Forced-air Evaporative Cooling for Postharvest Fruit and Vegetable Storage

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Refrigerated Cold Rooms

- 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

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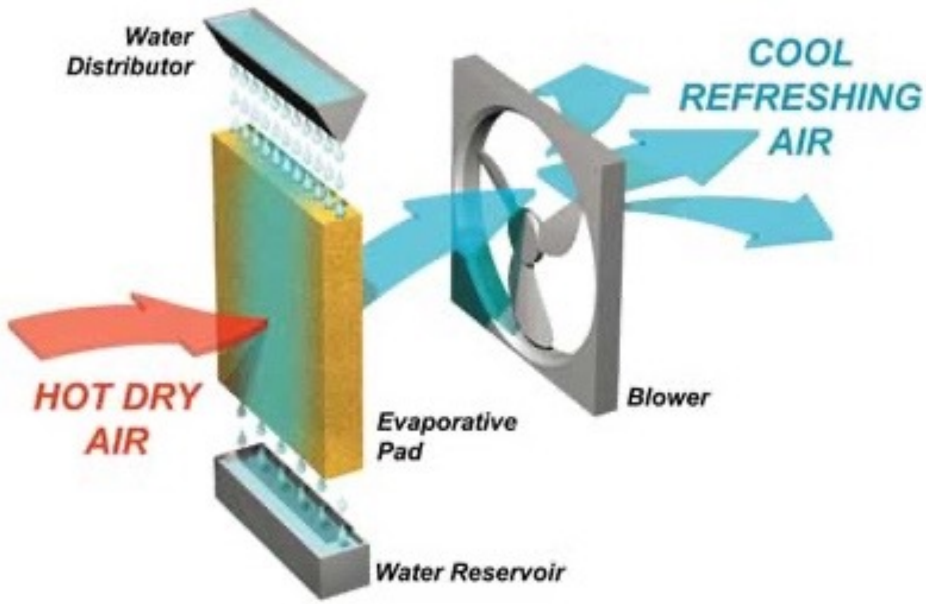
Active evaporative cooling "Swamp coolers"



