Investigating Clay Pot Coolers for Produce Storage in Developing Nations

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Introduction

Lack of Refrigeration in Off-Grid Communities

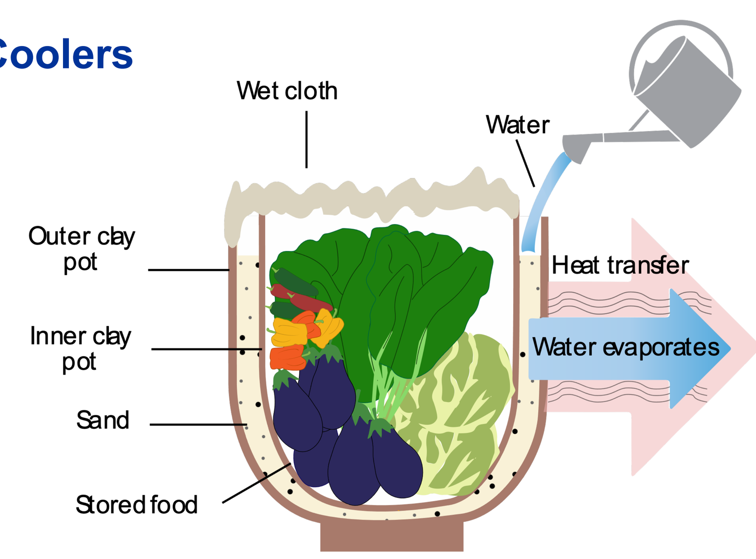
- Off-grid communities in hot and arid regions like Mali often lack access to reliable refrigeration.
- This causes significant food spoilage and decreases access to nutritious vegetables.

Evaporative Cooling Systems

- Evaporative cooling systems are more energy efficient than traditional cooling systems.
- Using the heat transfer induced by evaporation of water, evaporative cooling systems create a cooling effect.
- These systems create a cool, humid environment, well-suited for produce preservation

Clay Pot Evaporative Coolers

- Accessible, inexpensive, and effective method of personal produce storage.
- Efficacy will vary based on assembly style, so what aspects should users prioritize to construct more effective systems?



A diagram of a simple clay pot cooler

Objective

Establishing Differences Among Clay Pot Cooler Designs

- There are significant differences between different clay pot assemblies, but this has not been systematically studied.
- The primary goal of this project is to establish a basis for the differences between common clay pot cooler assemblies.
- The accessibility of materials, water efficiency, and cooling effect over time all must be considered when evaluating a clay pot cooler assembly.

References

Luu, Trang. Impact of surface area and porosity on the cooling performance of evaporative cooling devices. Retrieved from https://dspace.mit.edu/handle/1721.1/129010

Rehman, Danyal; McGarrigle, Ethan; Glicksman, Leon; Verploegen, Eric. A heat and mass transport model of clay pot evaporative coolers for vegetable storage. Retrieved from https://d-lab.mit.edu/resources/publications/heat-and-mass-transport-model-clay-pot-evaporative-coolers-vegetable-storage

Acknowledgments

- MIT Energy Initiative
- This work was greatly influenced by Trang Luu's Masters Thesis: *Impact of surface area and porosity on the cooling performance of evaporative cooling devices*

