# 7th Lecture: Physiology

# Refrigeration: methods of cooling

# What is the function of Cooling

Slow down the rate of ripening of fresh produce

Slow down the production  of ethylene and respiration

Slow down the rate of water loss

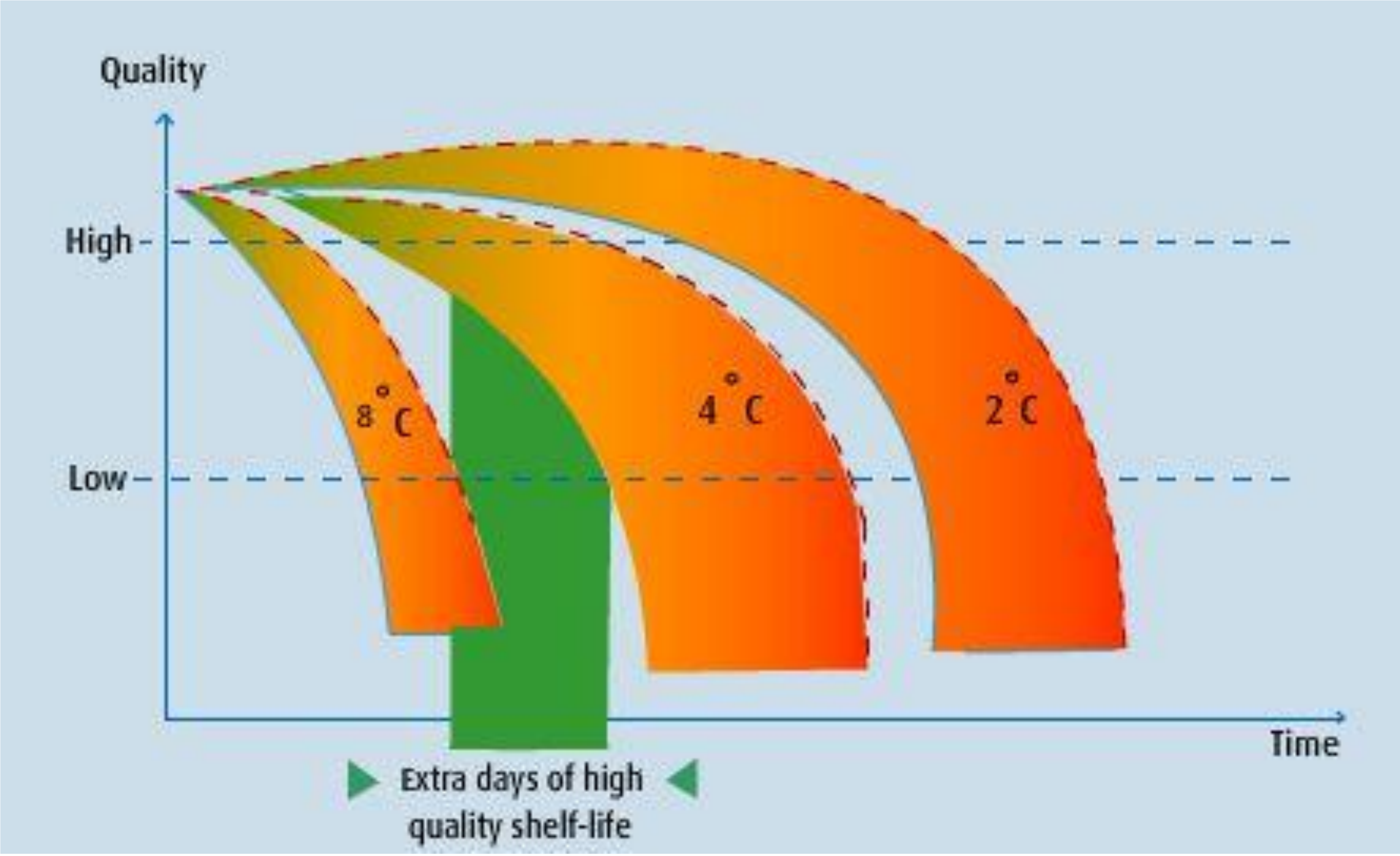
Slow development disease

Avoid the need for immediate marketing – flexibility in marketing

Regulation of temperature

**Remember**

**Respiration= Heat production**




**Impact of storage temperatures on the quality and storage capacity of fresh produce**

**It is very important to lower the temperature of the fruit immediately after harvesting!!!**

**This depends on the following:**

# The temperature of the fruit at the time of harvest depends:

1. "Fruit type"–respiratory rate, cooling requirements, minimum storage temperature
2. Packaging requirements – cooling rate (closed cardboard)
3. The amount of produce that needs to be refrigerated in a unit of time
4. Mixed produce (sensitivity to smells, ethylene, $CO_2$)
5. Market requirements (ice)
6. Budget constraints

# Metabolic heat production

**Heat generation in fresh produce is primarily developed through respiration, a process where fresh fruits and vegetables use energy from stored reserves and oxygen from the surrounding air to keep the plant alive, even after harvest.**

**Heat, known specifically as "vital heat", is released as a by-product of the respiration process (Kader, 2002), which contributes to the refrigeration needs that must be considered in designing storage rooms and during transportation of fresh produce (Saltveit, 2016).**

# Effect of product temperature on metabolic heat generation

| | Metabolic heat KJ · $T^{-1} \cdot hr^{-1}$ | | | | |
|---|---|---|---|---|---|
| **Crop** | **0C** | **5 C** | **15 C** | **20 C** | **25 C** |
| **Apple** | **44-24** | **78-53** | **330-145** | **373-179** | |
| **Asparagus** | **640-300** | **1120-630** | **2494-1236** | **2869-1856** | **5075-3965** |
| **Bean** | **320-112** | **383-208** | **1328-1066** | **1910-1415** | |
| **Carrot** | **218-102** | **281-136** | **572-276** | **1013-490** | |
| **Lettuce** | **179-63** | **213-141** | **480-339** | **640-543** | **974-780** |
| **Dry onion** | **238-112** | **727-184** | **1037-702** | **1663-824** | **2235-1042** |
| **Raphanus** | **102-34** | **141-63** | **451-238** | **616-475** | **945-645** |
| **Strawberry** | **198-131** | **354-175** | **984-756** | **2089-1091** | **2249-1793** |
| **Tomato** | | **87-53** | **301-175** | **441-301** | **543-368** |

**In addition to temperature, other key factors that affect fresh produce respiration include:**

- **Chilling stress**
- **Heat stress**
- **Physical stress**
- **Atmospheric composition**

