POSTHARVEST TEMPERATURE MANAGEMENT IN HORTICULTURAL CROPS AND NEED FOR SUSTAINABLE OPTIONS



Vijay Yadav Tokala, PhD

The Postharvest Education Foundation

vijayyadav.t@postharvest.org

www.postharvest.org

CONTENTS



Food Loss- Global Snapshot



Coldchain for Horticulture Produce



Components Of Coldchain



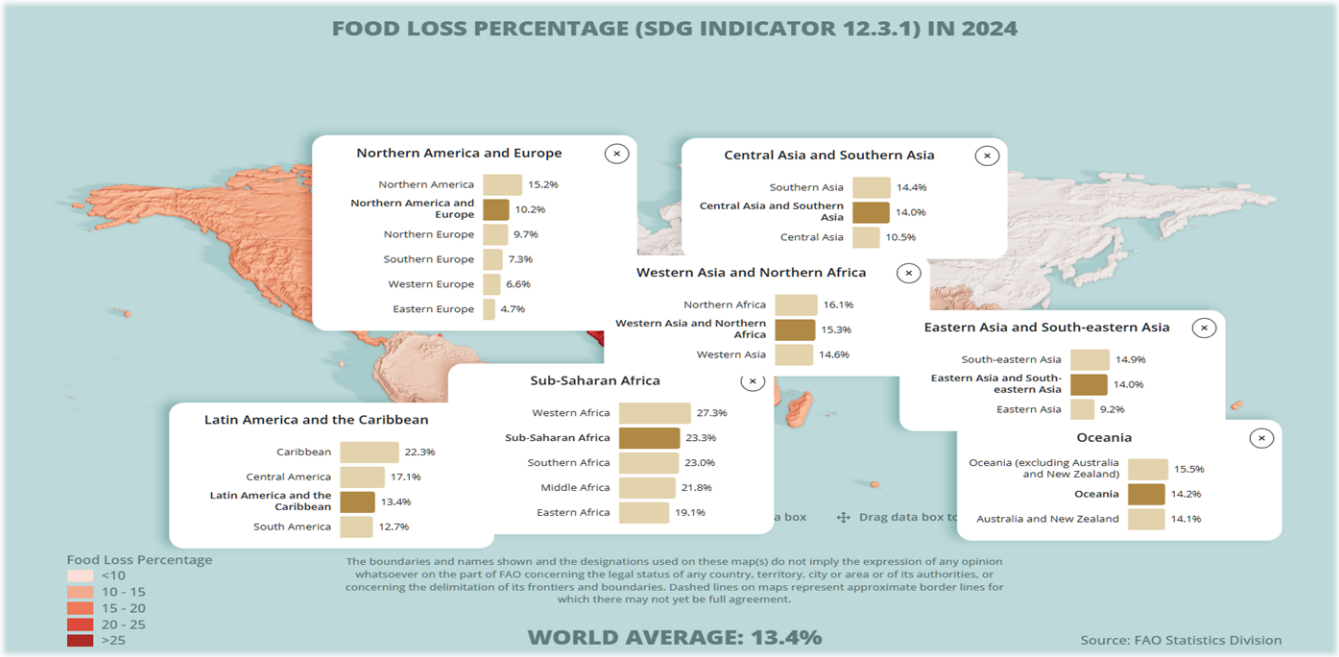
Sustainable Cooling Techniques



Conclusions

FOOD LOSSES – GLOBAL SNAPSHOT

World population is projected to reach **9.8 billion in 2050**, and **11.2 billion in 2100**



- Significant and evident in **all parts of the world**
- **Sub-Saharan Africa** has the highest regional food loss
- **Europe** exhibits the lowest food loss rates
- The global average is **13.4%**, with significant disparities