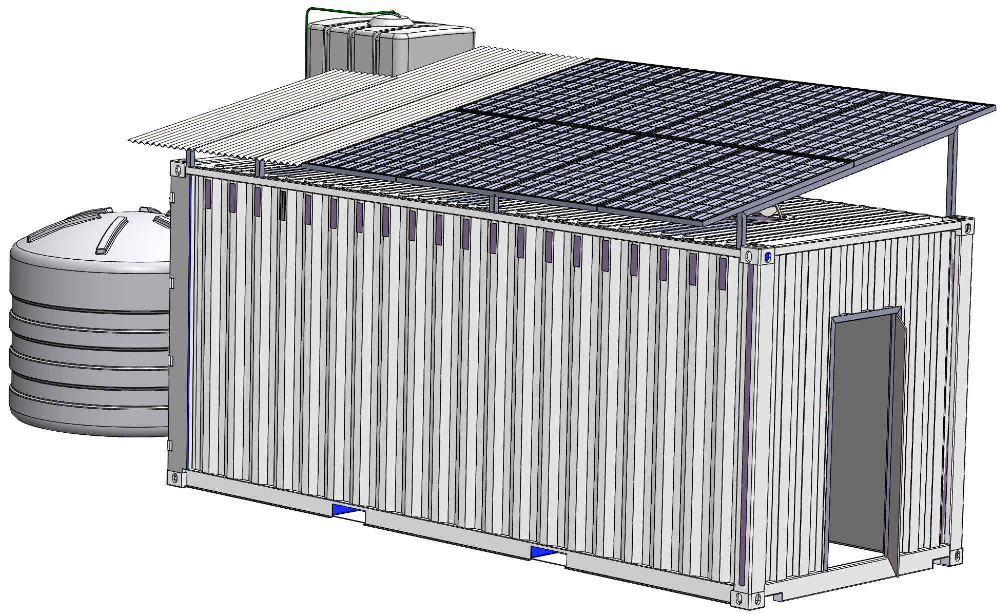
Corrugated cellulose

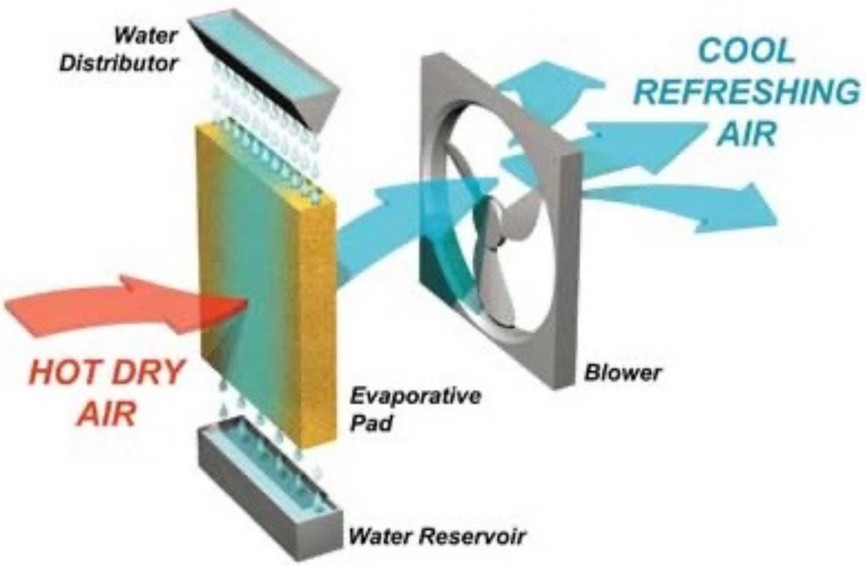
Aspen pad

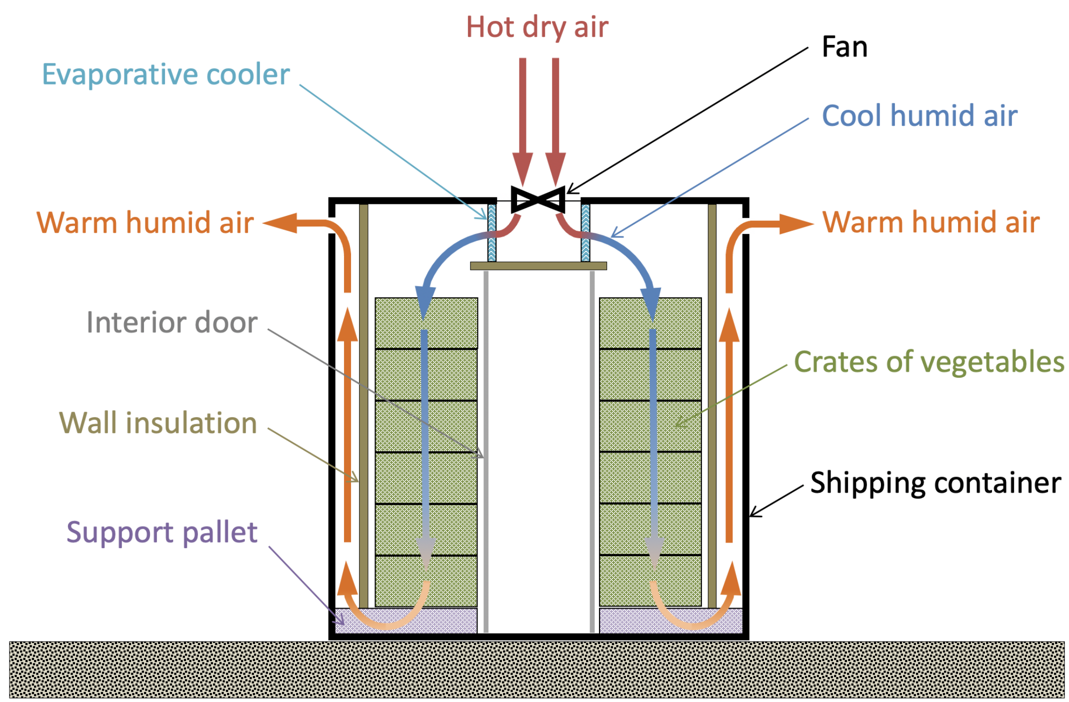
Forced-Air Evaporative Cooling Chamber

Concept:

- A used shipping container can be the primary structure
- “Swamp cooler” blows cool air directly through crates
- Rapid cooling of produce
- High humidity environment







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Pilot chambers in Kenya and India

Chambers with a storage capacity of 168 crates

- Kenya: Solar-powered off-grid system located at a produce market between Nairobi and Mombasa, cost $15,000 to construct (Solar Freeze)
- India: On-grid system located at a produce market near Bhuj, cost $8,100 to construct (Hunnarshala Foundation)

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- An off-grid refrigerated cold room with a similar storage capacity costs between $30,000 and $50,000 to construct

Pilot chambers in Kenya and India

- 6” thick packaged evaporative cooling pads
- 50 mm thick insulation panels
- Galvanized iron support structures
- IoT-connected control system
- 2-tank irrigation system
- 6 separate compartments for crates
- Door system design to minimize air gaps