# Chilling stress and injuries

**Pitting**

**Uneven color development**

**Watery type of regions**

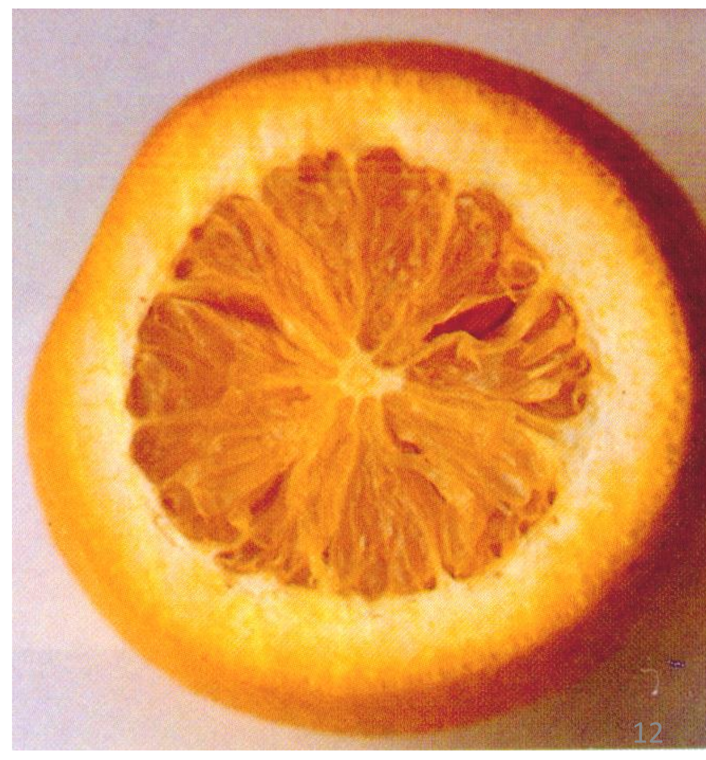
**Necrotic regions**

**Uneven maturation**

**Sensitivity to Decay**

**The damages of the chilling are expressed more strongly after the transfer of the fruit to shelf life!**



**The effect of Total Soluble Solids (sugar concentration) and chilling on the response to temperatures**

**The amount of TSS content affects the freezing point of the water in the tissue:**

**Lettuce will freeze at -0.2 C**

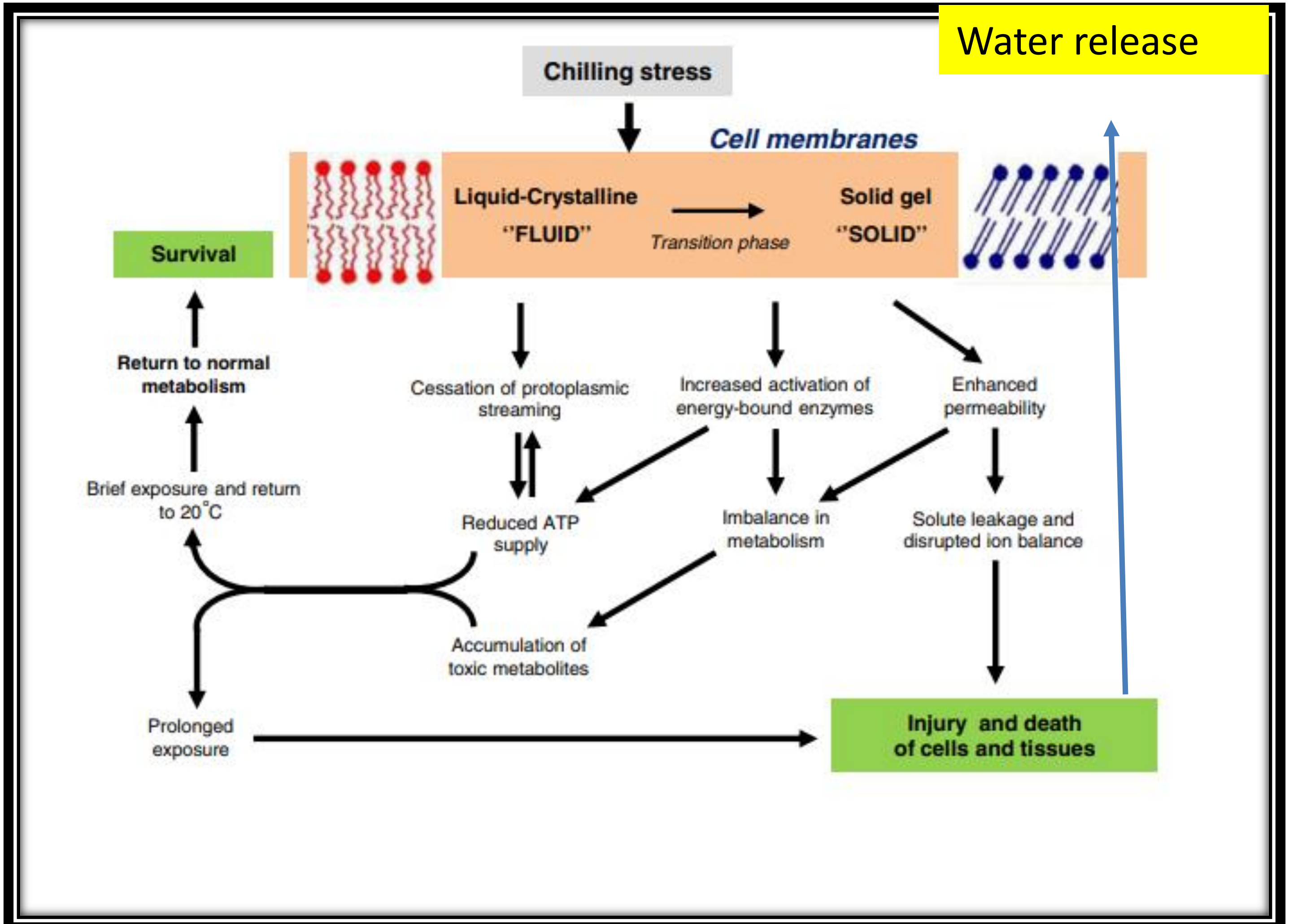
**Pear will freeze at -1.1 C**

**Grapes will freeze at -2.0 C**

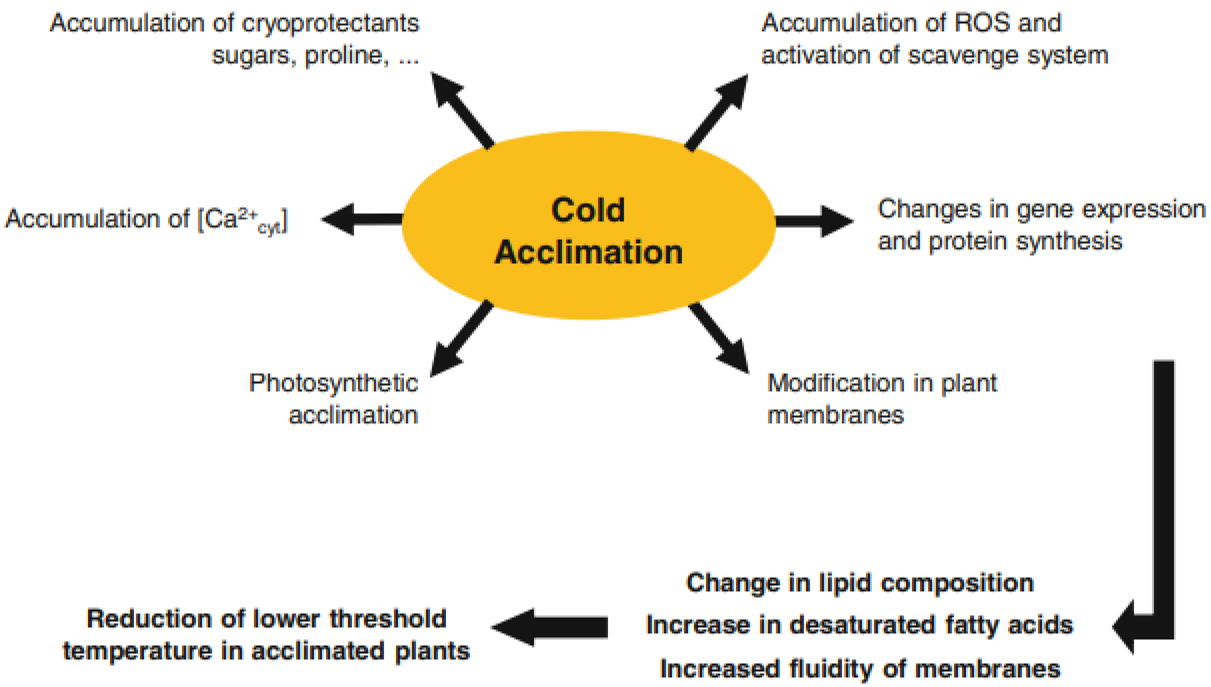
**Dates will freeze at -20.0 C!!!!**

# A model to explain symptoms of chilling injury in chilling-sensitive plants.

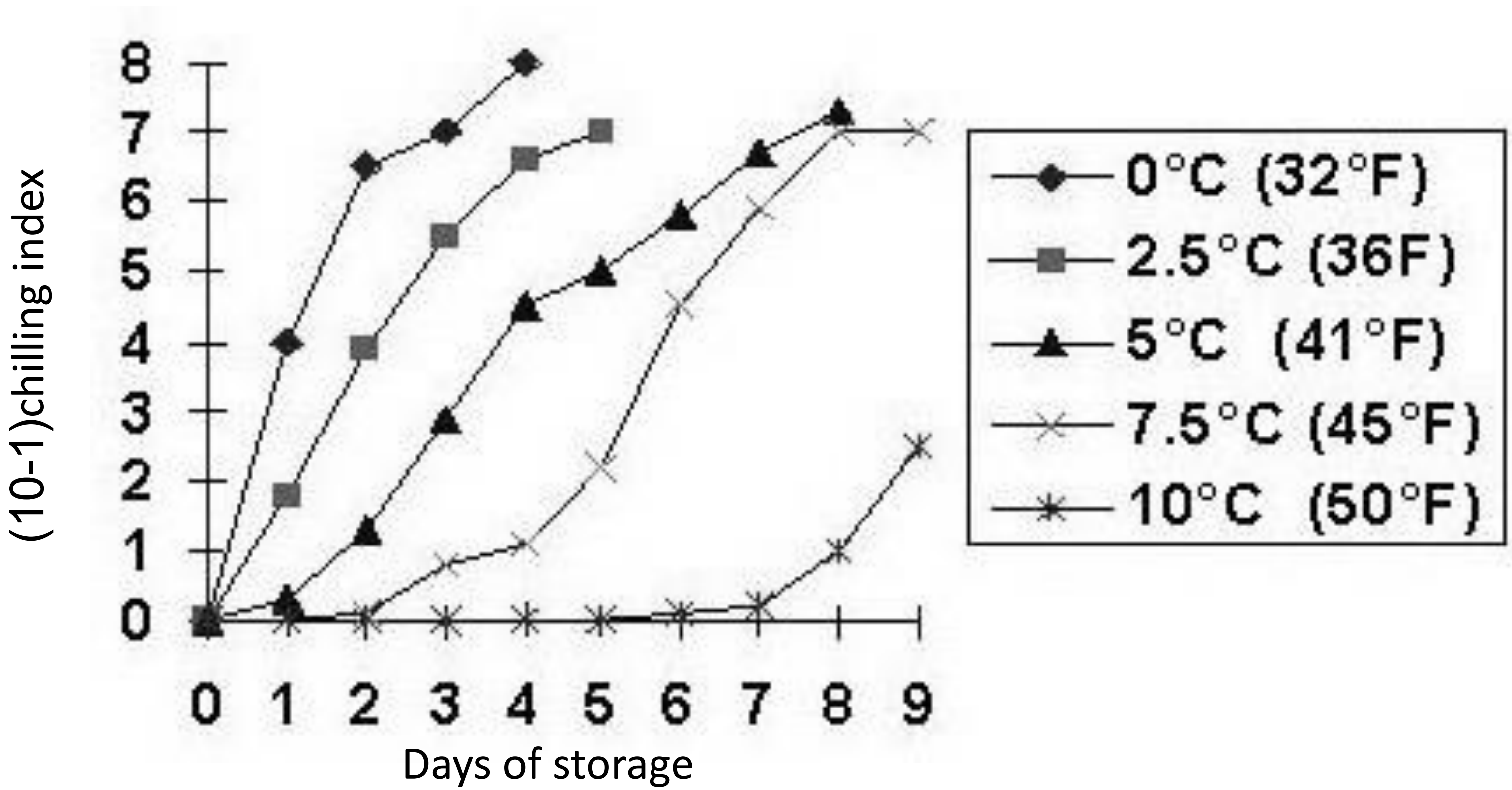
Membranes are the primary site of cold-induced injury, leading to a cascade of cellular processes with adverse effects on the plant. When exposure to low temperature is brief, the effects may be transitory and plants survive. However, the plant will exhibit necrosis or die if exposure is maintained (Lyons 1973; Raison and Lyons 1986)



# Different cellular processes induced as a consequence of plant acclimation to cold

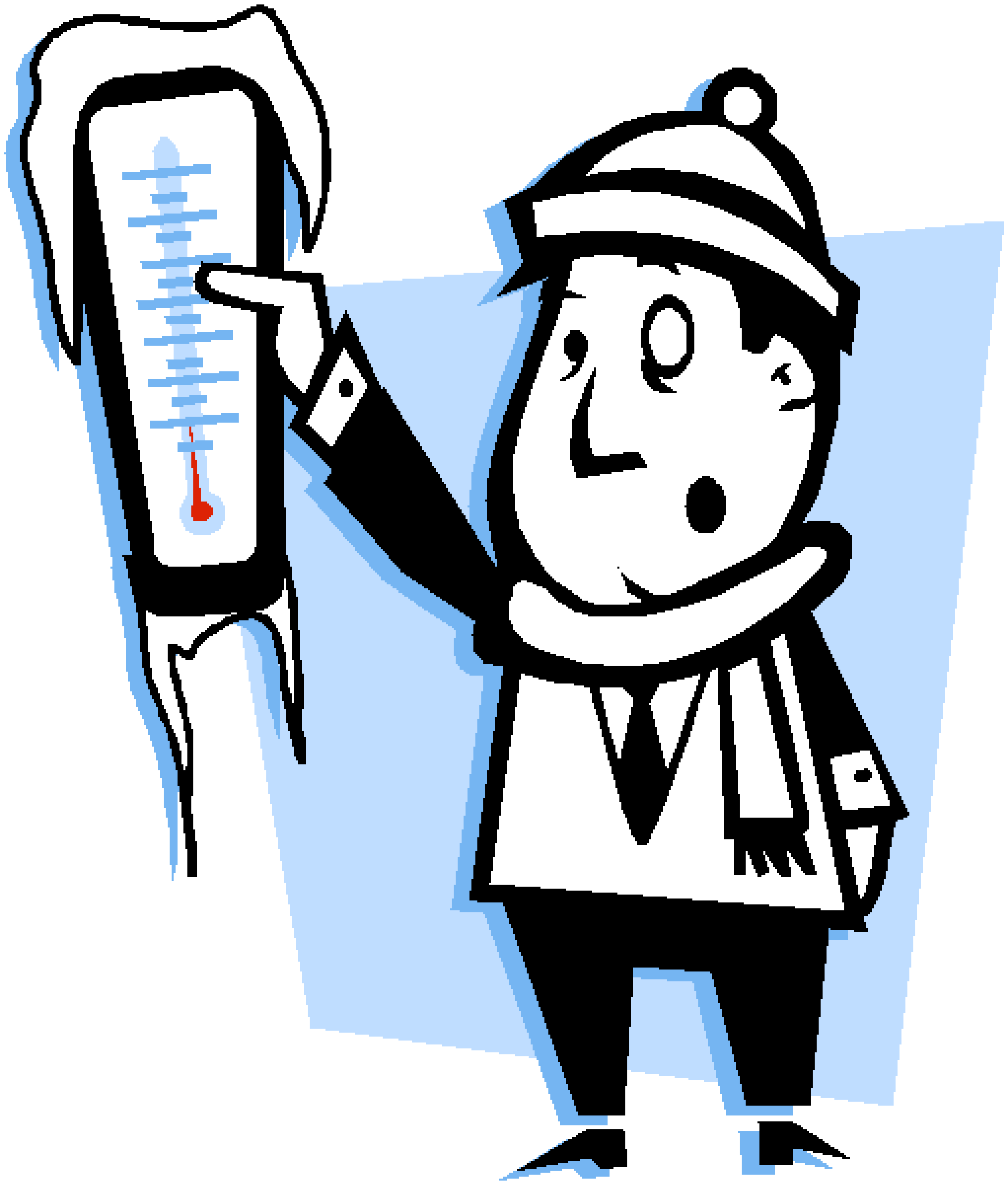


# Development of Chilling injury in Basil



# Ways to reduce chilling damage

- **Physical therapies (heat treatments) (stress against stress)**
- **Lowering the temperature gradually (potatoes, Sweet potatoes).**
- **Raising the temperature up to 24 hours and lowering it to the storage temperature (lemon).**
- **Fruit packaging (preventing water loss).**
- **A combination of several methods (quarantine treatments).**
- **Inducing high content of antioxidants (carotenoids, anthocyanin - strains).**
- **Treatments with methyl jasmonate .**
- **Irrigation with salty water (without causing damage)**



**How to maintain a minimum and harmless temperature?**

Picked in the early morning or late afternoon. Not at the highest heat at noon!!!

Keeping the produce in a shady and ventilated place and covering it (preventing direct sun and rain)

Constantly transfer the harvested fruits to the packing house (several trips a day)

Keeping the produce in a shady and ventilated place and covering it (preventing direct sun and rain)

**Keep the produce in a chilled or air-conditioned place**

**Moving the surfaces to cooling rooms with high humidity as quickly as possible from the packing time**

# Keeping a cooling chain – from farmer to consumer


- Harvesting
- Transfer from the greenhouse to the packing house
- In the Packinghouse
- Storage until transportation to the terminal
- Terminal (maritime or air freight)
- Transportation to the markets
- Transport to the local markets
- Final customer-consumer

**It's not just 'physical quality' (reduction of respiration, ethylene, water loss, disease development) but also 'food safety'**

# The effect of breaking the cooling chain on pepper quality. Average per 10 cartons per treatment.

| Treatment | Water loss (%) | Firmness (m"m) | Decay (%) | Apperance (1-5) |
| --- | --- | --- | --- | --- |
| No cooling brake. Storage at 7C 14 d | 2.8A | 2.5A | 4A | 2.9A |
| Braking the cooling for 2 h. Storage at 7C for 3 d, out for 2 h 20C, and then 7C for 10 d | 2.9A | 2.6A | 7B | 2.6 B |