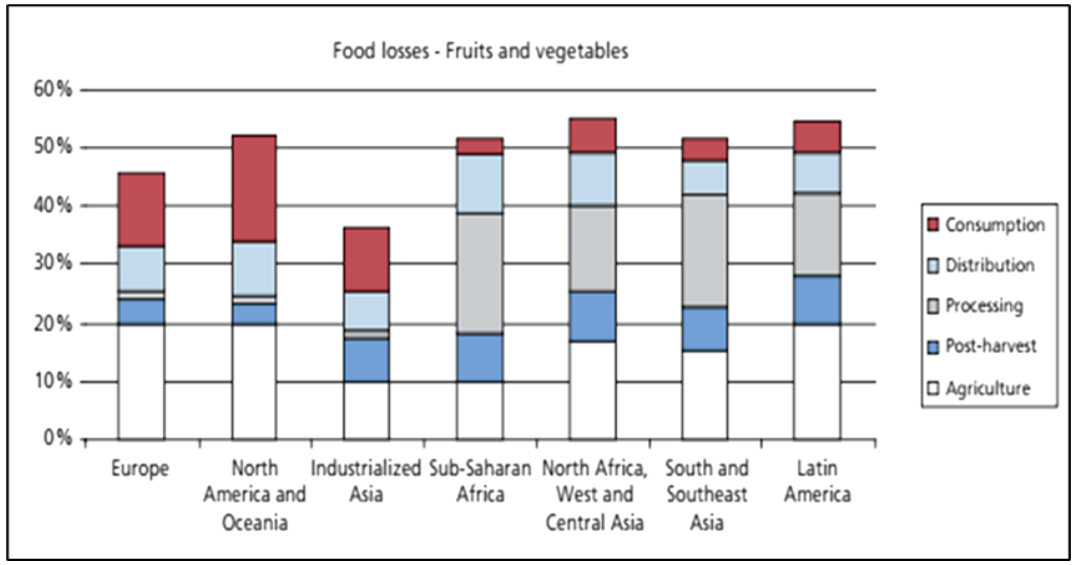
	Percent	~ Value	Key Stages
Food Loss	~13.4%	US$ 400 Billion	Post-harvest, transport, storage, processing
Food Waste	~19.0%	Multi-billion	Retail, food service, household consumption

- Highest losses in **Fruit and Vegetables @ 31.15 %**
- Due to **high perishability**
- **Few intervention** strategies compared to cereals and pulses

Source: UNFAO 2021, 2024

FOOD LOSSES - GAPS AND FIXES





- Occur in **all parts of the world** and at **all stages of the supply chain**
- May constitute **more than 50%** of total produce in **fresh perishables**
- **Food losses** = **Environment** (Resources used and GHG) | **Economic** (Reduced returns on investment) | **Social** (impede social progress)
- **Lack of infrastructure** and access to an affordable, **uninterrupted cold chain** during different steps of the value chain are main reasons for the losses in perishable foods
- Proper **cold chain management at every possible step** of the supply chain is an **easy and comparatively economical option** to reduce PHL

COLD CHAIN FOR HORTICULTURE PRODUCE

- Low temperatures **decelerate physiological activities**
  - ✓ ***Van't Hoff's rule*** – the **rate of reactions is doubled** as a result of a temperature increase of **10°C**
  - ✓ ***Arrhenius model*** - low temperatures **decelerate enzyme activity** (ethylene production)
- Unlike meat, fruit and vegetables have a **very specific safe storage temperature range.**
- Mango **~<9-12°C** ; Sweet Orange ~ **<5-7°C**

