Institution of MECHANICAL ENGINEERS

Low Tech Food Storage

Perishable Produce - Cold

Dr Tim Fox CEng CEnv FIMechE FRSA

Head of Energy and Environment
Institution of Mechanical Engineers

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Why engineers? Why IMechE?

Food-Water-Energy-Land relationship

A defining challenge for the 21st century

Perishable priority – why?

- Population growth and demographic change
  - Asia and sub-Saharan Africa projected to experience biggest growth in absolute numbers
  - Increased urbanisation demanding more and longer rural-urban supply chains
  - Dietary preference changes to food based on perishable produce with increasing affluence
  - Increased demand for convenience foods; largely based on perishable produce
- Global warming
  - Tropical and sub-tropical regions already warm; anticipated to experience most severe climate change
  - Productivity yields projected to reduce so critical to ensure as much produce as possible reaches market

India and Tanzania

- Perishable product loss
  - India & Tanzania loose up to 50% of nutrition-dense perishables between field – market
  - 97% Tanzanian meat not refrigerated and 16-25% dairy lost (seasonal)
  - Farmers often receive just 30 – 20% of potential produce value as income
  - Consumers pay produce prices that are higher than necessary

Cold is the need

- Cold is key to tackling perishable loss
  - Estimated that around 1/4 of total food wastage in developing countries could be eliminated if these countries adopted same level of refrigeration as in developed economies
  - Establishing a continuous temperature controlled environment is what is required – farm to home
  - Key to maintaining nutrients, leading to improved heath outcomes

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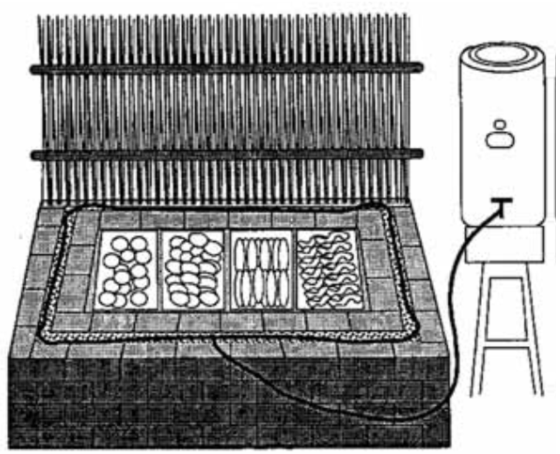
Cold chain technologies

Cold chain technology	Food products	Climate and technological issues	Supporting infrastructure needed
Step 1			
Use of shade	All	Shade will provide cooling in any climate, but works best at lower relative humidity (RH)	Shade cloth, sturdy poles or structures that can handle wind
Evaporative natural cooling	All	Requires relatively low RH	Small building enclosed by porous material (eg earthenware or woven palm fronds) and water
Evaporative forced air pre-cooling	Tropical and sub-tropical fruit and vegetables	Requires relatively low RH. Stacking patterns affect rate of cooling	Needs a building and power source to circulate air (electric powered fan)
Use of ice	Fish, leafy green vegetables (green onions, broccoli)	A roughly equal solution of water and ice is pumped through holed boxes to ice wax and cool produce. Requires waterproof packages and can be used only for water tolerant food products	Source of clean ice (can be inefficient and expensive), power for pumps
Hydro-cooling	Leafy vegetables, some temperate fruits	Well water is sometimes naturally cool enough to provide a source of cold – up to five times quicker than mechanical (vapour compression) refrigeration, but more energy-intensive and has the potential to contaminate food product. Can be used only for water-tolerant food products	Source of clean water (deep well or stream) with appropriate hygiene controls. Ice or refrigeration to cool water down to 0–2°C. Power for pumps and ice
Forced air pre-cooling	Most horticultural crops	Cooling is sped up via fans. Stacking patterns and package venting patterns effect rate of cooling. Delicate produce may experience dehydration if fan speeds are too high	Needs power source to circulate air (electric powered fan) and a cold room
Individually Quick Frozen (IQF)	Fruits, vegetables in small pieces	Need to match product with freezing rate, temperature, use appropriate pre-treatments. Need appropriate packaging (can be expensive). Can utilize a direct liquid nitrogen spray as source of freezing	Source of reliable power. Requires expensive conveyor style freezing equipment
Blast freezing	All	Forced air racked pallet systems can reduce energy costs	Source of reliable power