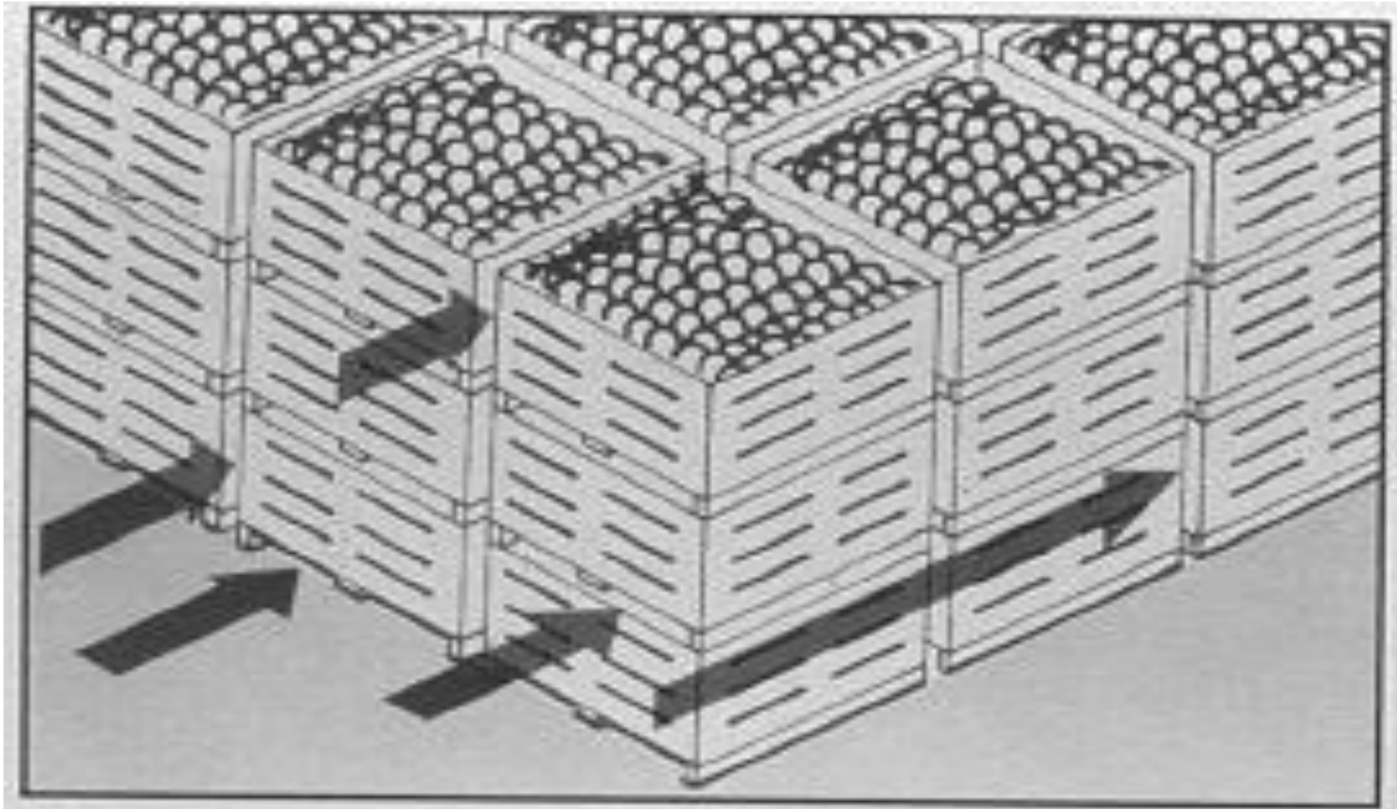
# Cooling methods

# Old time preservation and cooling conditions

# Refrigerator before the refrigerator

## We can also cooling without air condition

https://www.youtube.com/watch?v=EfBPd6zn_OA



**Cooling room – most products, slow, must have well ventilated cartons or packaging bins, cooling rate depends on the produce and disposition of packaging in the room**

**Room cooling**


Mehadrin Tnuport Export
Jaffa
HONEY MOR


Arava
ARAVA EXPORT GROWERS
ISRAEL
Arava
ARAVA EXPORT GROWERS
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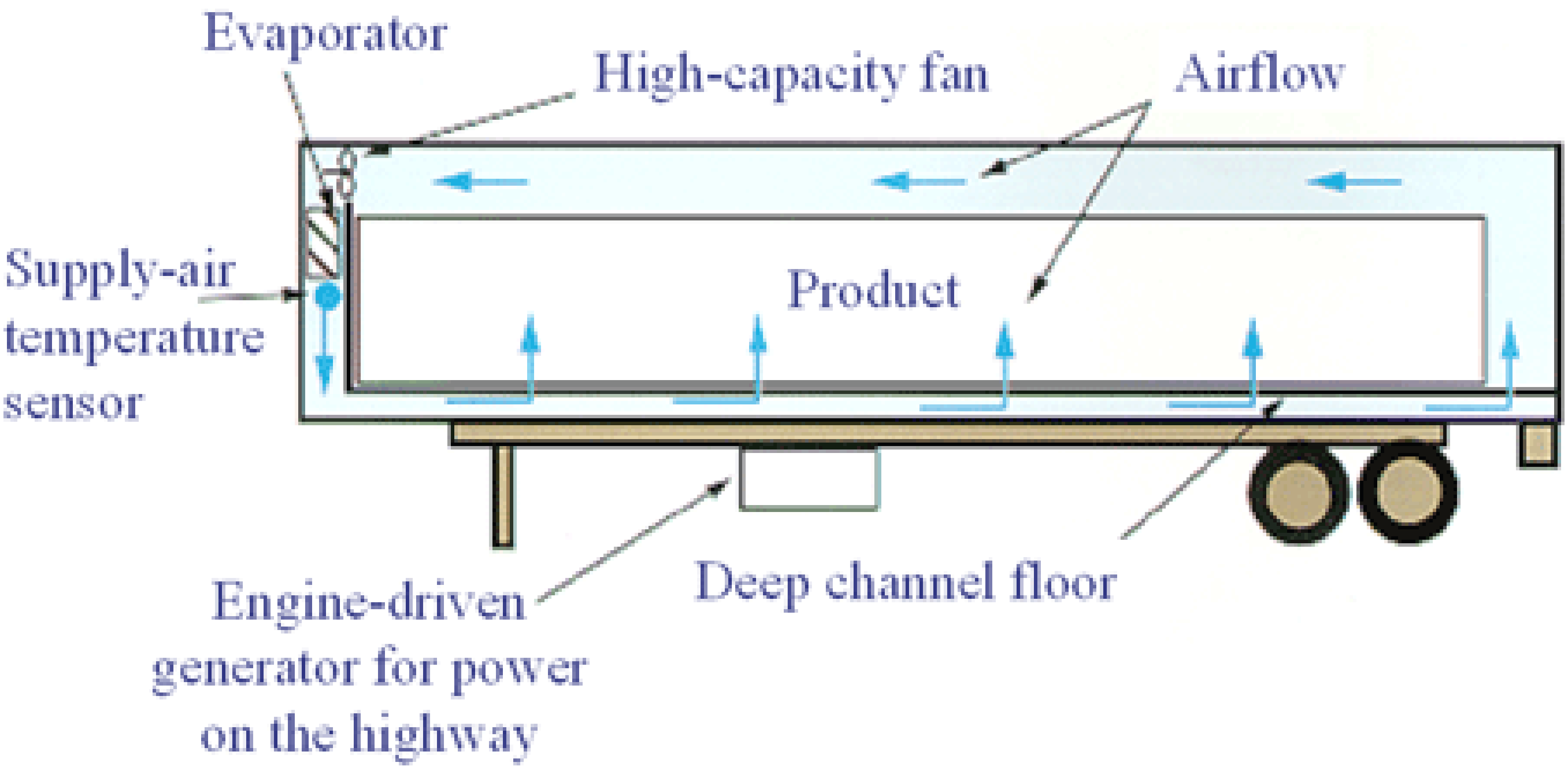
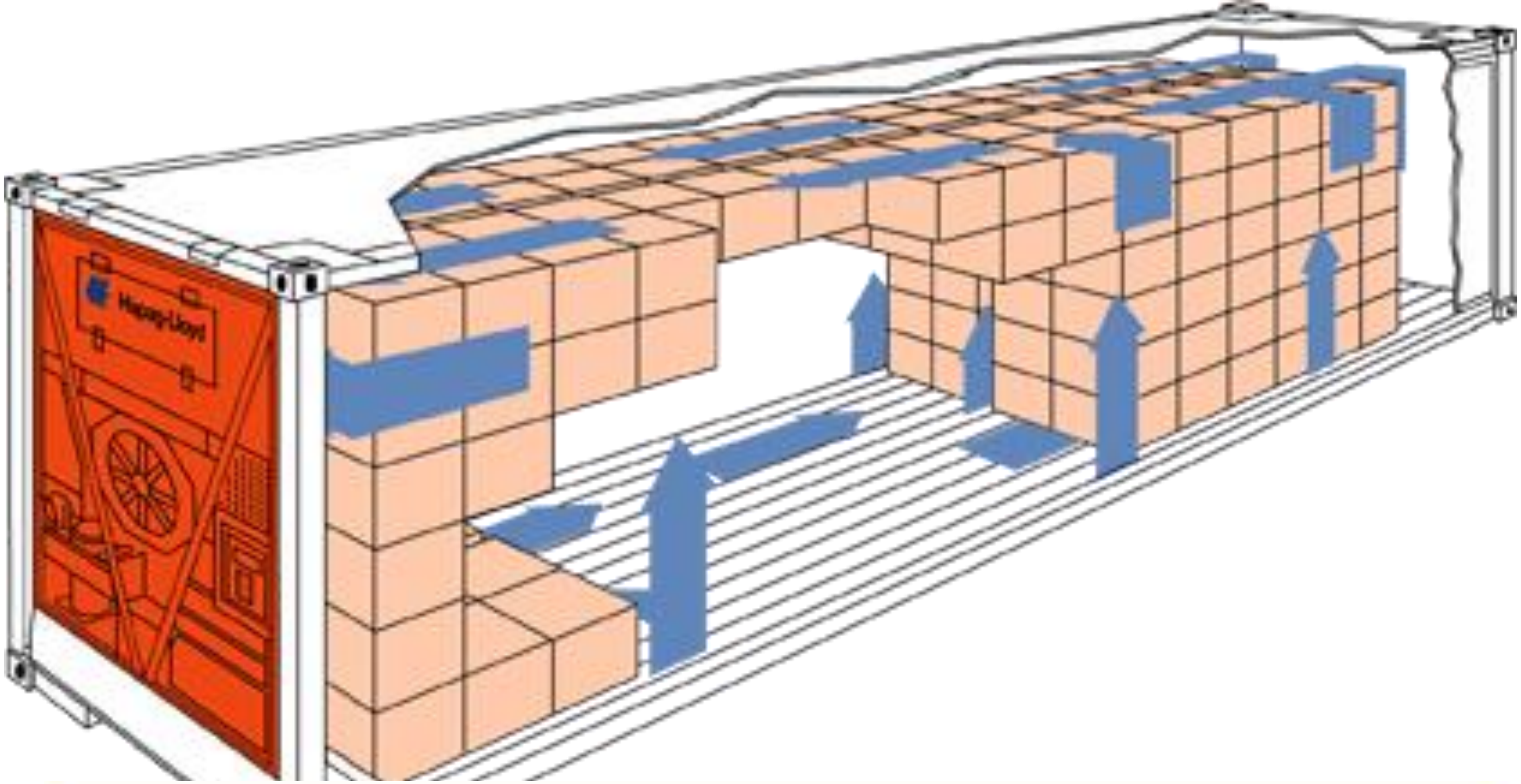
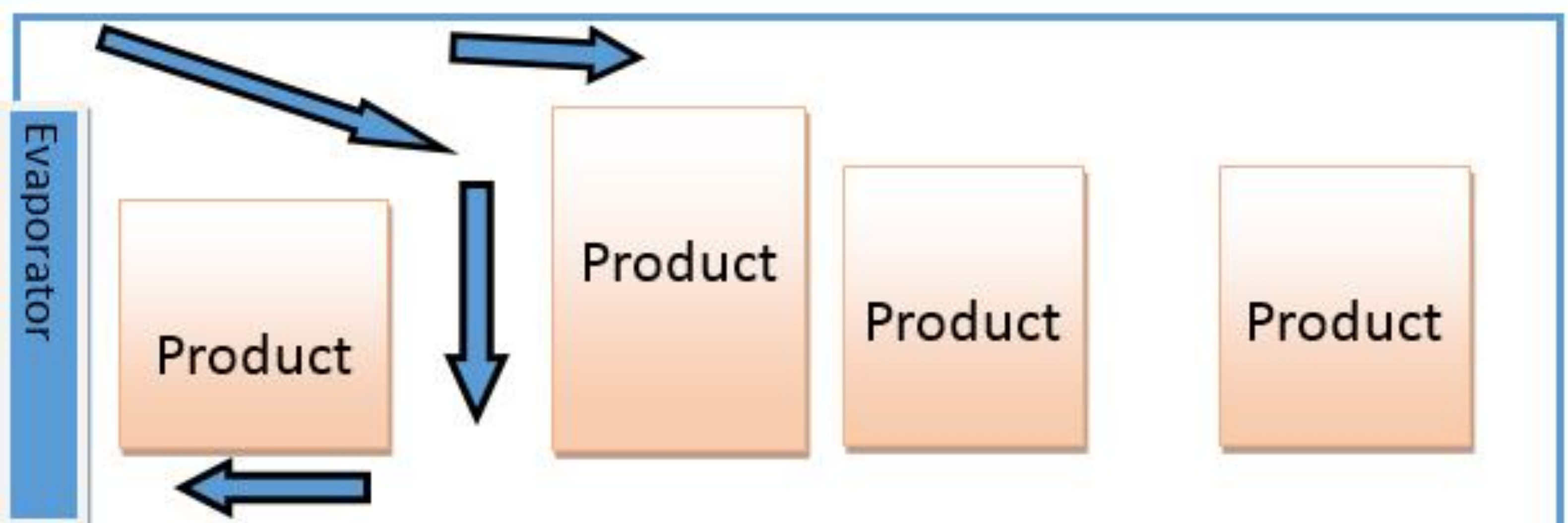

Evaporator
High-capacity fan
Airflow
Supply-air temperature sensor
Product
Engine-driven generator for power on the highway
Deep channel floor