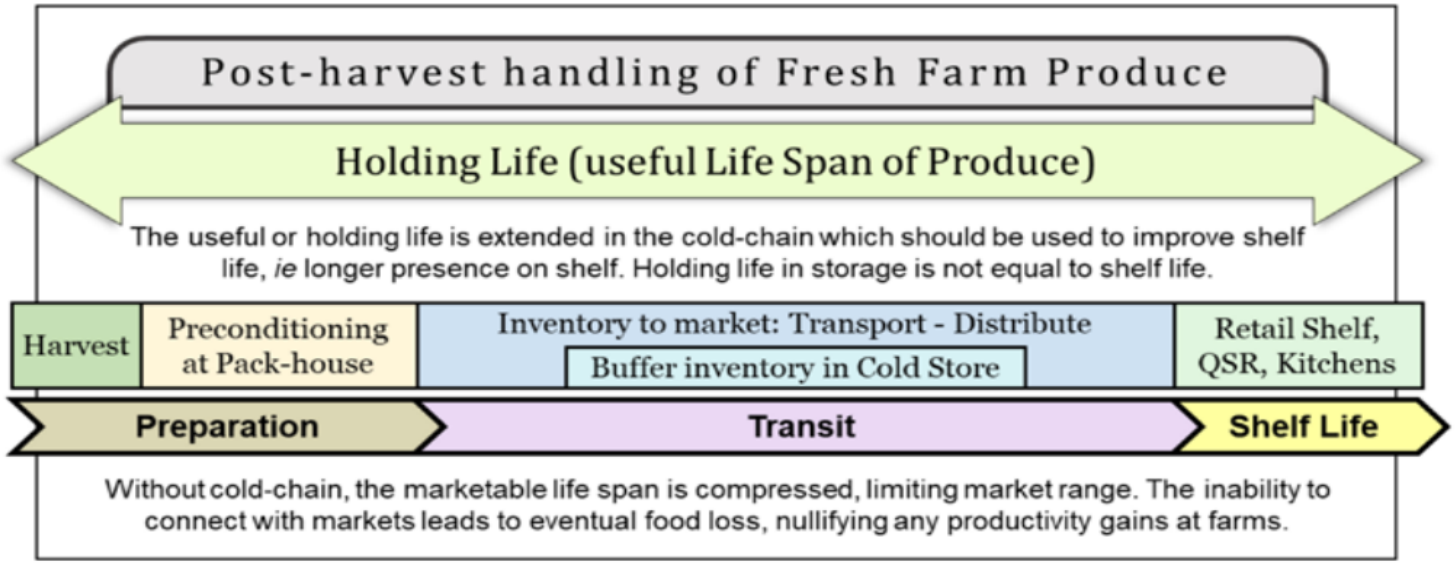


Chilling Injury symptoms in Sweet orange (<5°C)



Chilling Injury symptoms in Mango (<9°C)

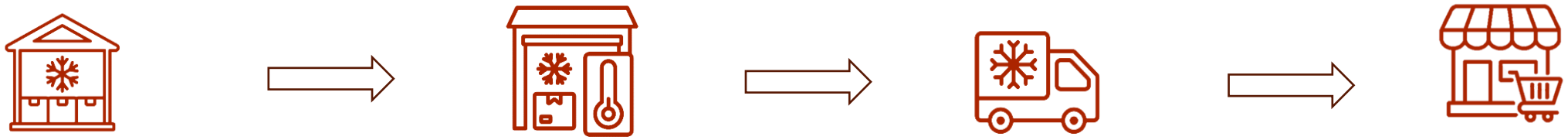
COLD CHAIN FOR HORTICULTURE PRODUCE



Holding life is not the same as shelf life (Source: Pawanexh Kohli)