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Comparison with Refrigerated Cold Rooms

- Energy consumption and cost
  - Forced-air evaporative cooling uses ~ 1/4 the energy of mechanical refrigeration
  - The forced-air evaporative cooling chamber costs less than half of the typical refrigerated cold room
- Cooling rate
  - Forced-air cooling allows for significantly faster cooling rates than room cooling
- Temperature control and minimum temperature
  - The minimum temperature that can be achieved through direct evaporative cooling is limited by the wet-bulb temperature, which is dependent on the ambient air temperature and humidity
- Humidity
  - Evaporative cooling provides a high humidity environment
  - Refrigerated cold rooms typically provide a low humidity environment
- Chamber optimized for inventory management and crop separation

Results from Chamber in India

Percent of produce spoiled after 2 days (chamber operating at 50% capacity factor)

Vegetable	Control	Chamber	Improvement
Alfalfa	50%	17%	33%
Coriander	70%	20%	50%
Cucumber	30%	15%	15%
Cabbage	15%	2%	13%
Cauliflower	18%	2%	16%
Eggplant	38%	12%	26%
Tomatoes	50%	10%	40%
Chili pepper	17%	5%	22%
Ladyfingers	20%	1%	19%
Ridge gourd	30%	8%	22%
Papaya	24%	8%	16%
Spinach	60%	20%	40%

<u>Average temperature</u>
- Ambient dry-bulb: 33°C
- In the chamber: 26°C

<u>Average relative humidity</u>
- Ambient: 45%
- In the chamber: 87%

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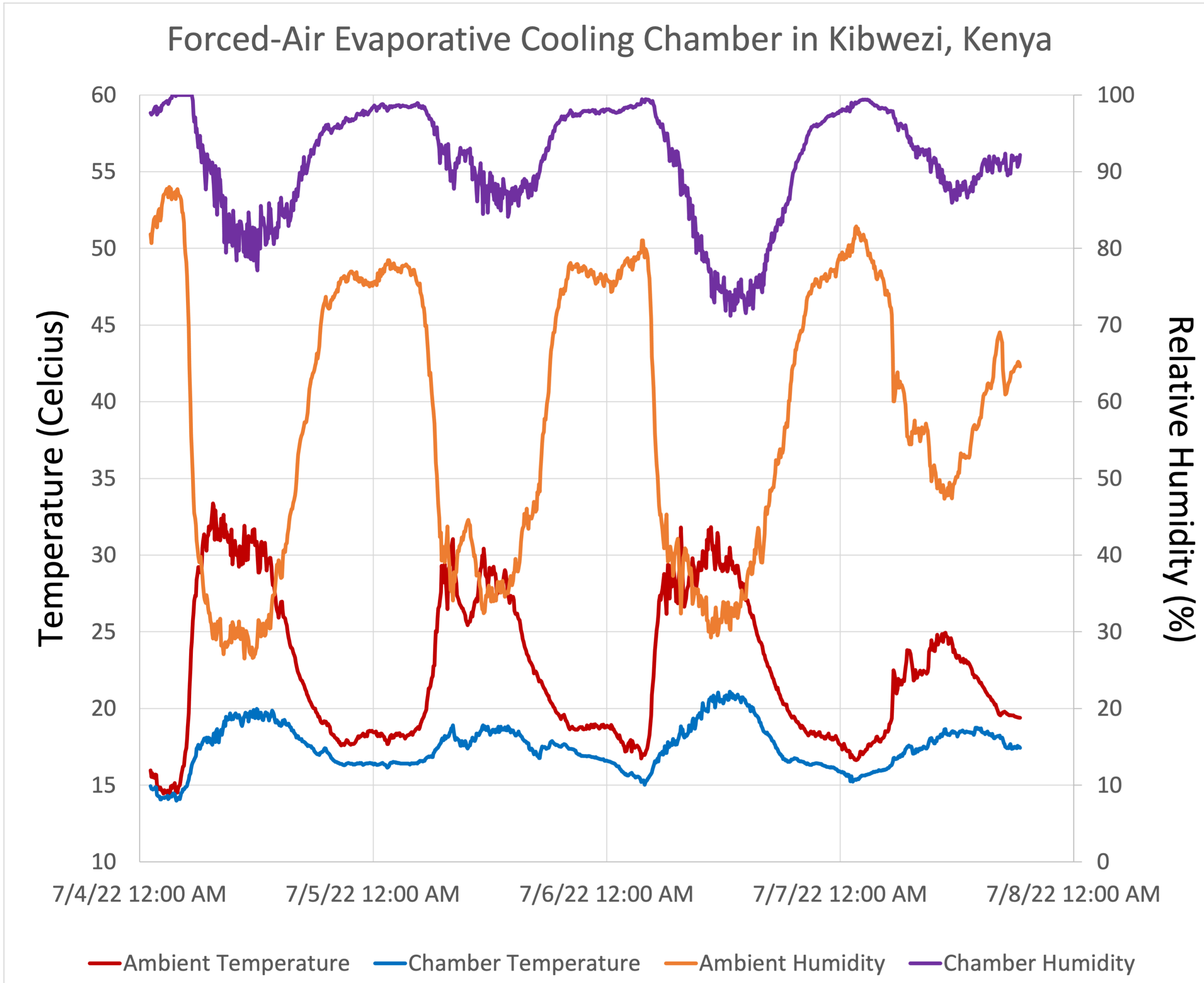
Results from Chamber in Kenya