Methods

Construction of the Six Clay Pot Cooler Assemblies

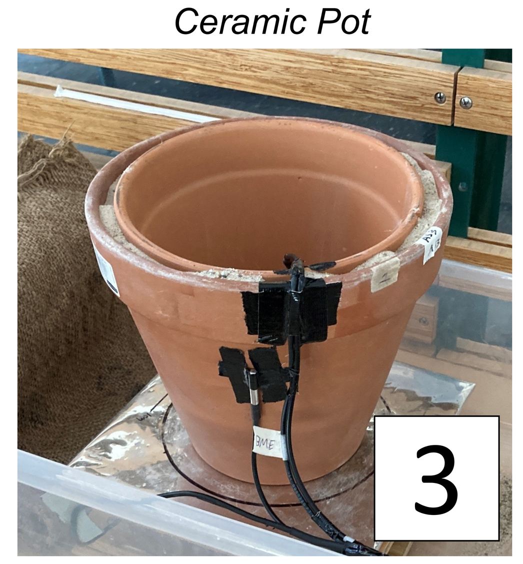
- Clay pot coolers were constructed from an inner pot and an outer pot or dish, separated by a layer of sand and covered by a wet jute sack.
- Water was poured into the sand gap to initialize the experiment, with a constant sand to water ratio by mass of 4.37:1.
- In this experiment, a standard inner pot was selected as a controlled factor across all tested systems.
- The size and shape of the outer pot or dish was varied, to establish a range of different clay pot cooler assemblies.
- The pots are pictured below, along with the measured dimensions of the outer pots and dishes.