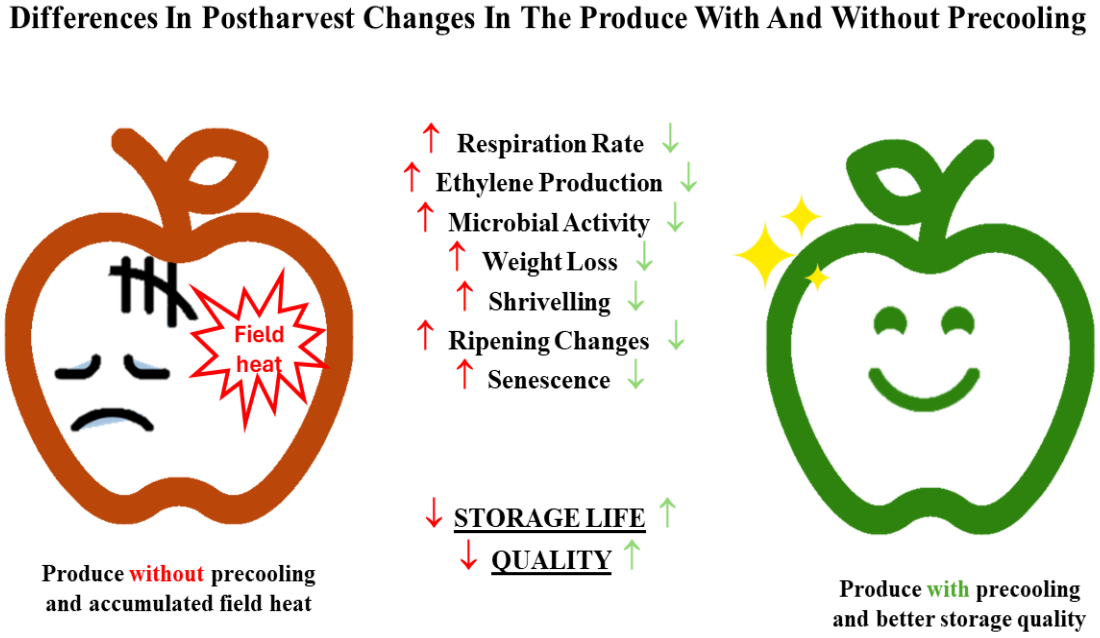
- **Coldchain ≠ Cold storage. Coldchain = Temperature management**
- Cold chain only extends '**holding life'**, but produce ultimately deteriorates
- The extended time should be used efficiently to **improve marketing chances**
- Every commodity has a **maximum period** where it is stored with **optimal quality**

COMPONENTS OF COLD CHAIN



Pre-cooling and Initial Processing	Temperature-controlled Storage	Transportation	Distribution/ Retailers
• After harvest or production, products are **rapidly cooled** to slow down physiological activity and microbial growth. • This step is crucial for fresh produce E.g., Pre-coolers, packhouses	• Products are stored in refrigerated warehouses or cold storage facilities to maintain the desired temperature • Fruit and vegetables have a particular **safe storage temperature range**	• Transport involves refrigerated trucks, reefers, and containers that **maintain specific temperatures during the journey** from storage to retail points	• The final leg involves the delivery of products to retailers and end consumers, often requiring last-mile delivery solutions to ensure freshness and quality

PRECOOLING



https://wikifarmer.com/library/en/article/pre-cooling-essential-for-improving-postharvest-management-of-horticultural-crops

- To **reduce field heat** (respiration and moisture loss) before transferring into storage.
- Essential in products with **high respiration rates** – berries, leafy vegetables, cucumbers, peas, chili peppers, and tomatoes.
- Types of pre-cooling:
  - **Hydrocooling**: Using chilled water to cool the produce
  - **Vacuum Cooling**: Reducing air pressure to lower the temperature quickly
  - **Forced-Air Cooling**: Using fans to blow cold air through the produce
  - **Ice Cooling**: Applying ice directly to the product to lower its temperature