Cold chain technology	Food products	Climate and technological issues	Supporting infrastructure needed
Step 2			
High altitude cold storage	All	Typically air temperatures decrease by 10°C for every one km increase in altitude	Roads from farms to storage sites
Night air ventilated storage	All	Effectively maintains product temperature when the outside air temperature is below the desired product temperature for 5–7 hours per night	Insulated storage structure
Underground cold storage	All	The average temperature will be similar to average surface water temperatures in local rivers or streams, or the average annual air temperature in the region	Cave or root cellar
Evaporatively cooled cold storage	Most horticultural, some dairy and fermented foods	Requires relatively low RH (best in dry regions where dew point temperature is low)	Needs water source (such as deep well), good air flow and power for fans and pumps
Small-scale refrigerated cold storage – commercial system (walk-in room)	All	Stacking patterns affect cooling effectiveness and costs	Source of reliable power
Small-scale refrigerated cold storage – CoolBot™ system (walk-in room)	All	CoolBot™ automated controller can be used with a traditional window-style air conditioning unit, reduced capital cost for cold room by 90% compared to a commercial refrigeration system. Stacking patterns affect cooling effectiveness and costs	Source of reliable power
Large-scale refrigerated cold storage warehouse	All	Stacking patterns affect cooling effectiveness and costs	Source of reliable power, back-up generators
Step 3			
Quilts and insulated blankets	All	Requires pre-cooling before packed products are covered	Source of power for pre-cooling. Return system in order to reuse expensive insulated containers
Refrigerated truck or trailer ('reefer')	All	Stacking patterns affect cooling effectiveness and costs. Traditional trucks and reefers do not have the refrigeration capacity to provide cooling (they can only maintain cold temperatures); liquid nitrogen evaporation systems have been developed to provide direct cooling of the insulated trailer compartment	Source of reefers for purchase or lease. Power to drive refrigeration units
Refrigerated marine container	All	Stacking patterns and package venting affect cooling effectiveness and costs. Typically powered via "plug-in" to electricity while at port and on ships	Source of marine containers for lease. Power to drive refrigeration units
Refrigerated rail cars	All	Stacking patterns affect cooling effectiveness and costs. Early designs used large ice banks as a source of cold	Availability of refrigerated rail cars, scheduling, routes. Power to drive refrigeration units

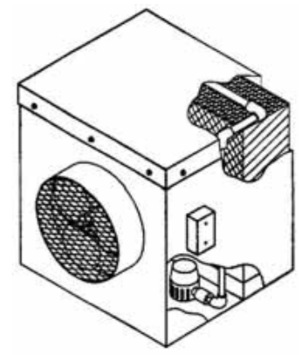
Low-tech cold storage - 1

- Passive/manual solutions
  - Painting storage buildings white or silver
  - Reflective insulation on outside of building
  - Massive walls of high thermal capacity
  - Roof overhang to provide shade
  - Radiant cooling
  - Underground storage or storage in caves
  - High altitude storage
  - Night air ventilation
  - “Zero-energy” cool chamber



Low-tech cold storage - 2

- Powered solutions
  - Evaporatively cooled storage room
    - need electricity for pumps & blower, cold water source and pad material; prefers low RH environment



  - Mechanically refrigerated walk-in cold rooms
    - ➢ Small-scale, simple self-build, e.g. CoolBot
    - ➢ Re-used van and shipping containers

    - ➢ Small-scale, commercial build
    - ➢ Large-scale, commercial build, warehouse
    - need electricity for compressors, fans etc