Top Ø: 31.1cm Height: 27.7cm

Ceramic Pot

Top: Ø=29.6cm Height: 9.2cm

Plastic Dish

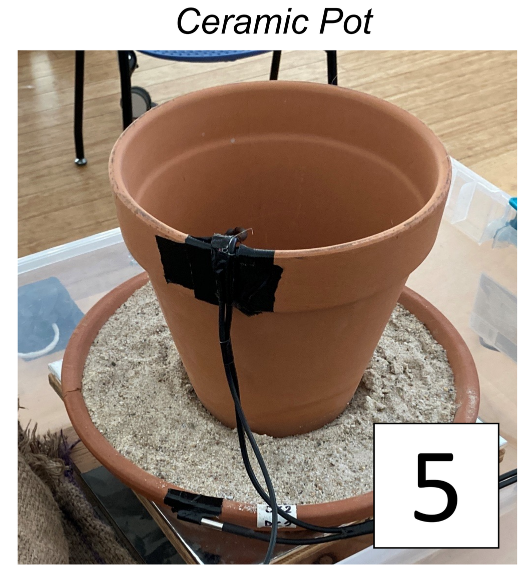


Top: Ø=24.6cm Height: 20.7cm

Ceramic Pot

Top Ø: 31.8cm Height: 12.5cm

Ceramic Dish



Top: Ø=30.8cm Height: 4.09cm

Ceramic Dish

Top: Ø=35.6cm Height: 29.3cm

Ceramic Pot

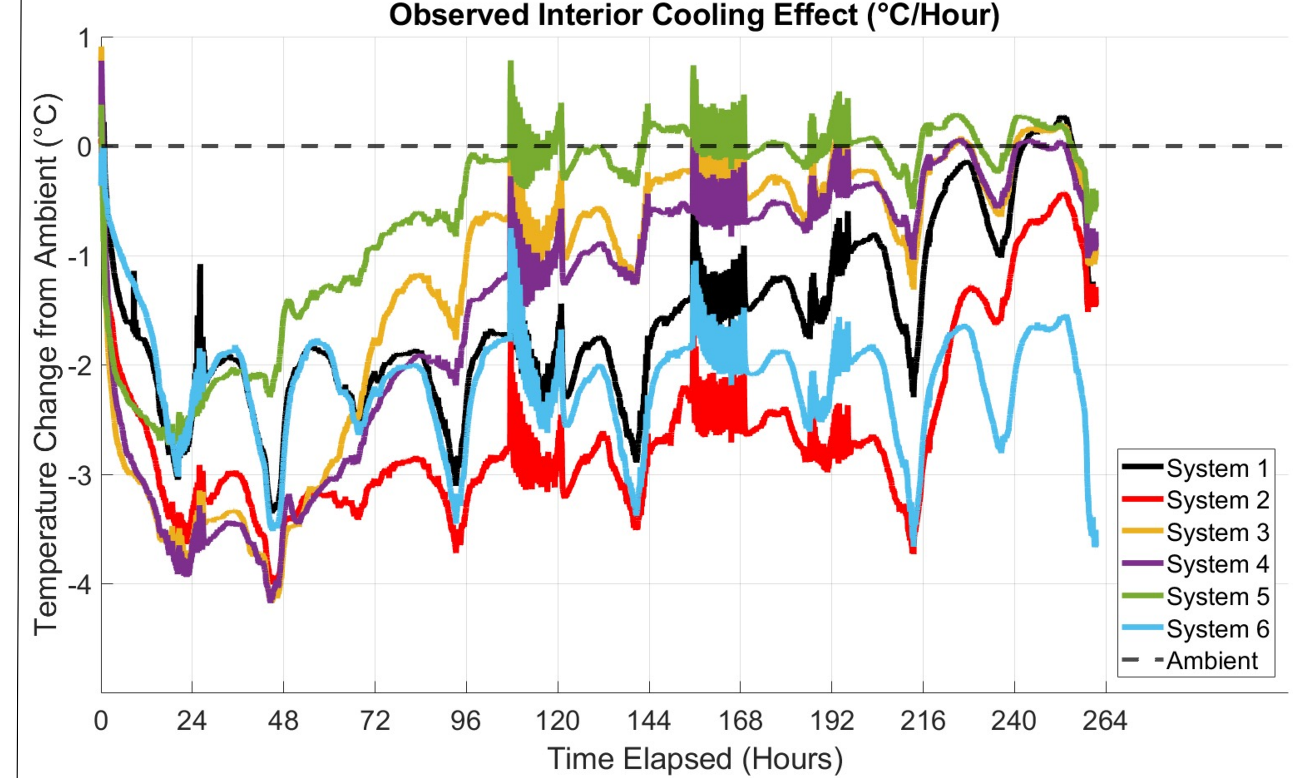
Automatic Data Collection System

- An Arduino Mega 2560 collects data from 10 BME 280 environmental sensors, 12 DS18B20 temperature probes, and 6 load cells.
- Six of the BME 280 sensors collect temperature and humidity inside the pots, and four measure ambient conditions.

Results

Figure 1:

Observed Interior Cooling Effect (°C/Hour)