PRECOOLING



Hydrocooling



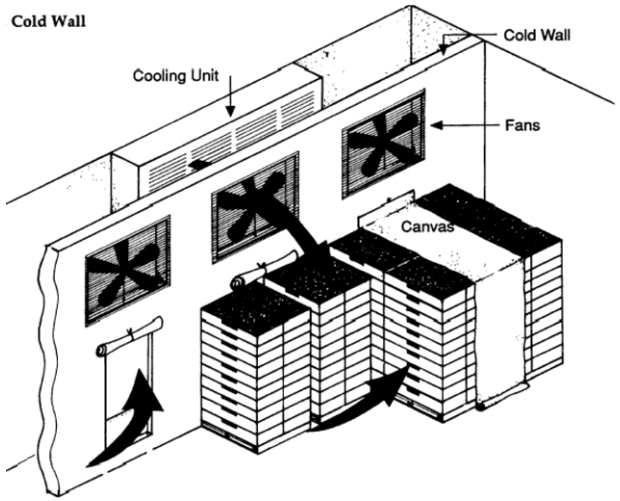
Contact icing of Broccoli



Portable forced-air cooling tunnel







Forced-air cooling of fruit

TEMPERATURE-CONTROLLED STORAGE

- Keeping produce at low temperatures to **improve 'holding life'**
- In developing countries, it is considered the first step in building a cold chain.
- Different methods – based on **cooling requirements** and **expected length of storage**
- Types of cooling:
  - **Evaporative cooling:** ZECC, Fan and pad system (desert cooler), Charcoal evaporative cooler
  - **Mechanical:** Ammonia/ Freon refrigerators, CoolBot-equipped cold rooms
  - **Solar-powered:** Ecozen Solutions, Ecofrost, ColdHubs
- **Limitations**:
  - Lack of awareness on right cooling procedures: **mixed loads**, **too-cold** temperatures, **produce-specific** requirements
  - Continuous electricity supply

TEMPERATURE-CONTROLLED STORAGE



Multi-chambered Cold rooms





Multi-storied Cold rooms





Mixed loads in cold rooms (Bakery foods, Dried chillies, Tamarind)

TEMPERATURE-CONTROLLED STORAGE



Zero Energy Cooling Chamber (ZECC)