ZCSU 587587 5
45R1
ZIM
ZCSU 580486 6
Carrier
THINLINE
R-134a
MICRO-LINK 3




Evaporator
Product
Product
Product
Product


Carmel
TUG
Carmel
הטעם המושלם שכבש את העולם

# Forced air (fast) – 95% faster than a cooling room, very uniform, cartons or well ventilated containers

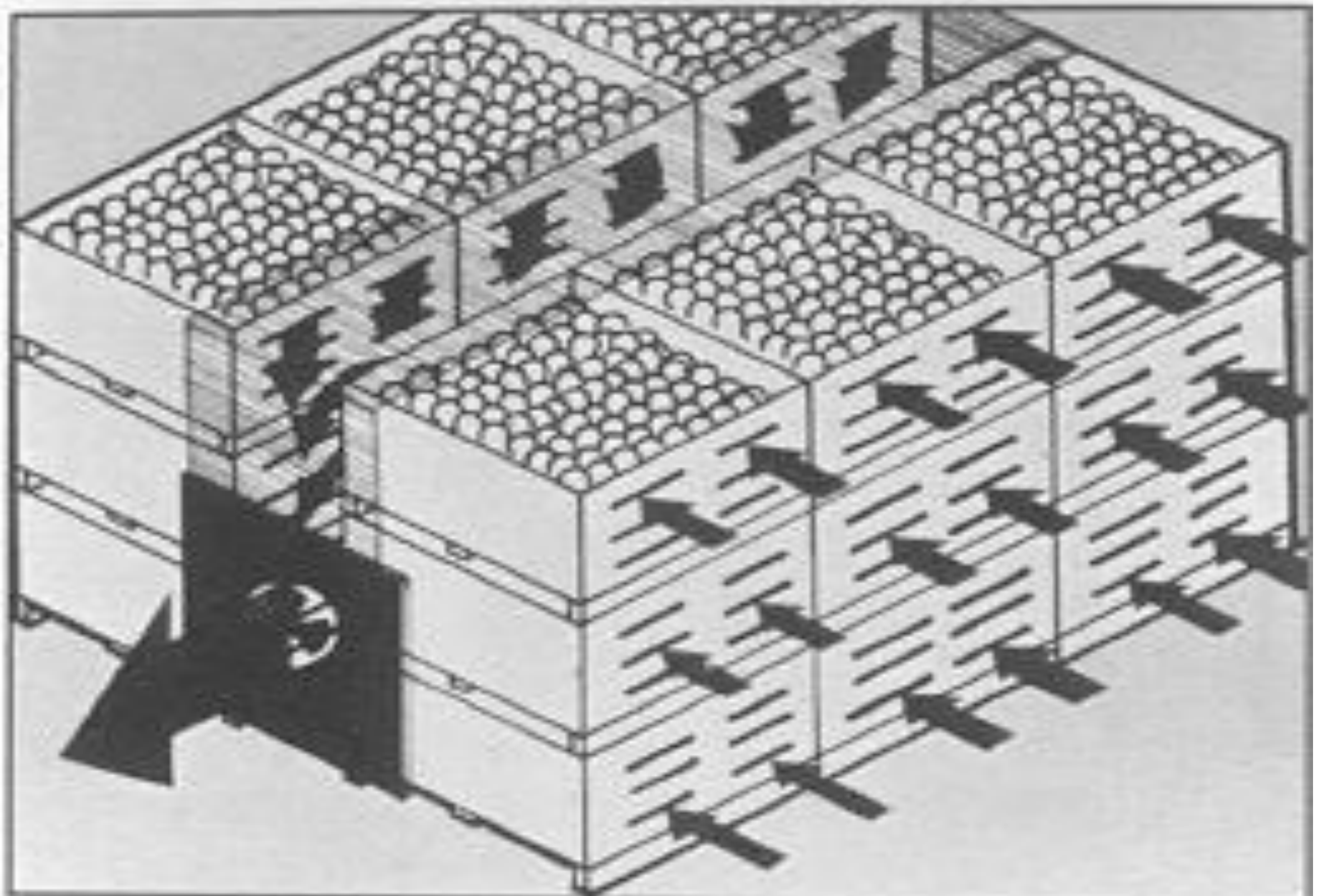
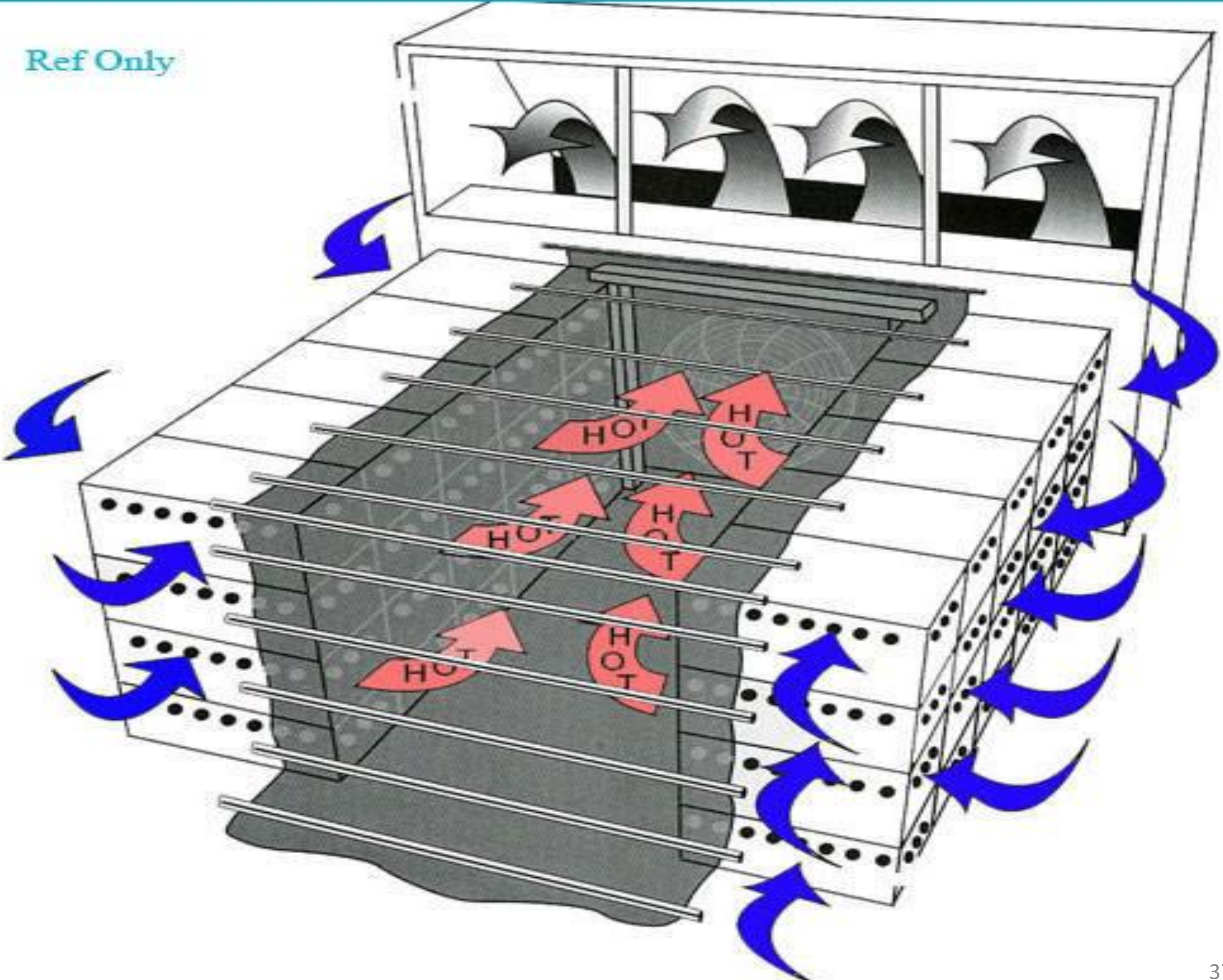


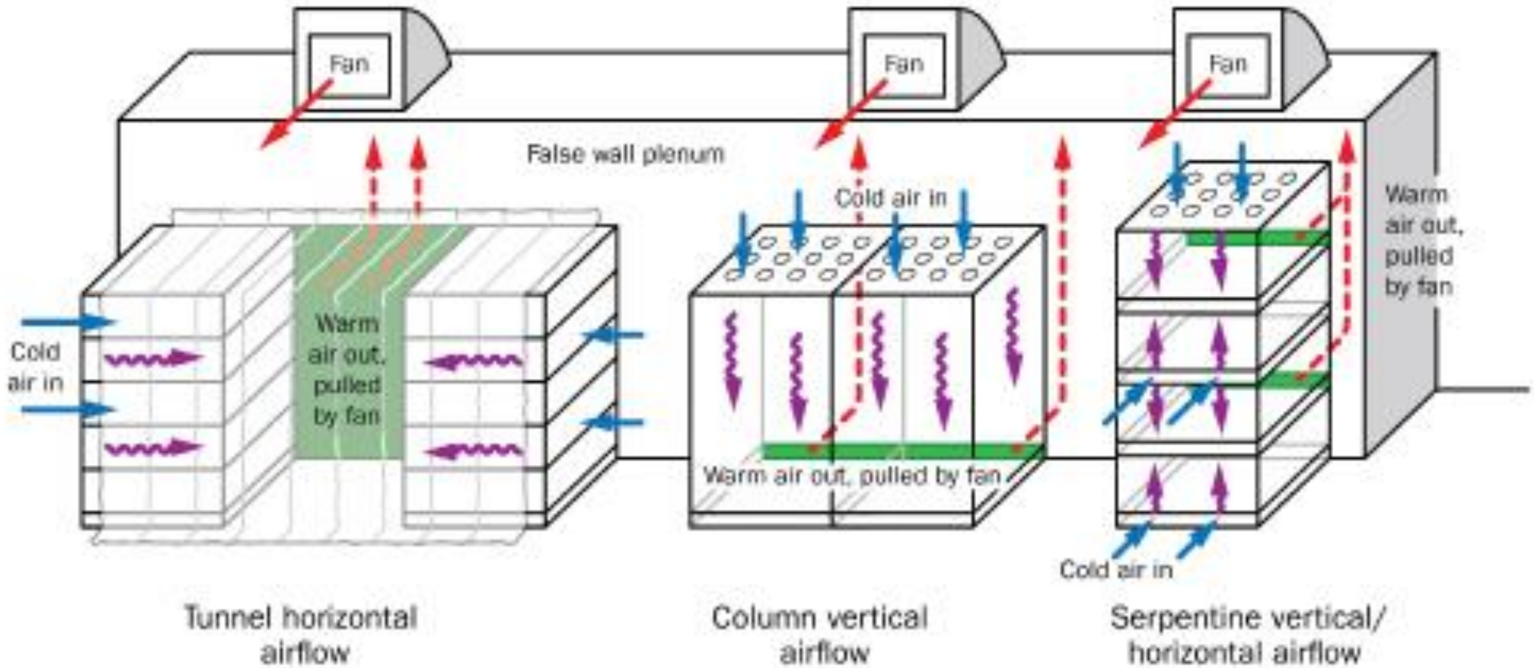
Fig. 8.2. Diagrammatic view of a forced-air cooling tunnel. Either bins or palletized containers can be placed to form a tunnel from which air is exhausted. The negative pressure then causes cold air from the room to pass through ventilation slots to directly contact the warm product.

**Forced-air cooling**

Ref Only



## Ontario, Canada




Cold, refrigerated air (blue arrows) is pushed through containers by high-capacity fans in a false wall plenum within a cold storage. These fans create a partial vaccuum and pull air through strategically located openings (green shading) in the plenum. Produce cools primarily by the convective action of high-speed cold air, when it picks up field heat from warm produce (purple arrows) as it passes around the produce. The warmed air (red arrows) is then blown back into the cold storage to the evaporator coils of the refrigeration system to be re-cooled.

