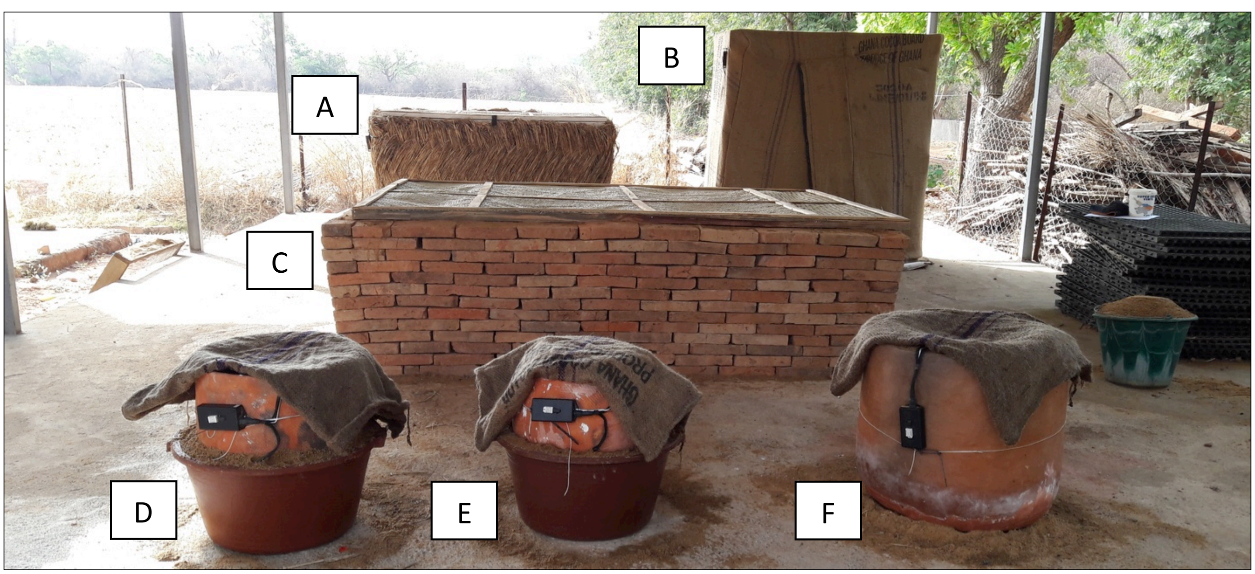
EXECUTIVE SUMMARY: Evaluation of Evaporative Cooling Technologies for Improved Vegetable Storage in Mali

Mali's horticulture sector plays a vital role in supporting the country's human nutrition and health, income generation for farmers, and poverty alleviation. A lack of affordable and effective post-harvest vegetable storage solutions often leads to vegetable spoilage, loss of income, reduced access to nutritious foods, and significant amounts of time spent traveling to purchase vegetables, particularly in rural communities. In Mali – and many other developing regions – these challenges are found where farming is the predominant source of income and food for populations who lack access to affordable methods for cooling and storage of vegetables and leafy greens.

The objective of this research study is to investigate the potential for non-electric evaporative cooling devices to address post-harvest vegetable storage challenges in rural Mali. The two classes of devices evaluated in this study are commonly known as "evaporative cooling chambers" (ECCs), which are generally used by horticulture cooperatives, and "clay pot coolers," which are generally used in households. These devices rely on the evaporation of water to create a cooling effect, and their performance is significantly affected by the ambient temperature and humidity of the environment in which they operate.

In this study, we used a combination of electronic sensors and structured user interviews to gather information about users' needs for improved post-harvest vegetable storage, current methods of post-harvest vegetable storage, and the performance of evaporative cooling devices.



Above is an image of the three ECCs and three clay pot cooler devices included in this study: A) straw ECC, B) sack ECC, C) brick ECC, D) cylinder pot-in-dish, E) round pot-in-dish, and F) pot-in-pot.