Solar-powered cold rooms

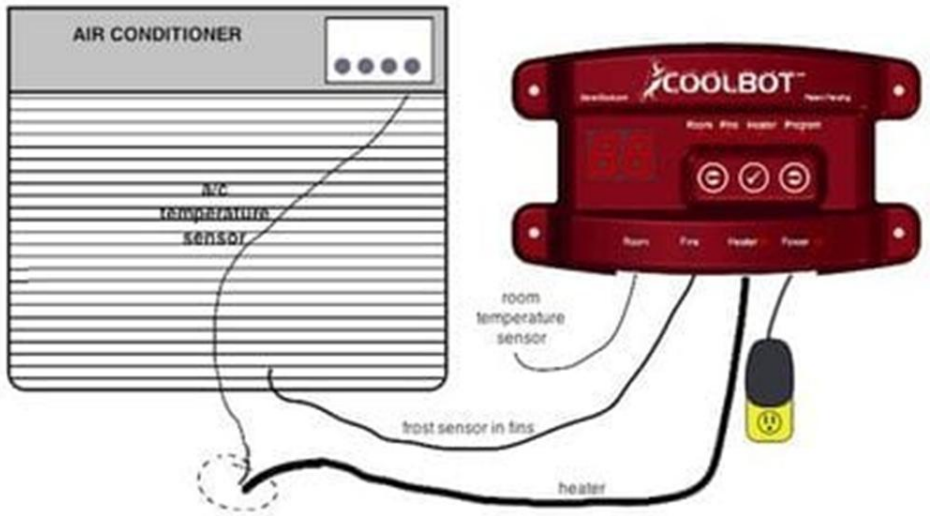




Charcoal cooler

TEMPERATURE-CONTROLLED STORAGE





CoolBot Cold rooms

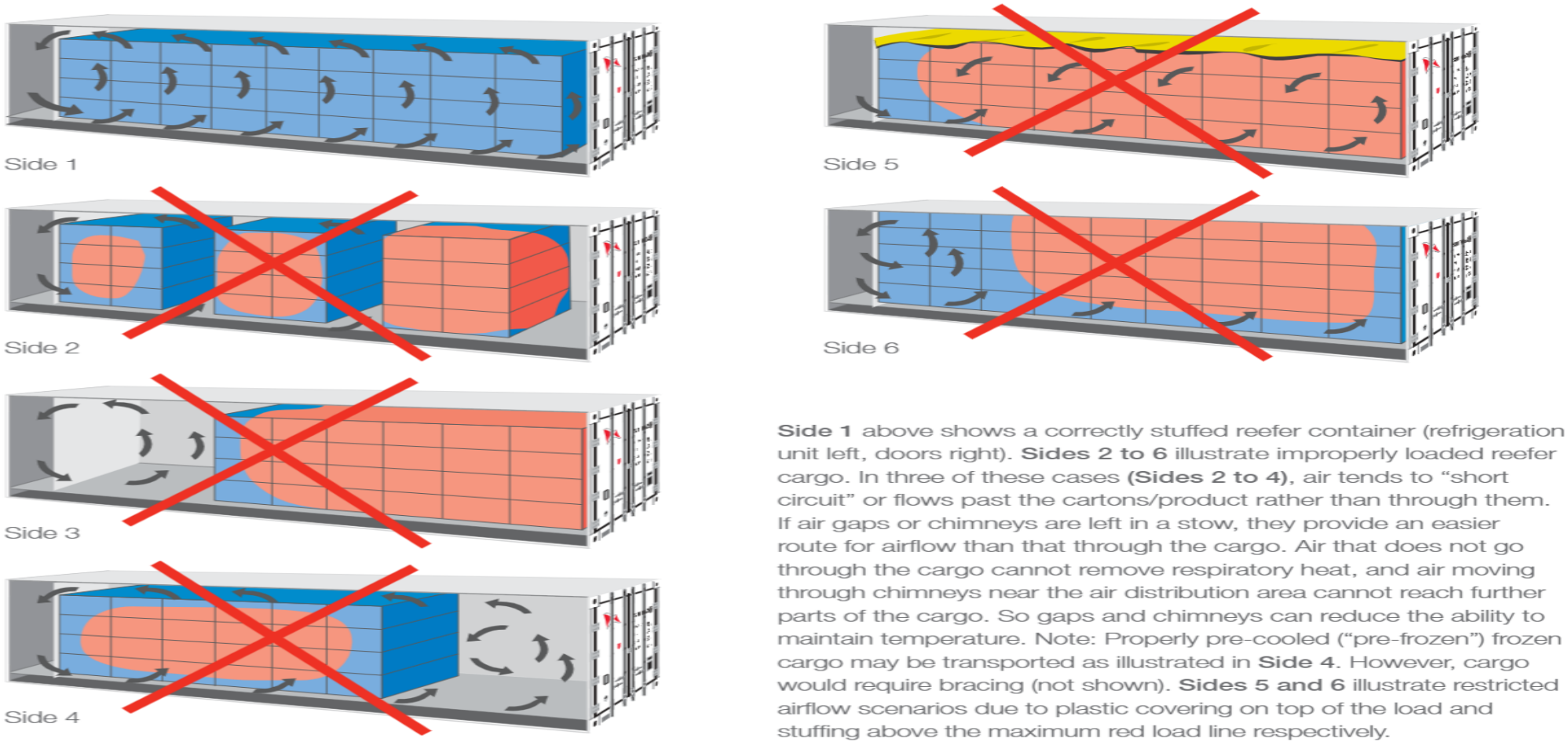
TRANSPORTATION



Reefer vans

- Temperature management is a critical factor for long-distance transport
- **Load stacking** – different patterns to ensure maximum (cool) air circulation
- Losses are mainly due to **physical and mechanical injuries or uncontrolled temperature and humidity**.
- Road – short distance.
- Rail or air – long distance.