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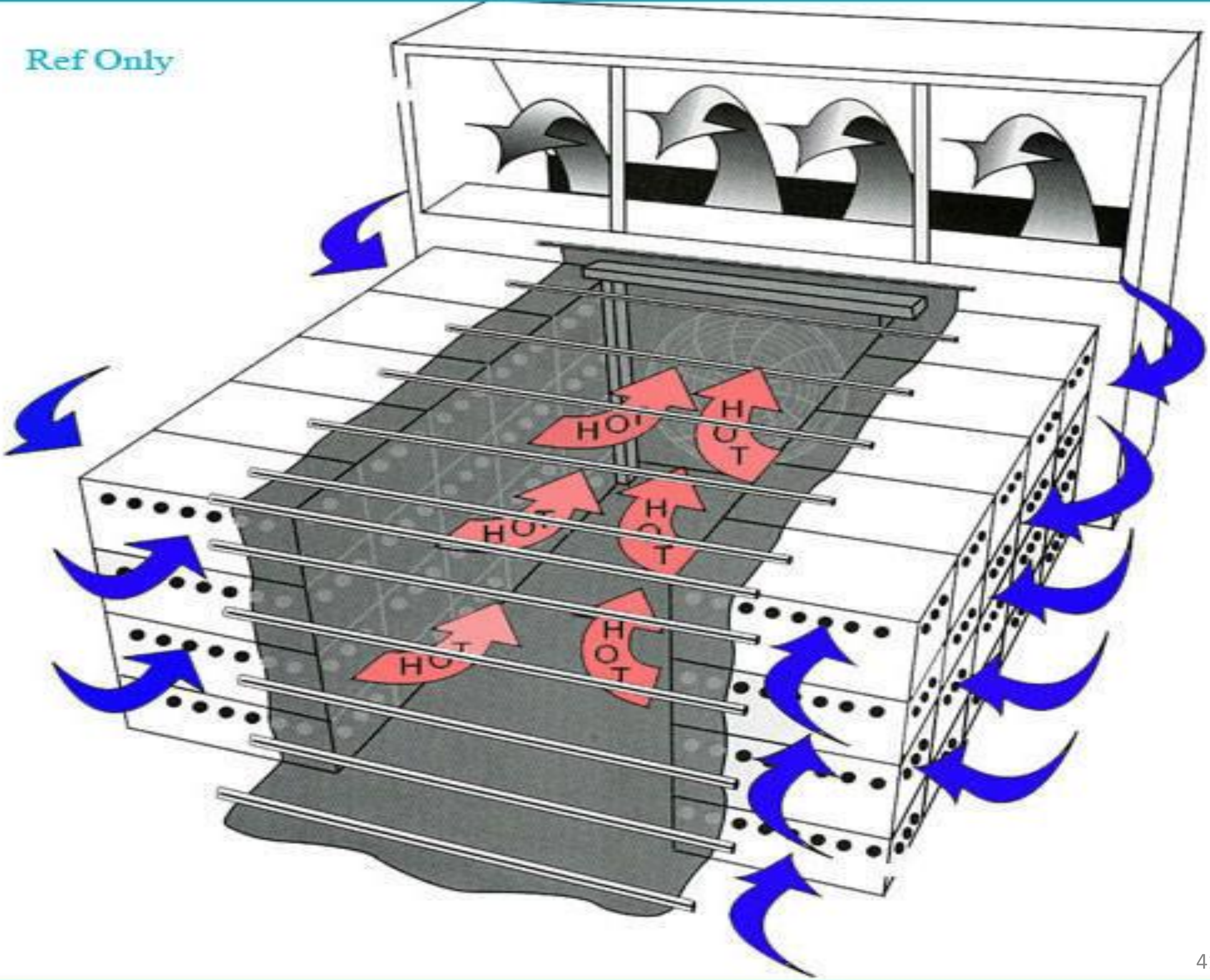
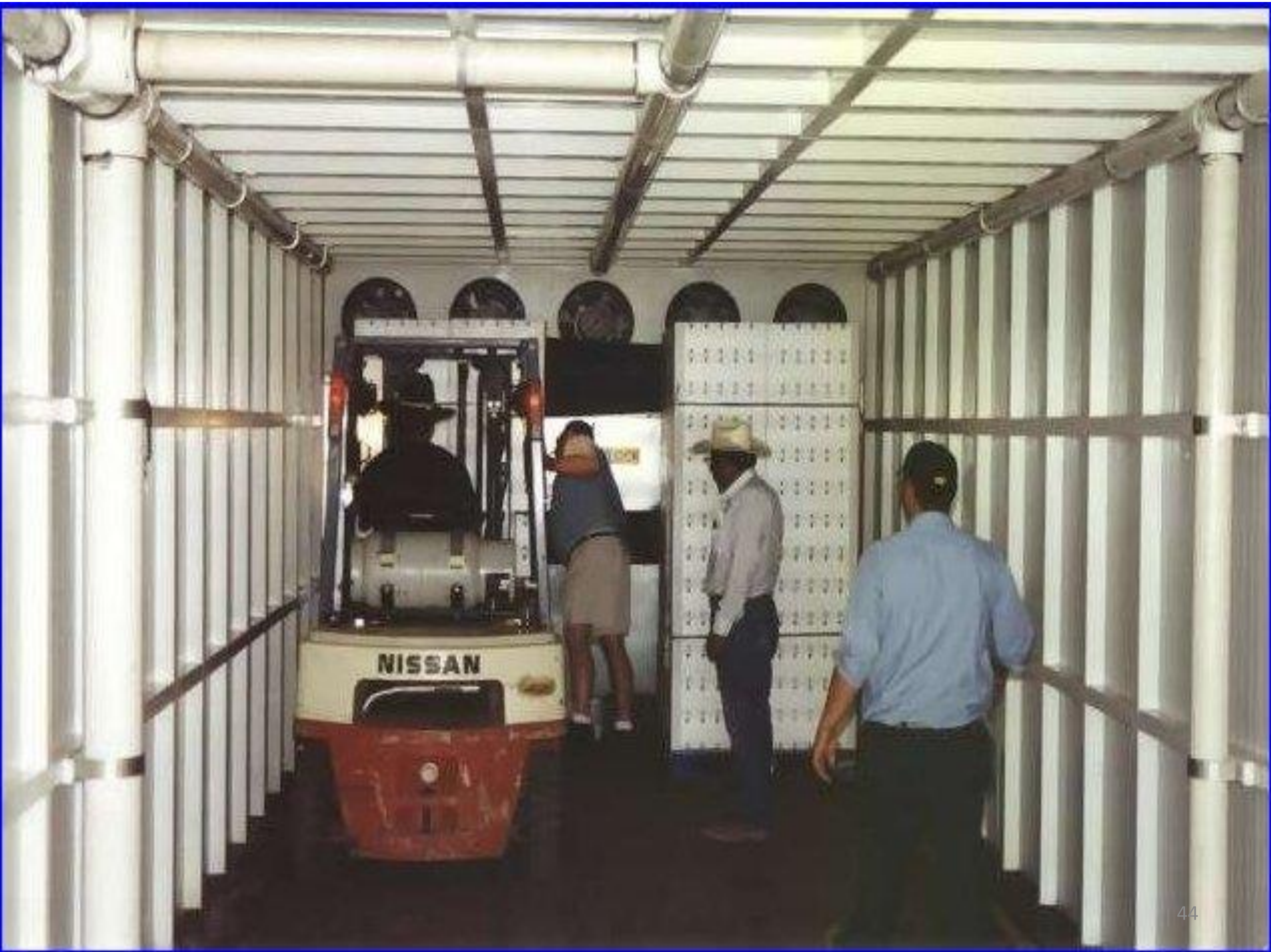
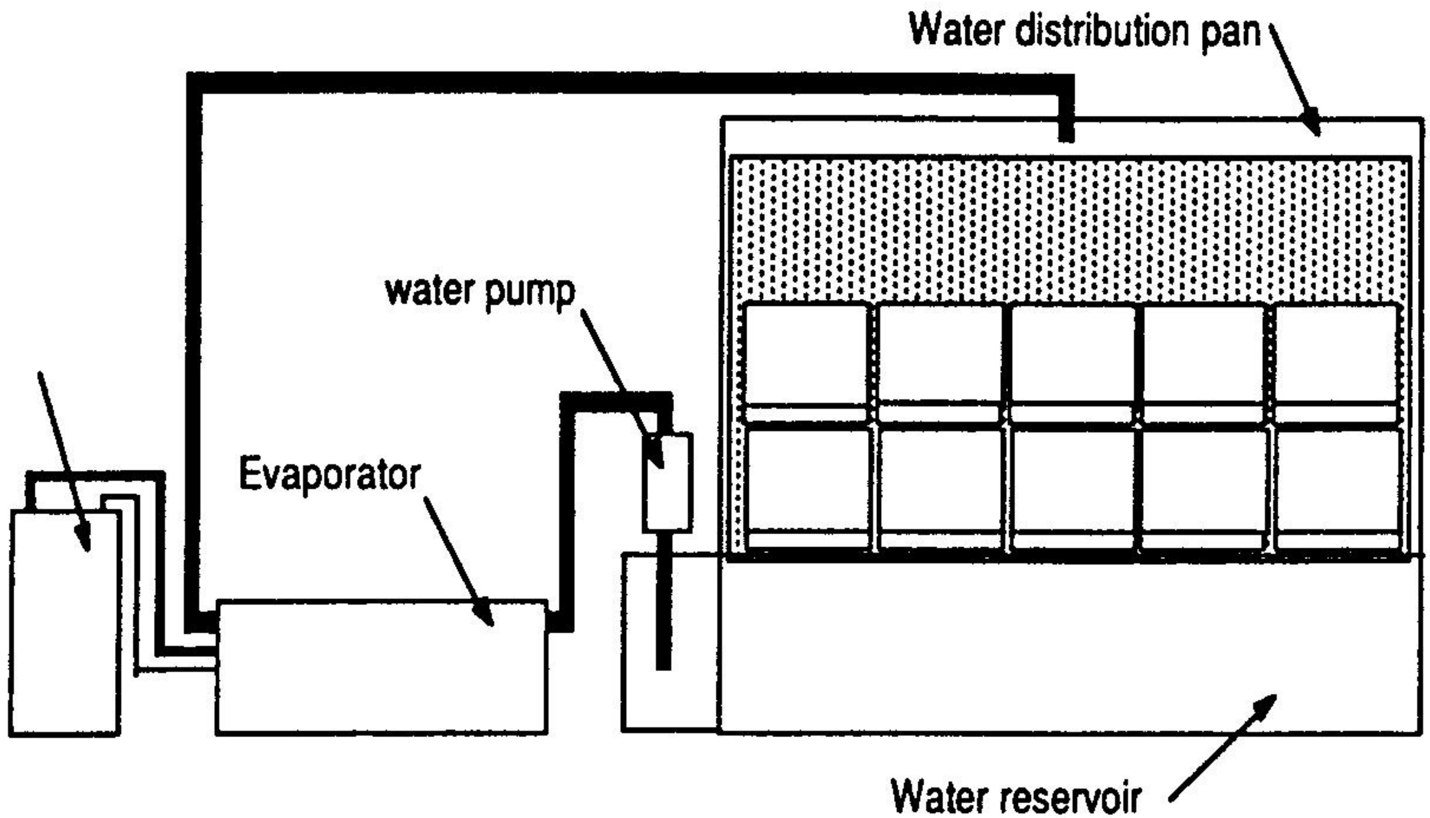


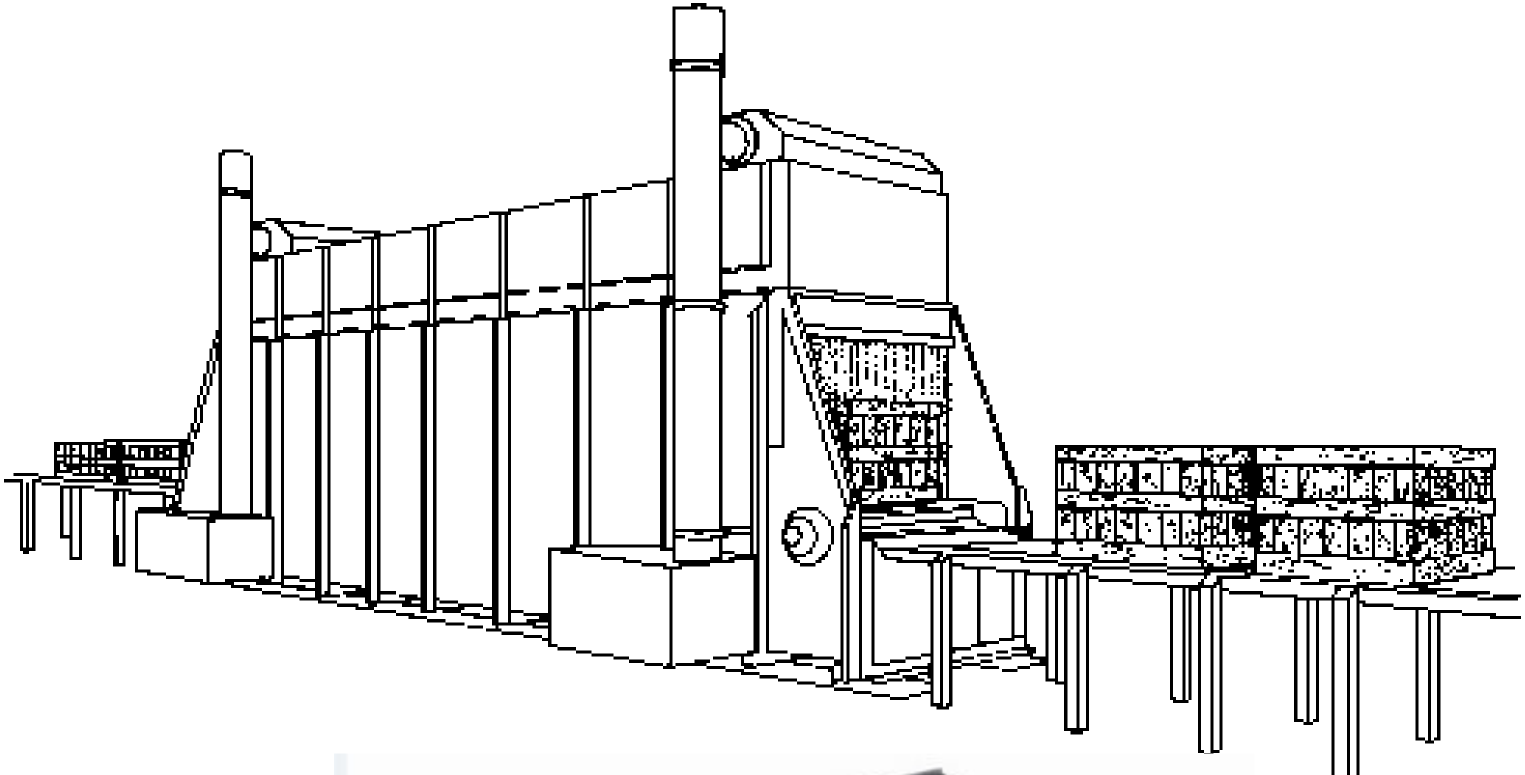

THE COOL FORCE
MOBILE FORCED AIR COOLING SERVICES
MOBILE PRESSURE COOLING
HYDRO COOLING SYSTEM


NISSAN

# "Cold shower" for products that are insensitive to moisture, very uniform and fast cooling. The water is recycled, so it must be chlorinated