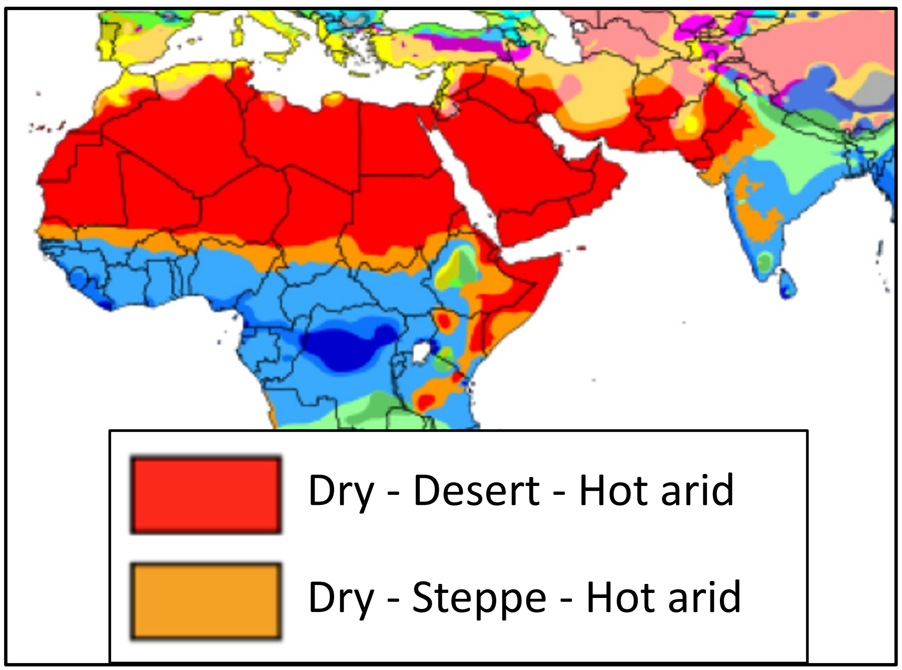


- Average ambient dry-bulb temperature: 22.6°C
- Maximum ambient dry-bulb temperature: 33.4°C
- Average ambient relative humidity: 56%
- Average ambient wet-bulb temperature: 16.4°C
- Average dry-bulb temperature in the chamber: 17.5°C
- Maximum dry-bulb temperature in the chamber: 21.1°C
- Average humidity inside the chamber: 91%
- Average evaporative cooling efficiency: 82%

Potential Markets

Geography

- Broad Regional Markets:
  - Sub-Saharan Africa
  - India
  - Middle East and North Africa



Application

- Fixed location:
  - Farming cooperatives
  - Produce markets
  - Large producers
- Mobile / seasonal:
  - Moving the container to where the need is greatest
- Pre-cooling:
  - Rapid cooling at the farm gate
- Transportation:
  - Transport from the farm gate to central location

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Open-Source Designs

The MIT team published documents covering each of these topics:

1. Introduction
2. Dimensional Design Schematics
3. Airflow System Diagrams
4. Electrical System Diagrams
5. Plumbing System Diagrams
6. Construction Guidelines

- Video overviews for each section of the documentation
- A dedicated website for hosting the documentation

https://www.cooling-chamber.mit.edu/

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Next Steps for Forced-Air Evaporative Cooling Chamber

- Test and optimize system performance (ongoing)
  - Pilot chambers in India and Kenya
  - Test chambers at MIT
- Pilot chambers with users in Kenya and India (ongoing)
  - Deployed with farmers and vendors and currently gathering data
- Identify additional partners to replicate the design
  - Cold storage providers
  - Other horticulture value chain stakeholders

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