TRANSPORTATION



Load arrangement in the container

Image Source: Hamburg Sud, 2010

COOLING AT DISTRIBUTION/ RETAILERS

- **Last link** in the cold chain and often neglected
- Limited to carbonated beverages, ice creams, or expensive products
- Range of temperature-control measures at retail – **fundamental methods like spraying water to refrigerated displays**
- Mostly, refrigeration is done **for high-value items**, but not by understanding the requirements of specific produce
- Awareness of retailers/staff about appropriate temperature choices, packing, as well as food safety issues is needed

COOLING AT DISTRIBUTION/ RETAILERS



Retail displays at ambient (using water and jute bags for cooling)



Refrigerated retail display in racks

SUSTAINABLE COOLING TECHNIQUES

- Currently – mostly **mechanical refrigeration systems.**
- Stationary system – **Electricity.**
- Mobile system – **Diesel or other fuels.**
- 80% of cases - **Fossil fuels (natural gas, petroleum, coal, LPG)** used to run machines and generate electricity
- **Cooling – emits GHGs = shipping and aviation combined**

“Today’s solution shouldn’t be tomorrow’s problem”

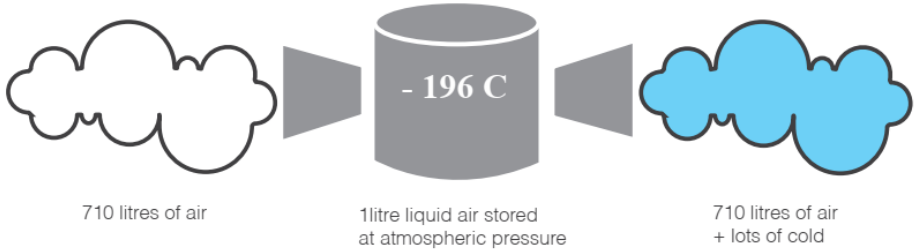
SUSTAINABLE COOLING TECHNIQUES

- With the expansion of the cold chain infrastructure, there will be a proportionate surge in the **demand for energy**
- Using sustainable cooling techniques is essential to meet the cooling needs without adversely **affecting the environment**
- Key ways to reduce energy consumption:
  - ✓ Using **efficient** and **low-Global Warming Potential (GWP) and non-Ozone-Depleting Substances (ODS) refrigerant-based** technologies
  - ✓ Better **operation and service practices** to optimize operational efficiency and **minimize leakages**
- Alternate technologies :
  - ✓ **Solar-powered** storage facilities – CoolHubs, Ecozen
  - ✓ Off-grid fridges with **Phase change materials (PCMs)**
  - ✓ **Liquid Air technology:** Liquid Nitrogen) (-196°C) = ~150-200 kWh per ton Liq. N_2 | Liquefied Natural Gas (LNG) (-162°C) = ~400 kWh per ton LNG

SUSTAINABLE COOLING TECHNIQUES

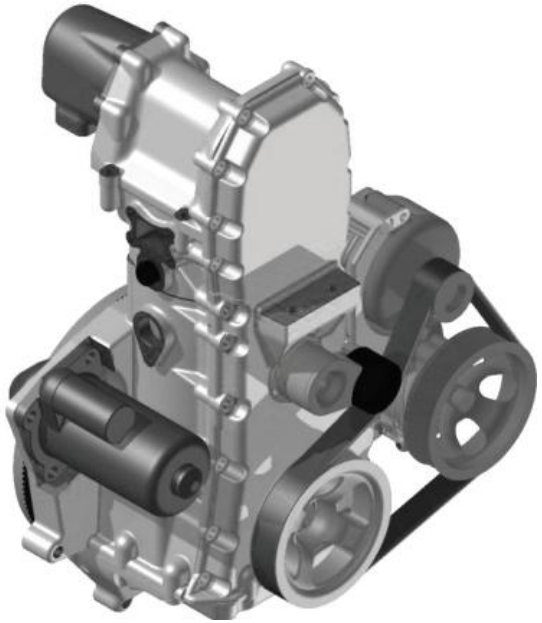


Phase Change Materials (PCM)