**Hydro cooling**



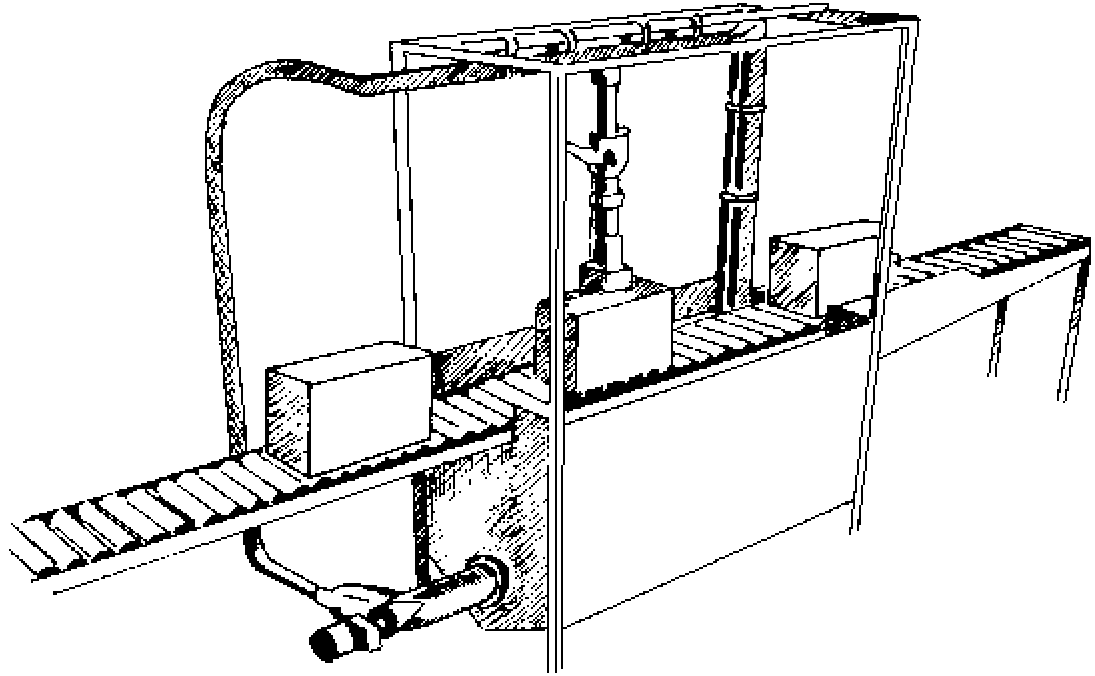

Ref Only

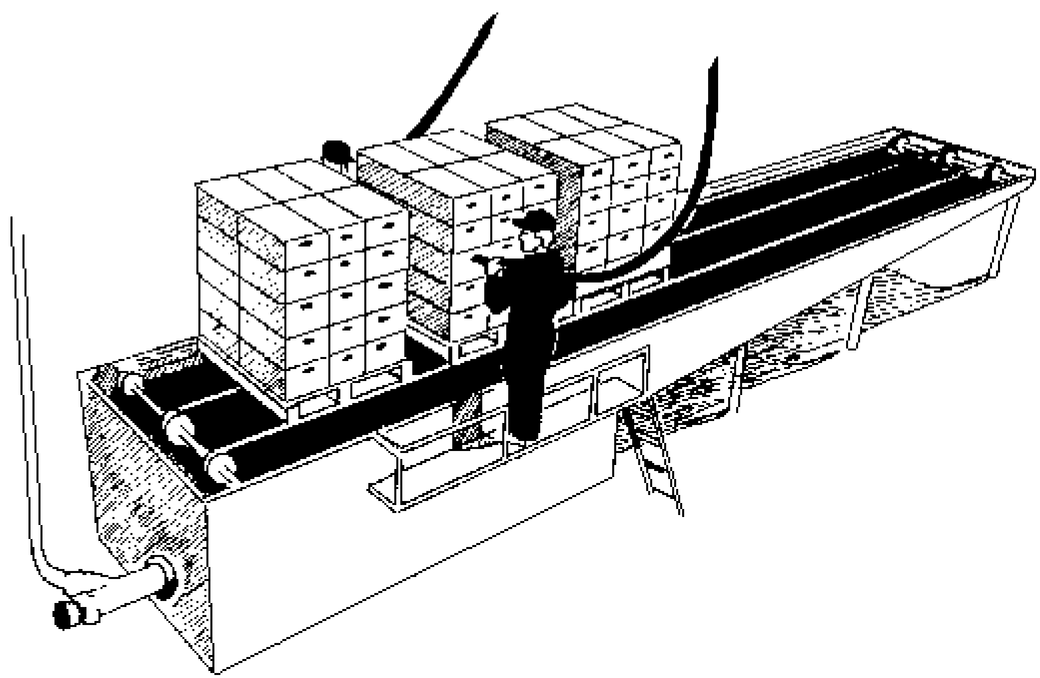

Corn
6425

**Solid ice – efficient in cooling "dense" products (green onion, broccoli, radishes), resistant to low temperatures, very cheap, very slow, uneven**

# Iced-top cooling

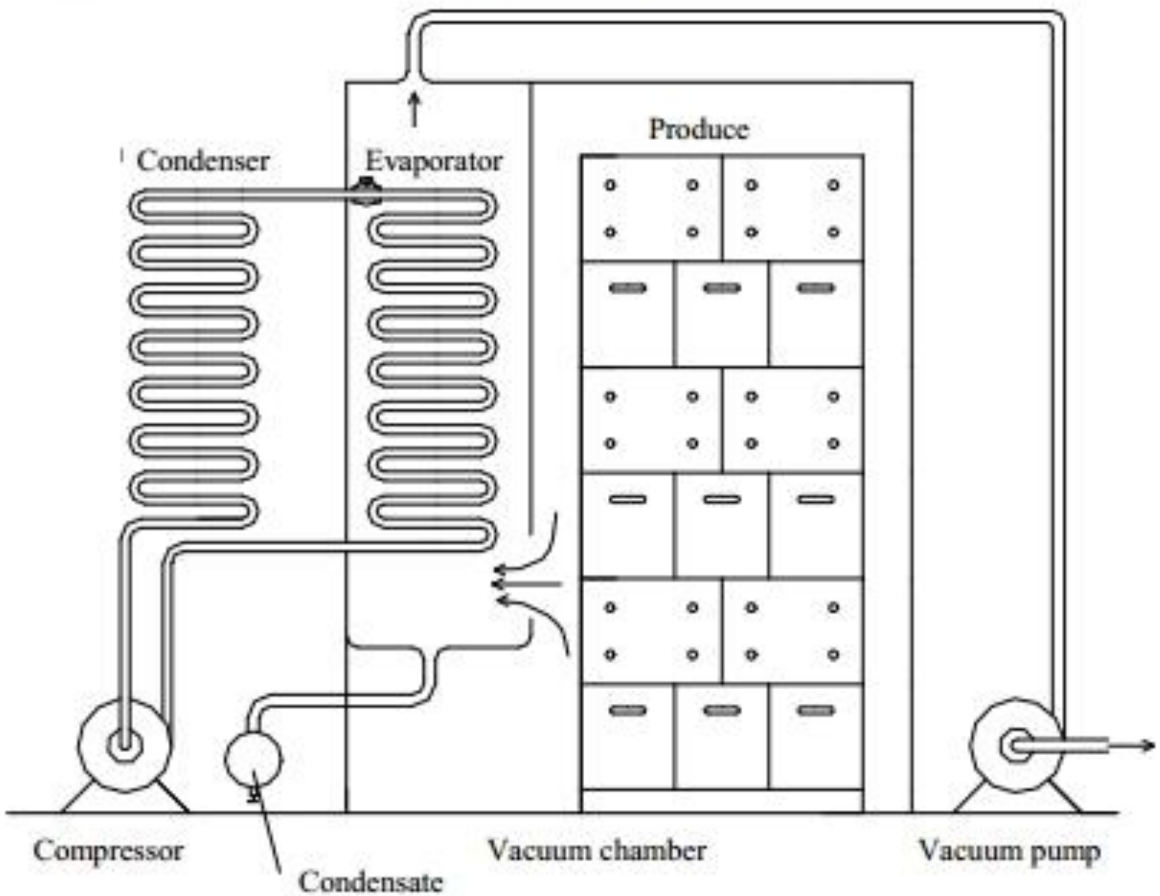

FOXY





# Vacuum cooling – Air pressure is lowered to 4.6 mmHg. Makes the produce dry (1% weight loss per 5° cooling), very efficient, very expensive, "dense" products (celery, Chinese cabbage, cabbage, lettuce)

