Postharvest Fruit and Vegetable Storage

Dan Frey, Leon Glicksman, and Eric Verploegen
Farmers have a need for improved postharvest fruit and vegetable storage
- Food spoilage, lower prices at market, time spent transporting produce

Areas for improvement for refrigerated cold rooms:
- Cost of construction, energy consumption, low humidity

Areas for improvement for charcoal cooling chambers:
- Temperature decrease, water consumption, cost
Shipping Container Based Design

Idea:

- A used shipping container can be the primary structure
- “Swamp cooler” blows cool air directly through crates
Evaporative cooling pad materials:

Cross section of shipping container showing airflow pathways (view from the front with doors removed)
Interior of the shipping container located on MIT’s campus (prior to the installation of the electronic control system and insulation on the left wall and the ceiling). The team is modifying this 10’ x 8’ x 8’ container to function as an evaporative cooling chamber. Visible is insulation (blue) on both open doors, insulation on the back wall (pink), an insulating wall (pink) spaced 3” from the exterior steel wall of the container, and the evaporative cooling unit hanging from the center of the ceiling. The stacks of plastic vegetable crates filled with water bottles are on the back-right corner of the container but are not visible.
Shipping Container Based Chamber at MIT

Left: Crates (black) in the experimental storage area are visible prior to the installation of the front wall. The experimental storage area contains 3 stacks, each stack is 6 crates tall, and each crate contains eighty 8-ounce water bottles. The door to the left of the crates is mounted on an overhead track.

Center: The experimental storage area after the installation of the front wall to isolate the three stacks of crates. The door is in the closed position.

Right: The experimental storage area with the door slid open to expose the crates for removal and placement.

In practice the full length of the container would be used with multiple sliding doors to allow enclosure and access to all of the storage area. For our current testing we are using ¼ of the available storage area to avoid purchasing an additional 4,000+ water bottles.
Electronic Control System

Measures and records

- Temperature
- Humidity
- Pressure
- Air speed
- Moisture
- Water levels

Controls:

- Water pump
- Fan speed
Heat and Mass Transfer Modeling

- Expected that we can cool vegetables by 8 °C in 6 hours
- Requires ~1.6 kW of solar panels and ~12 kWh of battery backup
1) On the sides of the chamber, the gap between the interior of the shipping container wall and the wall insulation should be between 4 cm and 7 cm. We can make a final decision once we have the other dimensions. Note that the wall of the shipping container is corrugated, and this measurement is made from the surface closest to the interior of the container.

2) The thickness of the wall insulation should be between 4 cm and 6 cm. This insulation should be a rigid board that can support its own weight.

3) The back wall, ceiling, and front wall (doors) will also be insulated. The same 4 cm to 6 cm thick insulation can be used for these surfaces but can be placed flush with the inner surface of the container. It is OK to leave air gaps between the insulation and the steel container wall where the container wall is corrugated.
We have found that there are fairly consistent sizes for vegetable crates around the world. Our chamber design is intended to be tailored for the most common crate sizes in a specific region. The size of the crates will impact the location of the interior doors. Can you send the dimensions of any common crate sizes? (length, width, and height)

The distance between the interior door and side wall insulation will be slightly larger than the crate length.

Distance between the side wall insulation and the interior door
Boards are attached to the rigid insulation running horizontal to the ground.

The width of the boards can be between 3 and 10 cm wide.

The boards should be between 1 and 2 cm thick.

Air flow optimization (inducing turbulence)
There needs to be gaps in the support structure to allow air to flow down into the structure from the crates above, and then into the channel that is the gap between the wall insulation and the container wall.

The total height of the support structure will depend on the thickness of the structure itself, the **minimum** height of the **air gap** inside the support structure is 10 cm, but can be larger.

The height of the support structure under the crates should be between 12 cm and 17 cm.

Support pallet

Air can flow through the bottom of the crates through these openings.

The support structure could stop at the insulation (as shown on the right side).

Or it could go all the way to the container wall (as shown on the left side).

Support structure and airflow under the crates
There needs to be gaps in the support structure to allow air to flow down into the structure from the crates above, and then into the channel that is the gap between the wall insulation and the container wall.

The total height of the support structure will depend on the thickness of the structure itself, the minimum height of the air gap inside the support structure is 10 cm, but can be larger.

The height of the support structure under the crates should be between 12 cm and 17 cm.

Support structure and airflow under the crates
Holes will need to be cut in the exterior wall of the shipping container for air to exit.

We cut holes 8 cm wide and 20 cm tall near the top of the container wall at each of the parts of the exterior wall that is farthest from the interior of the container.

One rectangular hole at each of the parts of the corrugation that is farthest from the interior of the container.

Holes for airflow exit
This distance will be determined by the height of the evaporative cooling pad, which will likely be between 45 and 55 cm.

This material (some rigid plate, wood, metal, etc.) is used to support the water collection, and is suspended from the ceiling of the container.

The doors could be hung from this support structure but having a separate support structure had some potential benefits.

Support structure for evaporative cooling pads and water collection
Support structure for evaporative cooling pads and water collection

A plastic sheet covers the plate and collects excess water coming off the evaporative cooling pad and return it to the water reservoir. A lip of \(~ 5-10\) cm in height is needed to prevent water from exiting over the sides.

We will want to have a slight tilt inside the water collection tray to allow water to flow towards the drain hole.
Mounting of the fans

The holes in the ceiling will be determined by the size and number of the fans. The fans will need to be less than 70 cm in diameter. Because the roof is corrugated extra care will need to be taken to prevent water from running into the hole beneath the fan or fan mounting plate.

A mounting plate is used to attach the fan to the roof of the container.

We used spray foam to seal the gaps under the mounting plate.

For the system in India where we will not be using solar panels, we will need some type of tilted rain and shade cover over the holes for the fans.

Mounting of the fans
The doors are suspended from track that is either mounted on:
1) A header (shown here) or
2) Directly onto the support structure for the evaporative cooling unit

This extra plate was added to prevent airflow between the top of the door and the track.

The doors should be a slim profile so that they can pass by each other without leaving a large air gap between the crates and the outer door.

Sliding doors
The designs in this document developed by MIT D-Lab are open-source and licensed under a Creative Commons Attribution-ShareAlike 4.0 International License.

https://creativecommons.org/licenses/by-sa/4.0/legalcode