Results

The results of this study indicate that low-cost evaporative cooling devices, such as clay pot coolers and ECCs, have the potential to benefit both off-grid populations with limited access to electricity and on-grid populations with high electricity and/or equipment costs for refrigerators. Evaporative cooling can improve vegetable storage shelf life by providing:

- A stable storage environment with low temperature and high humidity, which reduces water loss and spoilage in most vegetables
- Protection from animals and insects that contaminate and eat the vegetables

The improved storage environment can have positive impacts including reduced post-harvest losses, less time spent traveling to the market, increased availability of vegetables for consumption and monetary savings. These devices can also have farther-reaching impacts, particularly for women who could benefit economically from producing and selling clay pots.

Our comparison of three types of ECCs demonstrates that ECCs made of brick are superior to ECCs made of straw or burlap sacks. Brick ECCs provide a more stable low temperature and high humidity environment, are easier to refill with water, and provide protection from animals and insects. Due to these considerations, straw and sack ECCs are not recommended.

When comparing clay pot coolers, devices with the pot-in-pot configuration provided a greater temperature decrease than clay pot coolers with the pot-in-dish configuration. Both types of devices performed similarly on other metrics such as interior humidity, ease of watering, and protection from animals and insects. Ninety percent of those interviewed reported that they were no longer using any of their previous storage methods after receiving the clay pot coolers, indicating that the 50 liter capacity of the clay pot coolers used in this study is sufficient to meet the vegetable storage needs of most households. These results indicate that there are relatively loose design constraints for constructing a clay pot cooler that provides a basic level of performance, even if not optimized, creating an opportunity for locally available materials to be repurposed to create an effective clay pot cooler for vegetable cooling and storage.

Summary of key characteristics for each evaporative cooling device

Evaporative cooling device	Average temperature decrease*	Interior humidity range*	Minimum watering frequency	Protection from animals and insects	Storage volume	Cost
ECC (straw)	5.4 °C	30-50%	1-3 times per day	No	250-4000 L	$50 - $250
ECC (sack)	2.6 °C	10-30%	1-3 times per day	No	250-4000 L	$50 - $250
ECC (brick)	5.8 °C	80-100%	once per 1-7 days	Yes	500-5000 L	$70 - $350
Round pot-in-dish	5.1 °C	80-100%	once per day	Yes	10-150 L	$6 - $35
Cylinder pot-in-dish	4.7 °C	80-100%	once per day	Yes	10-150 L	$6 - $35
Pot-in-pot	6.7 °C	80-100%	once per day	Yes	10-100 L	$10 - $50

*For the data provided, the ambient relative humidity was less than 40% and the average daily ambient temperature was between 29 °C and 37 °C.

Recommendations

The most important first step for prospective users, producers, or promoters of ECCs and clay pot coolers is to consider the suitability of evaporative cooling devices for the specific context of interest by answering the question: *Does the technology have the potential to effectively meet the needs of the intended users?*

The following factors should be assessed to determine the suitability of evaporative cooling devices for a specific context:

- **Operating conditions:** Specific conditions are required for evaporative cooling devices to effectively operate: low humidity, high temperature, access to water, and a shady, well-ventilated location.
- **Need:** The storage conditions provided by evaporative cooling devices must meet the user's needs, and the need for improved vegetable storage must occur during times of the year when evaporative cooling devices can operate effectively.
- **Value:** The cost of the ECC or clay pot cooler must be affordable and justified by the benefits that will be realized due to the improved storage provided.

If evaporative cooling devices are deemed suitable for a given context, the key factors for increasing their use are awareness, availability, quality, and affordability in the specific region. If the devices can meet a community or region's vegetable cooling and storage needs, the following steps should be taken to increase their dissemination:

- Identify end users who could benefit from evaporative cooling technologies
- Raise awareness of the technology's benefits among prospective end users
- Increase availability of appropriately designed clay pots; organized production and distribution can increase availability, quality, and affordability

In addition to the full Evaluation Report from this research, we have created an interactive "*Evaporative Cooling Decision Making Tool*" and an "*Evaporative Cooling Best Practices Guide*" to support the determination of ECCs and clay pot cooler suitability and the devices' proper construction and use. The intended audience for these resources includes government agencies, nongovernmental organizations, civil society organizations, and businesses that could produce, distribute, and/or promote ECCs or clay pot coolers. These resources are available at: http://d-lab.mit.edu/resources/projects/evaporative-cooling

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