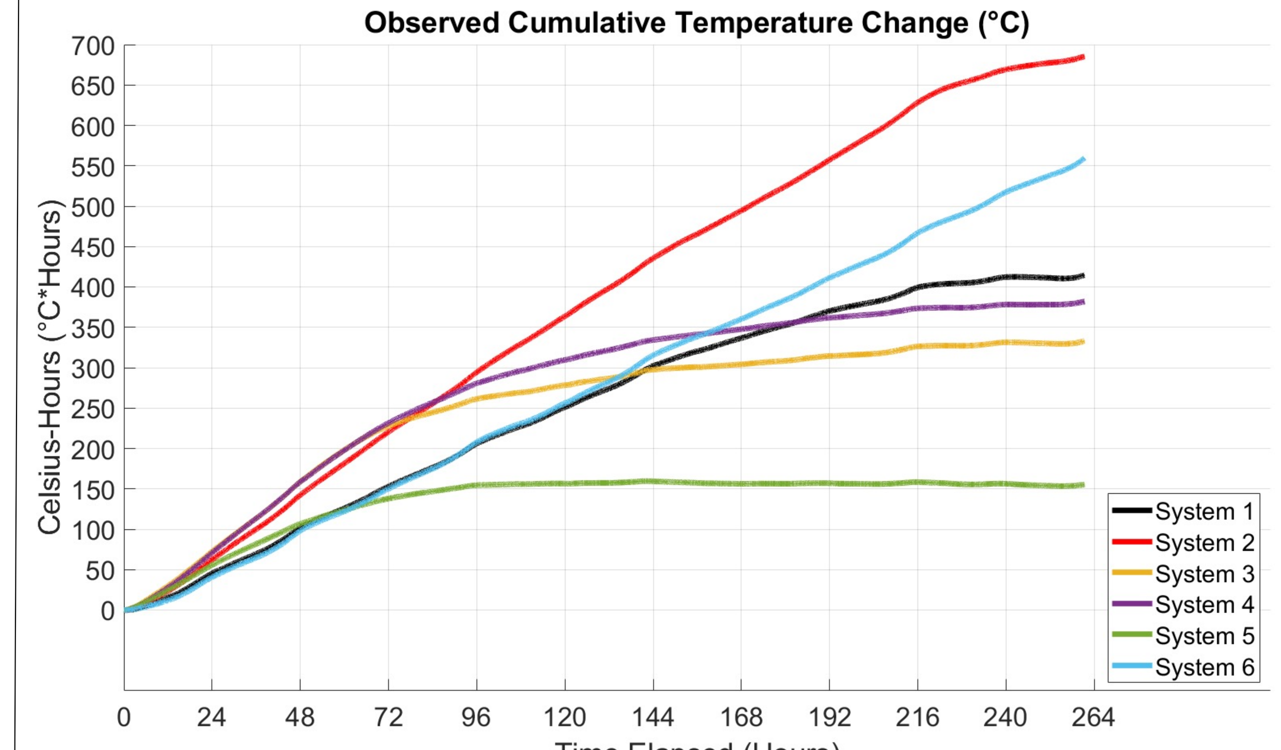


Temperature Change

- Systems 2, 3, and 4 produce a larger amount of initial cooling compared to 1, 5, and 6. (Fig. 1)
- But after three days, the cooling effect of 3 and 4 diminishes, and they are surpassed by the other systems (Fig. 1)
- The cooling effect of 2 diminishes, but does so slowly, over a period of 9 days before diminishing rapidly. (Fig. 1)
- Over the 11-day course of this experiment, System 6 maintains a relatively consistent cooling effect. (Fig. 1)

Figure 2:

Observed Cumulative Temperature Change (°C)



System Number	1	2	3	4	5	6
Total Water Evaporated (kg)	1.3	1.3	0.9	0.9	0.6	1.8
Total Celsius Hours Produced	414.8	685.5	332.9	382.0	155.3	559.8
Celsius Hours per kg Water Evaporated	331.8	548.4	387.1	419.8	277.4	309.3