**Figure 1. Schematic of a typical vacuum cooler.**




## Vacuum cooling


87-755-30

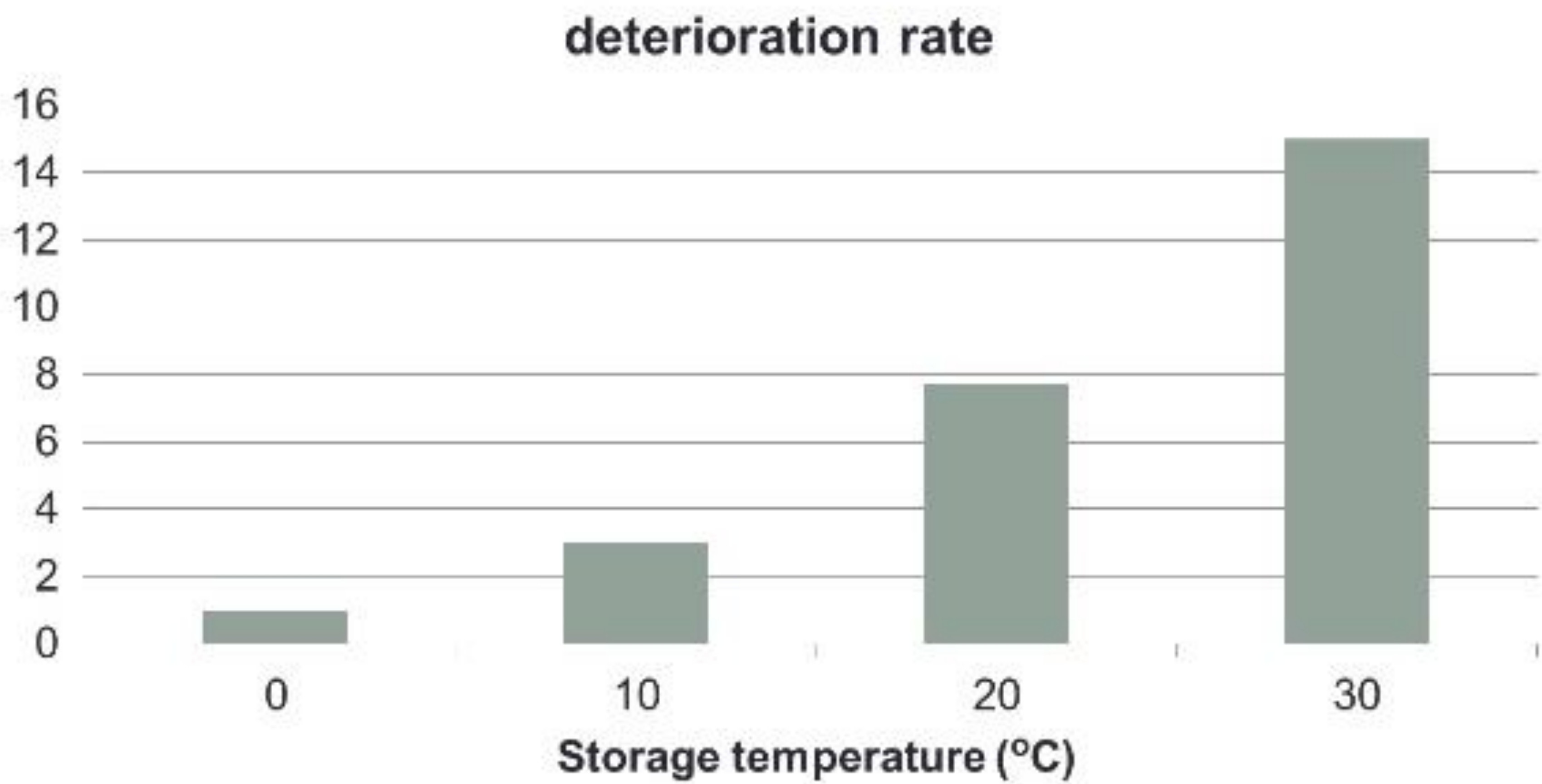

FCC12
$25
HIRE

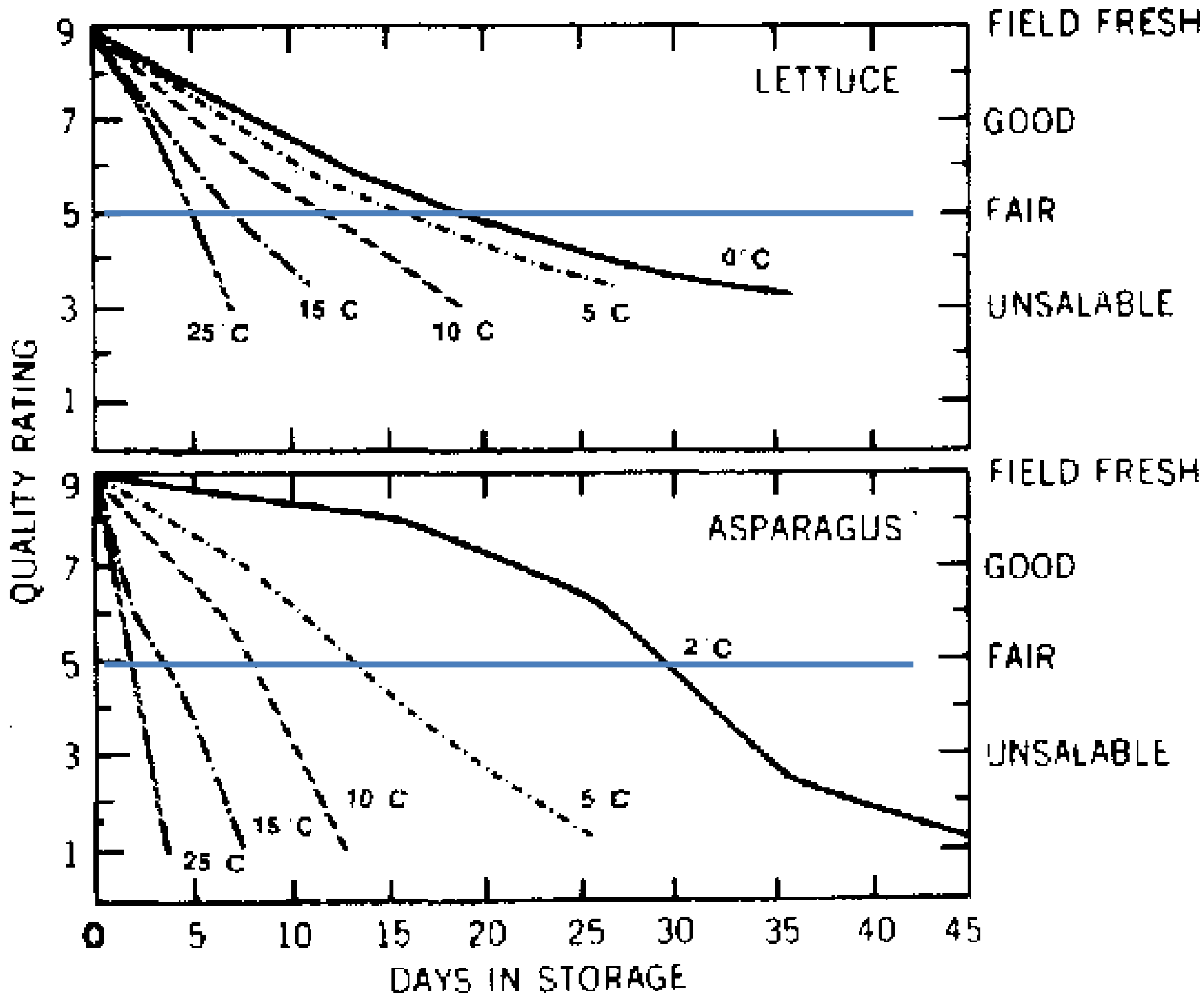
**Mobile vacuum cooling unit (4 bins)**

# Relation of storage temperature and quality

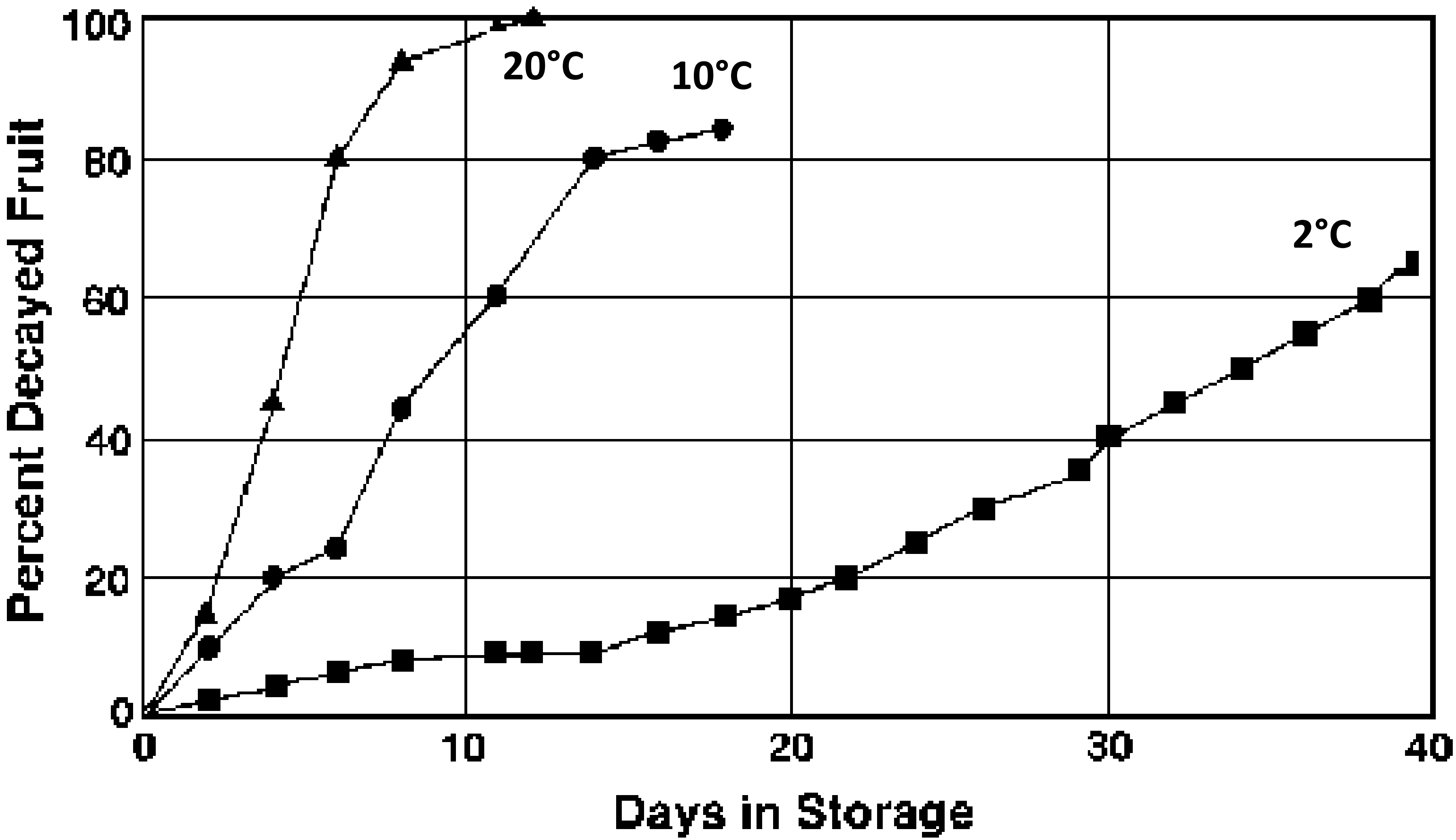
# Effect of temperature on the physiological and pathological rate of fresh produce