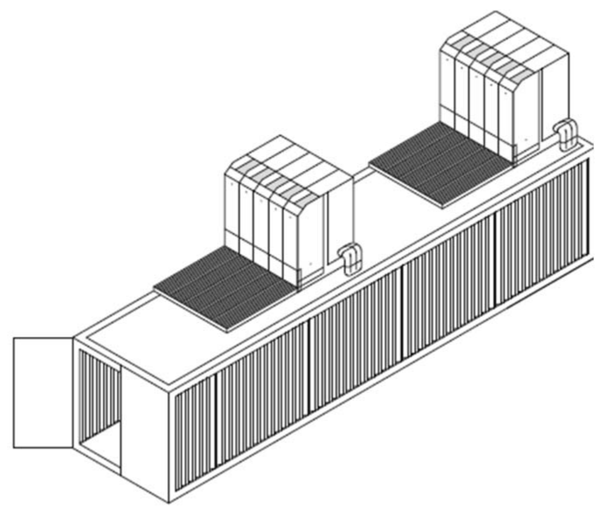
Energy security

- The primary challenge
  - Many cold chain technologies require reliable, continuous and affordable source of electricity (pre-cooling/chilling/freezing & storage) or diesel (transport)
  - 400 million people in India are not connected to grid and 350 million of those are located in rural villages
  - Less than 14% of Tanzanians have access to electricity and in rural areas the figure reduces to 2%
  - Farmers resort to diesel generator sets; energy security issue – often expensive and in short supply
  - Energy security will become more challenging as global competition increases and diesel subsidies withdrawn

Renewable energy for cold

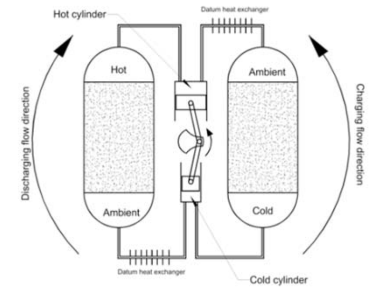
- Direct use of solar thermal energy
  - Refrigeration based on absorption process driven by solar thermal (e.g. SunChill, Solar-Polar)

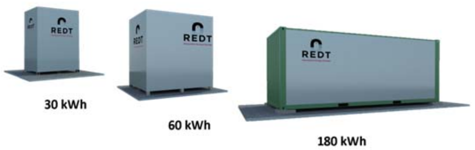
- Small scale power use
  - Solar (e.g. SunDanzer, Promethean)
  - Biogas (e.g. UGARF)



Reliable power: energy storage

- Needs to be suitable for local context
  - Pumped Heat Electrical Storage
    - 2 containers of local mineral & reversible gas machine; engine & heat pump
    - Low-cost, modular, closed, 2-5MW units
  - Flow Batteries
    - Extension of conventional battery thinking
    - Decadal lifetimes, little maintenance, no safety issues, scalable 5kW to 250+kW
  - Cryogenic energy storage
    - Liquid air of nitrogen formed by chilling air, stored, expands to drive turbine when exposed to ambient temperature





A Tank of Cold - power & cold

- Enables scaleable holistic systems level approach
  - Not only reliable electricity, but also direct cooling
  - Avoids traditional refrigerants and uses benign feedstock (air) and working fluid (liquid air)
  - Established mechanical engineering with embedded global supply chain in place
  - Enables provision of ‘fuel’ for transport refrigeration units
  - Case studies explore ‘Getting Started’ on the ground in India and Tanzania

Challenges for engineers?

- Focus on delivering appropriate cold storage technology for use at scale in off-grid and micro-grid applications
- Offer alternative technologies that deliver ‘power and cooling’ for both rural and urban areas – systems level view
- Tackle issues of equipment and plant scaling to enable a range of facilities to be delivered
- **Ensure solutions are affordable, safe, reliable, easy to build, operate and maintain and suitable to local technical skills**
- Recognise finance, politics, regulation, ethics, access and ownership are often key barriers to meeting the challenges

Thank you

Twitter: @TimFox_IMechE