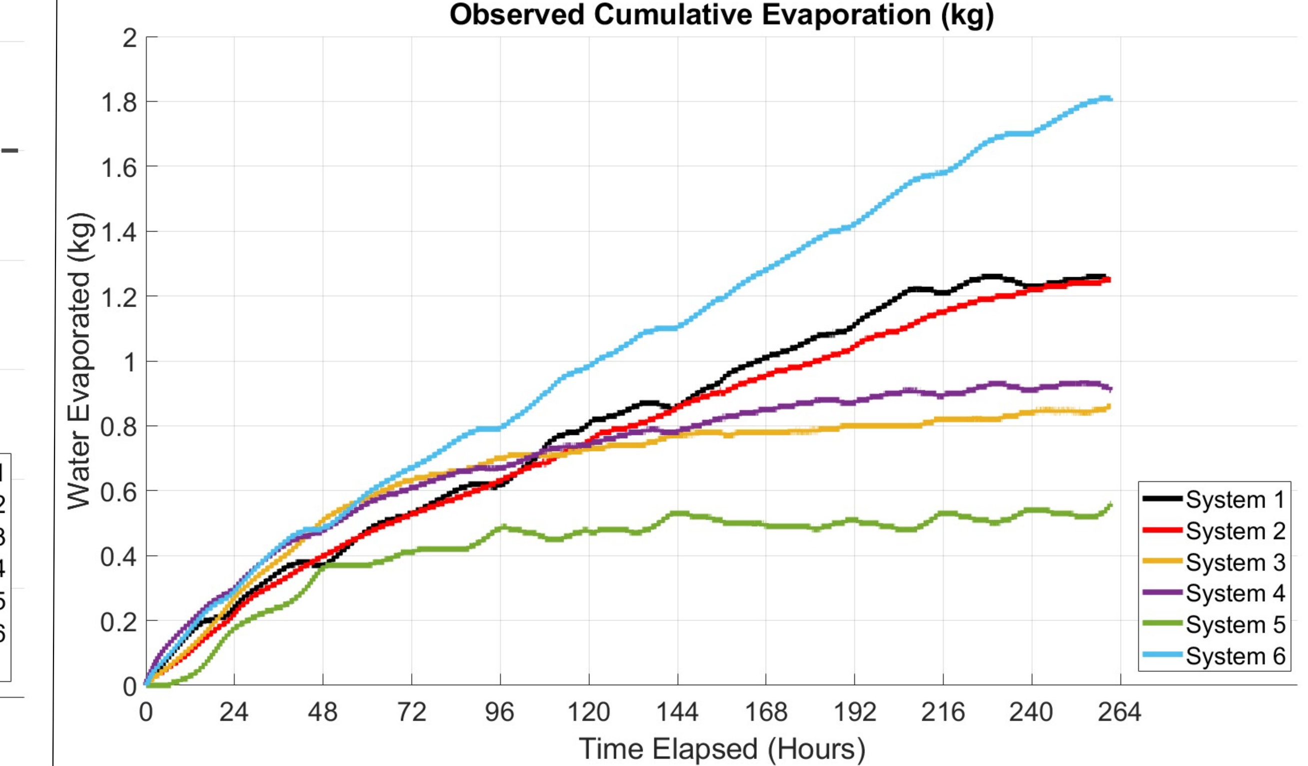
Cumulative Celsius-Hours

- In all systems but 6, Celsius-hours increase at a relatively constant rate until suddenly slowing significantly. (Fig. 2)
- The Celsius-hours produced per kilogram of water evaporated varies greatly. System 2 is the most efficient system in this regard, while 5 is the least efficient. (Fig. 2)

Results

Figure 3:

Observed Cumulative Evaporation (kg)



Cumulative Water Evaporated

- For each kilogram of sand used in the systems, 0.229 kg of water was added.
- System 6 has a relatively high rate of evaporation. (Fig. 3)
- As the rate of water evaporation for each system declines, the cooling effect follows. (Fig. 1, Fig. 3)
- Total water evaporated does not exactly follow total cumulative temperature change, efficiency varies. (Fig. 2, Fig. 3)

Conclusions

Identifying Differences Between Systems

System 1:
- Performed almost identically to 6 for five days, until it ran dry.

System 2:
- Produced greatest cumulative cooling effect.
- Initial cooling comparable to 3 and 4, but maintained effect for seven days longer.
- Effective and efficient system.

Systems 3 and 4:
- Produced the greatest magnitude initial cooling effect.
- Ran dry after two days.

System 5:
- Produced magnitude of initial cooling similar to 1 and 6.
- Only lasted two days due to limited water capacity.
- Performed relatively poorly.

System 6:
- Produced consistent and long-lasting cooling effect because of large water capacity.
- Total cooling was of a lesser cumulative total than 2.
- Excellent long-term system.

Conclusions about geometry: Larger outer pots are less water-efficient than smaller pots but are effective for a longer time. High-walled dishes produce greater cooling and are more water efficient than shallow dishes.

Future Work

Next Steps: Increasing Watering Frequency

- In a community with easy access to water, re-watering a personal clay pot cooler more frequently is entirely feasible.
- To simulate use-case, the next experiment will consist of the same systems, watered once every two days.
- This will more closely match how clay pot coolers are used in communities that need them.
- Past this, the effect of pot and dish geometry on cooling effect, capacity, and efficiency will be investigated more thoroughly.