khurdiya 1985) to address fruit and vegetable postharvest losses, especially in rural areas without electricity. ZECC design is composed of a double brick wall structure, supported by a base layer of brick, and covered with a straw mat. The space in between the two brick walls is filled with clean river sand, which retains the water that is added. Inside the ZECC, food is placed in unsealed plastic crates or containers, to keep the produce off the ZECC's floor, allow them to breathe, and allow for the circulation of cool, humid air inside the device (Figure 1). A water source is arranged or manually poured to always keep the sand saturated when it is in use (Figure 2). The storage capacity is around 1 MT and during the hot summer months, this chamber can maintain an inside temperature between 15 to 18 °C lower than the ambient temperature and relative humidity of about 95 %. The cost and benefit calculations for the usage of ZECC installed in Rwanda are presented in Table 1.

An evaporative cool room, a larger version of the ZECC, has been designed by Indian Agricultural Research Institute (IARI) and constructed by Central Institute of Post-Harvest Engineering and Technology (CIPHET), Ludhiana, India as a small cold room (6 to 8 MT capacity) and needs only the addition of a small water pump and a ventilation fan at the roofline (similar to the vent fans used in greenhouses). Since relatively large amounts of material are required to construct these cold storage chambers, they may be most practical when handling high-value products.

[1] BD4FS is a multi-country Feed the Future project funded by USAID and implemented by Food Enterprise Solutions (FES).

Zero Energy Cellar Storage

Traditional cellar storages are widely used in higher elevation regions and some European nations to be able to eat fruit and vegetables during the winters. The cellar storage uses natural cooling and insulation of the earth to maintain stable cool temperatures and high humidity in the chambers. It not only keeps the fruit cool during summers but also protects them from freezing temperatures during the winter months.

It has been proved to be an effective and cost-efficient technology to store fruits and vegetables in hilly areas of Nepal. Apple, citrus fruits, and potatoes can be stored for up to 3-6 months while maintaining ideal quality (HVAP, 2021). It is a double-walled mud-mortar structure with a cavity filled with sand and a pipeline is arranged to keep the sand wet while in use. Usually, three sides of this structure are enclosed in the earth or two-thirds of the structure is laid at underground level. The chambers can reduce temperatures by 4 to 7° C and maintain relative humidity as high as 95% (HVAP, 2021). The capacity of the structure can be up to 15 MT and can be operated even in absence of electricity (Figure 3).

Charcoal Cool Room

A charcoal cool room is a type of walk-in storage chamber made of an open timber frame with sides filled with charcoal, which is continuously kept moist. The timber frames are fixed with chicken-wire mesh leaving up to a 10 cm gap for charcoal to be filled. The charcoal should not be compressed or packed down while filling as it would reduce free air movement across the wall. The roof can be constructed using a plastic sheet, thatch made of grass or banana leaves, or any durable material to provide protection from possible heavy rains. The door should be fitted to open outwards so that the interior space is efficiently utilized. The temperatures inside the cooling structure can be maintained at about 5-10° C lower than the ambient temperature, depending upon the prevailing climatic conditions. When warm dry air when passes through the moist charcoal, it draws energy from the surroundings and produces a cooling effect inside the chamber. It is best suited in warm regions with low atmospheric humidity.

Conclusions

In rural areas of developing nations, the supply of electricity is often erratic and cooling technologies that require electricity may not be feasible options. Depending upon the crops being handled and the climatic conditions of the region, evaporative cooling structures are a convenient option for storing horticulture produce for a short duration. Using a suitable storage structure has the potential not only to reduce food losses but also enhances opportunities for additional income generation in off-grid areas.

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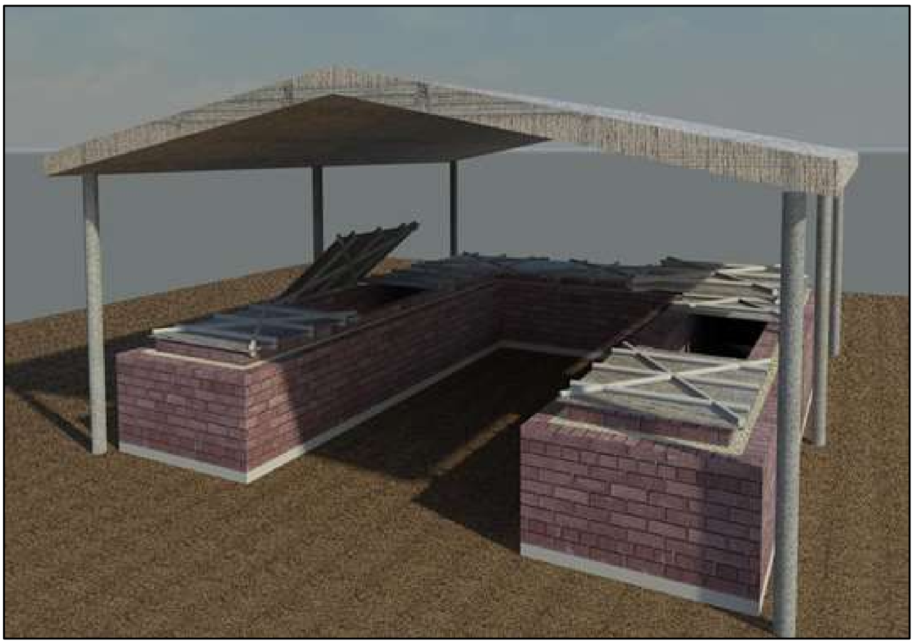

Figure 1. Design for a 1 MT capacity ZECC (Kitinoja, 2010). Diagram credit: Amity University, India.

Figure 2. Manual watering of the sand and brick of a ZECC to activate evaporative cooling for fresh produce storage in Rubona, Rwanda. (Source: Feed the Future Innovation Lab for Horticulture, 2019)

Figure 3. Two-story cellar storage building managed by the cooperative and inside view in Jumla, Nepal (Source: Padam Bahadur Subedi, Nepal).

Figure 4: Walk-in size charcoal cool room for small-scale cool storage in Semera, Ethiopia. (Source: Lisa Kitinoja).

*Table 1. Use of **ZECC** in Rwanda*

	Current practice	New practice
	No storage	Tomatoes can be stored in ZECC for 6 days if needed before the sale.
Cost		
Building a ZECC		$ US 250
Buying 6 plastic crates		$ US 45
Expected benefits		
% losses	8.4	1.8
Amount for sale	91.6 kg	98.2 kg
Value per kg	$ US 0.45	$ US 0.45
Total market value for one load	$ US 41.22	$ US 44.19
Relative profit		+ $US 3
ROI	293/3= 98 The investment repays itself after 98 uses if 100 kg of tomatoes is harvested and packed per week. After 98 uses, farmers will earn an additional US $3 per week. The ZECC structure has a 2 year life, after which it can be dismantled and the bricks used for other building purposes.	

Source: van Djik et al., 2015. Updated by RWUBATSE Bernard