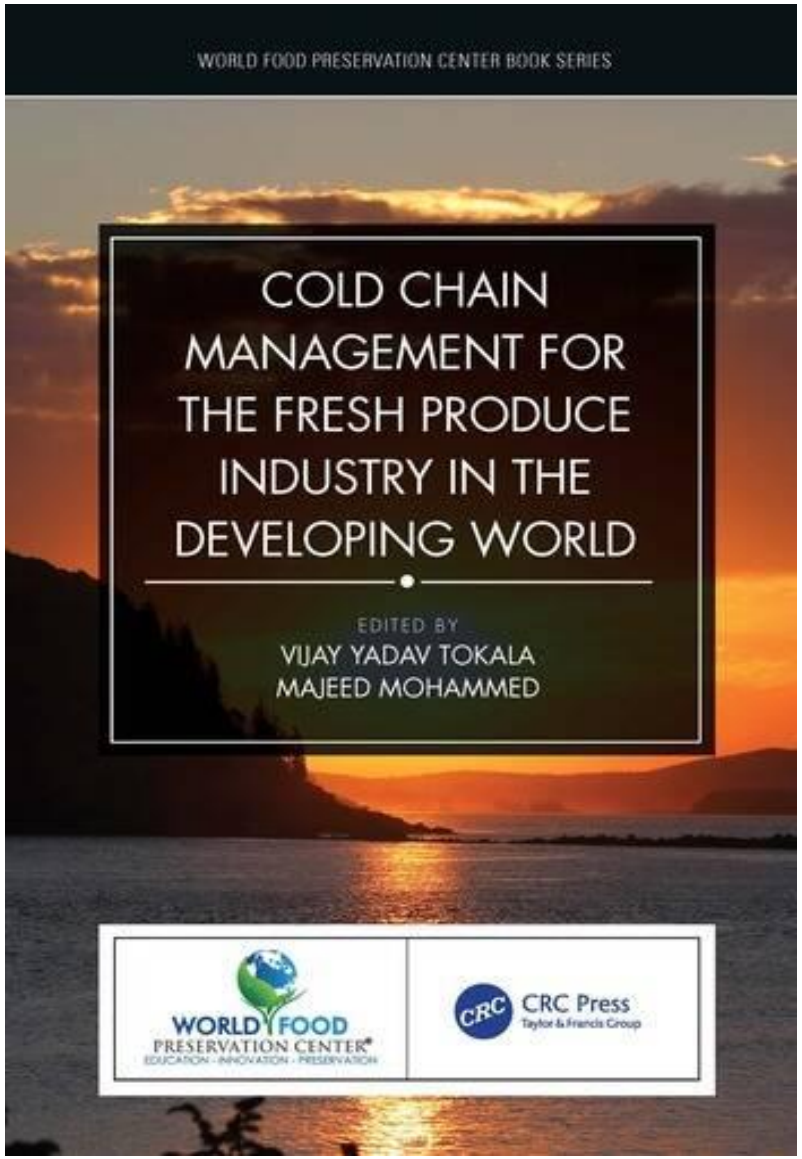
Solar-powered cold rooms



Dearman engine model [Image source: Univ of Birmingham]

CONCLUSIONS

- Cold chain management **enhances income** as well as **ensures food security**
- The concept of the cold chain is more than just cold storage; it **starts from the farm and continues until the produce is consumed**
- Success of cold chain management depends on **how the extended holding time is efficiently used** to improve shelf life, maintain quality, or expand marketing options.
- As more investments are made in this sector, there is a need for wide adoption of **sustainable technologies and clean cold chain development**



- Case studies for promoting the **expansion of existing technologies** for cold chain development in Asian, African, and Caribbean nations.
- Assesses **cold chain management as crucial** to the growth of global trade in perishable products.
- **Resilient, sustainable, and creative** concepts to develop cold chains to enhance food distribution

THANK YOU

Email : vijayyadav.t@postharvest.org

Website: www.postharvest.org