**Physiological and pathological**

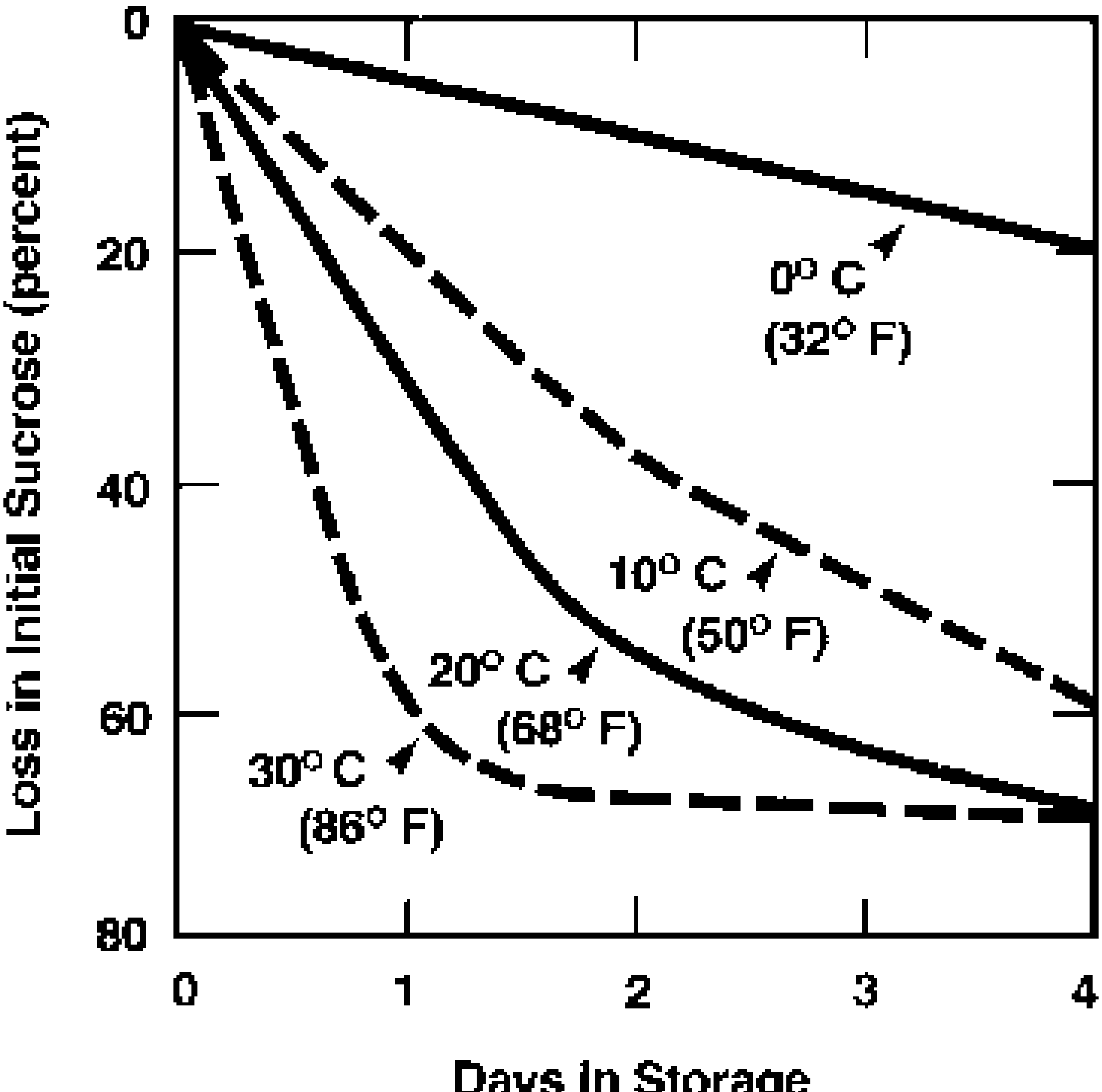





**Impact of storage temperature on storage capacity depending on <u>vegetable quality</u>**

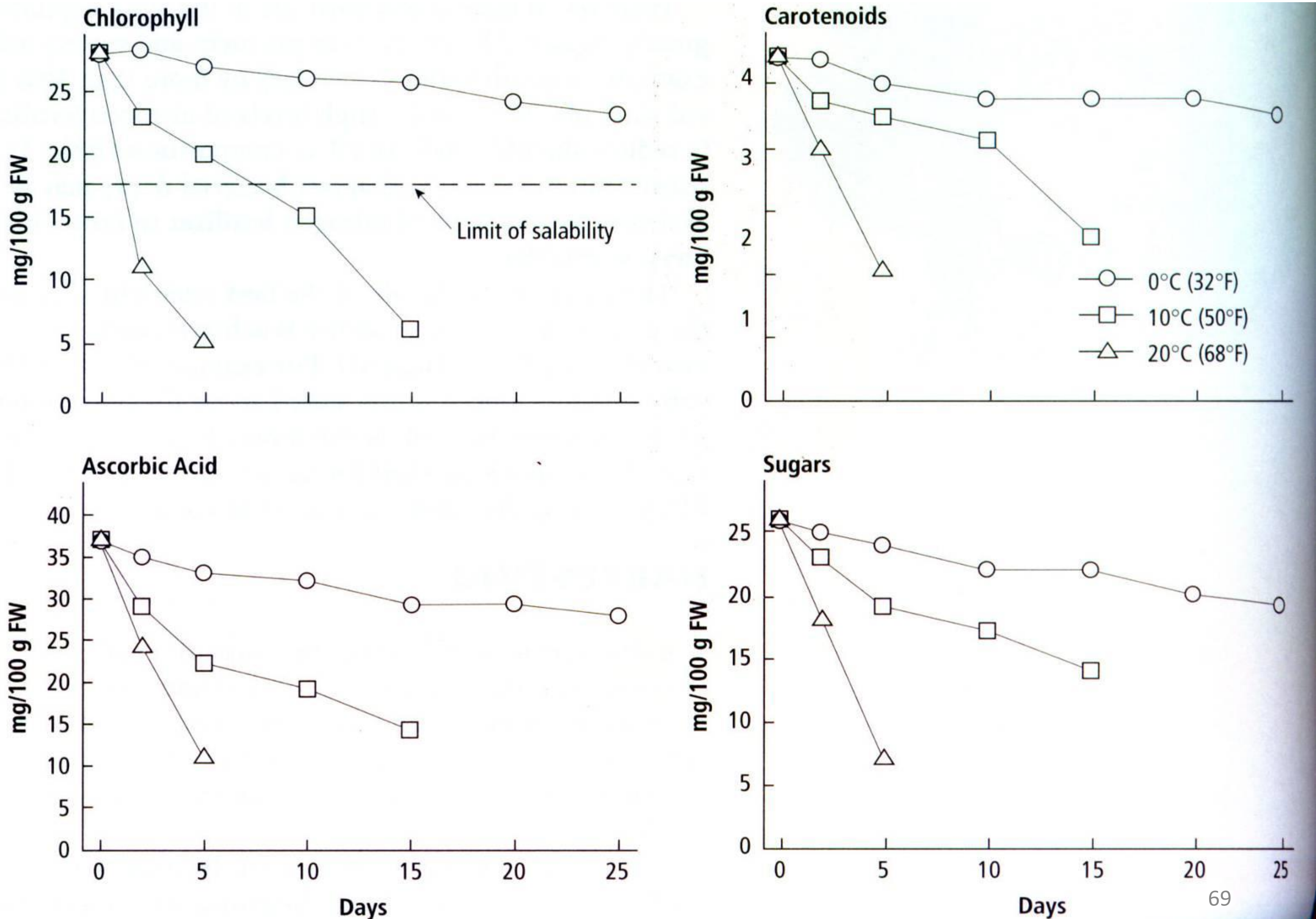



**Effect of storage temperature on the development of decay on untreated apples**

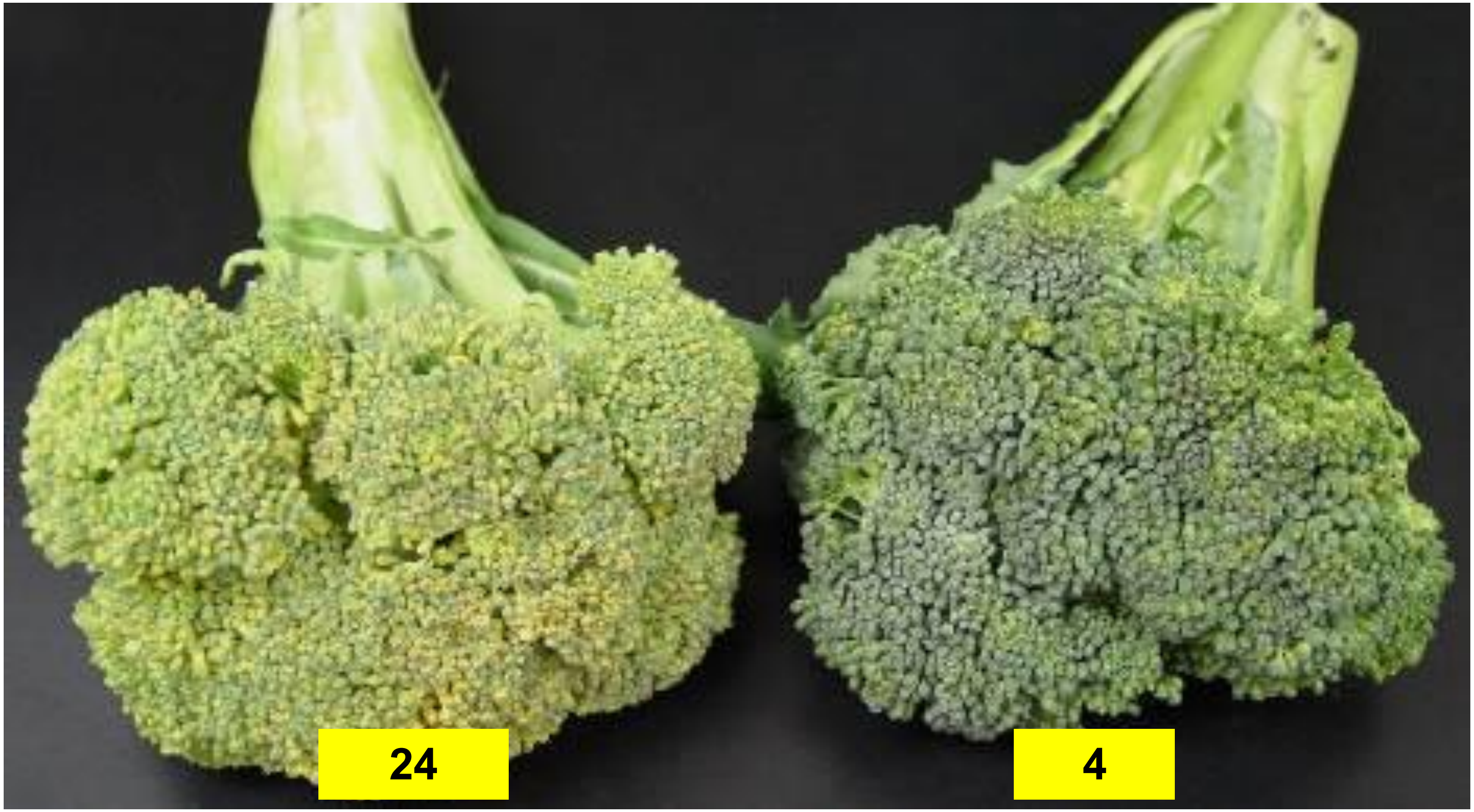



Effect of storage temperature on loss of sugar content in corn

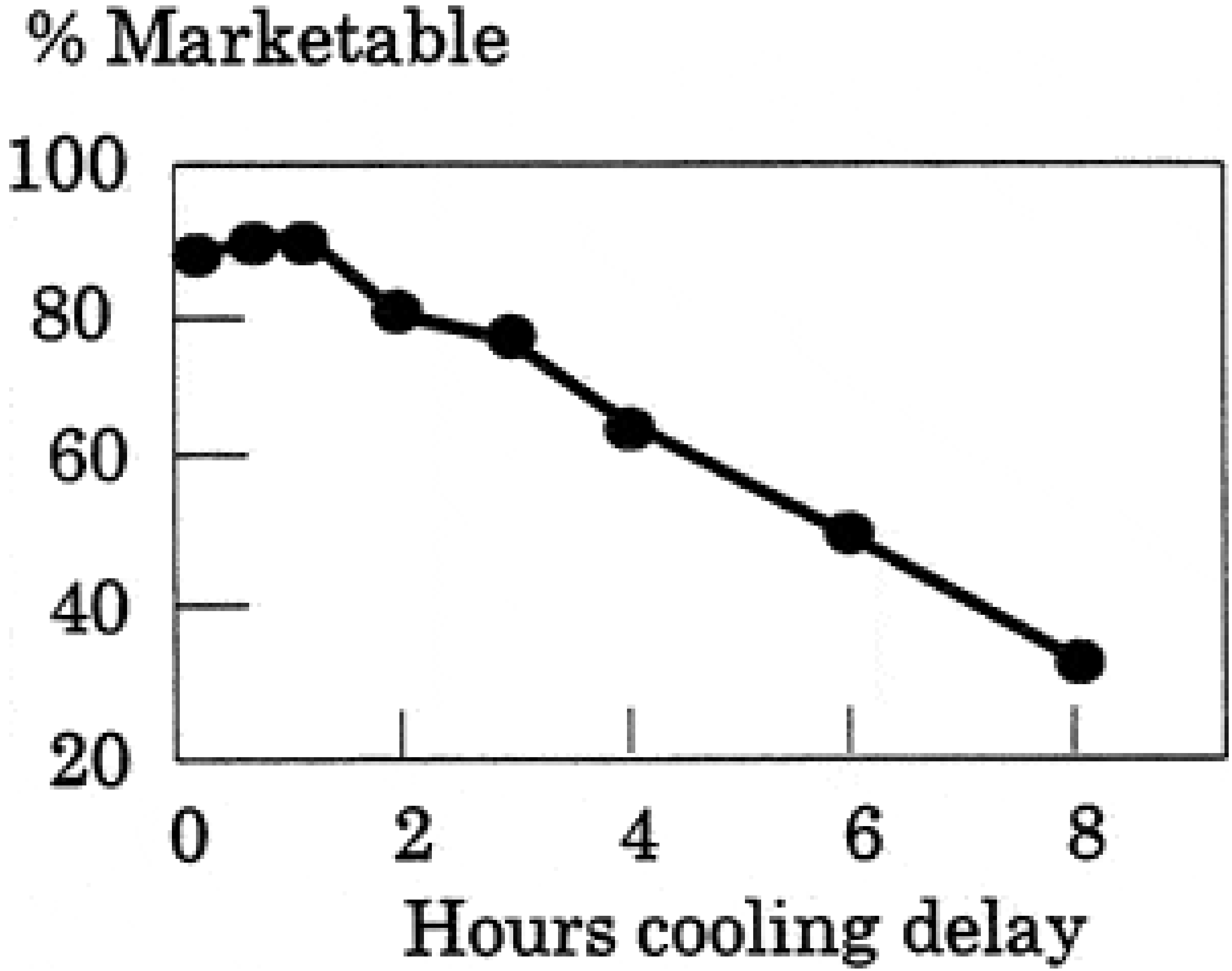
## Color ingredients and nutritional ingredients in broccoli relative to storage temperatures



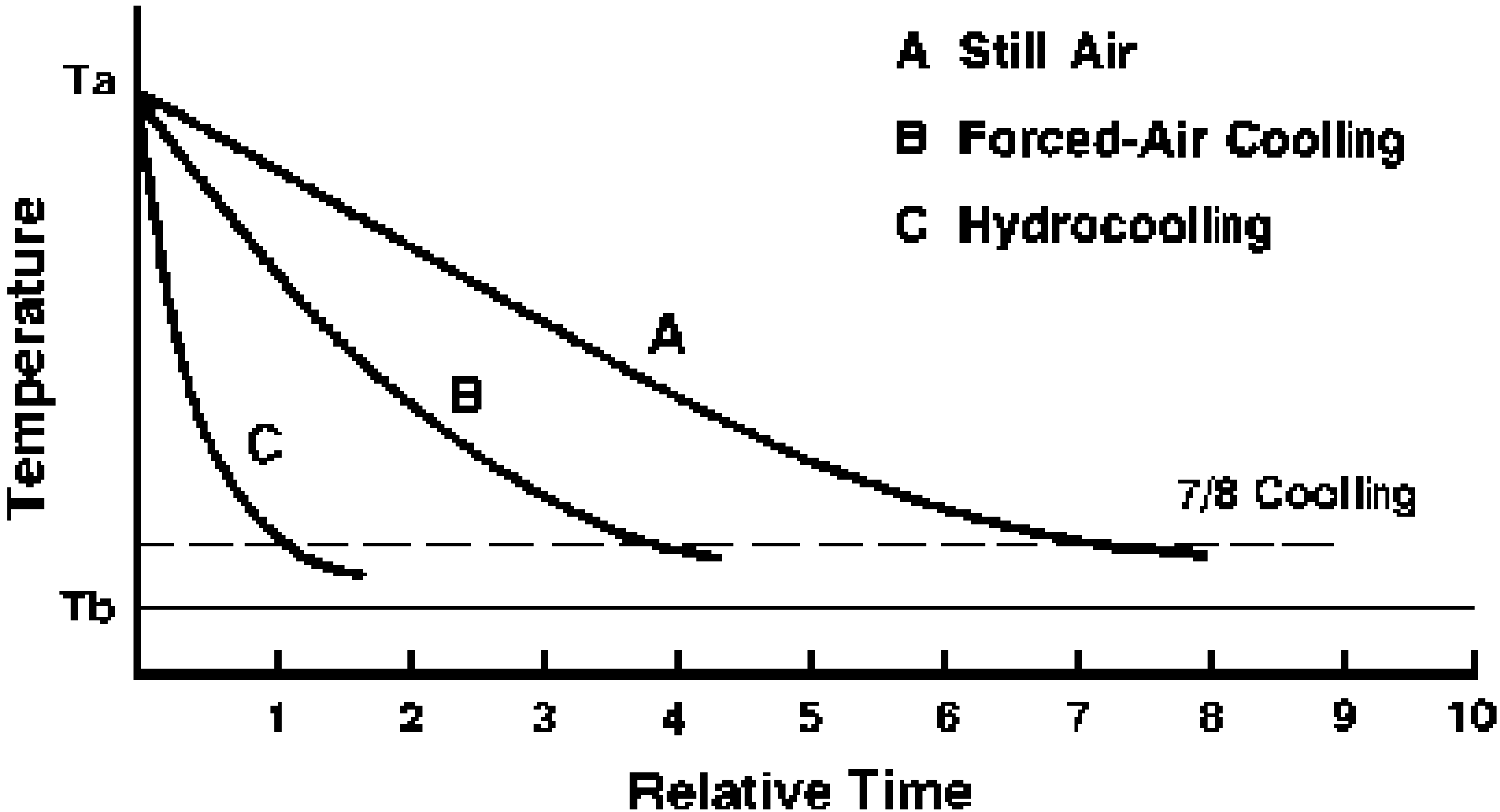
**Effect of storage temperature on the appearance of broccoli after 48 hours**



# The importance of cooling delay in the percent of marketable produce



# The effect of different cooling methods on time of cooling



# Summary

**1. Keeping the cool change and its importance**

- Special conditions during harvesting
- Rapid transfer from the green house to the packing house
- Storage until  transportation to the terminal
- Cooling at the Terminal (maritime or air freight)
- Cooling during the transportation to the markets
- Cooling during the transportation to the local markets
- Rapid cooling when transferred to the final consumer

**2. Cooling methods to preserve low respiration and store at low temperatures**

- Standard cooling
- Fast (forced) cooling
- Water cooling
- Ice cooling
- Vacuum cooling

# COOLING ALTERNATIVES