Department of Horticulture
Faculty of Agriculture at Kamphaeng Saen
Kasetsart University, Kamphaeng Saen campus
Hort.ku.ac.th

Cooling

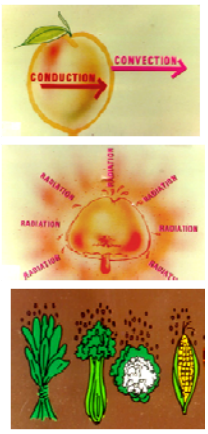
Kietsuda Luengwilai
agrkdl@ku.ac.th or kietsuda@hotmail.com

Topics of Cooling

- Cooling methods
- Factors affecting cooling efficiency

Heat sources

- Filed heat
- Vital heat (respiration)
- Others; container, operation, facility (bulb, storage wall etc.)



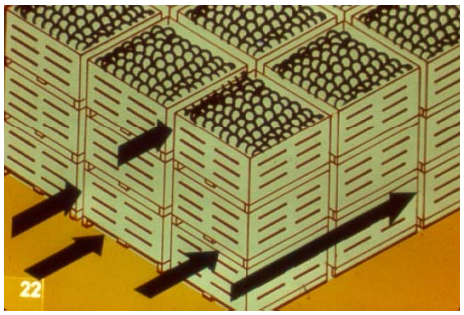
Heat transfer

- Conduction
- Convection
- Radiation
- Evaporation

Commercial cooling methods

1. Room cooling
2. Forced air cooling
3. Hydro cooling
4. Package-icing
5. Vacuum cooling
6. Transit cooling

1. Room cooling



Advantages

- Very fluid
- Reasonably clean and sterile
- Free i.e. can be cooled and stored in the same room

Disadvantages

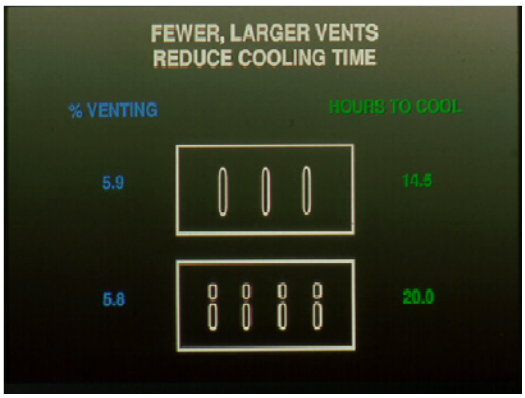
- Using cold air as a cooling medium
  - Low thermal capacity and conductivity

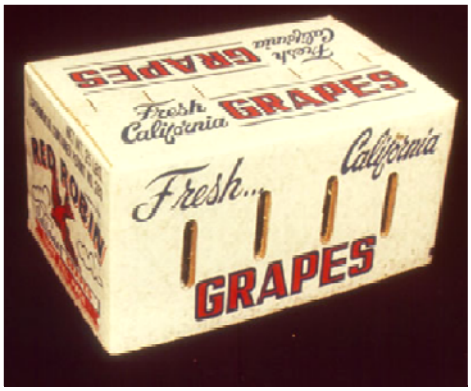
Most common used for

- produces with a **relatively long storage life** which stored in the same room e.g. **cut flower** before packing, **potatoes, citrus, apples, pears**

Increase cooling rate

- Space stack product
- Well vented boxes or unpacked produces
- Lowest possible air temperature





4 -6” between lanes

http://hort.ku.ac.th

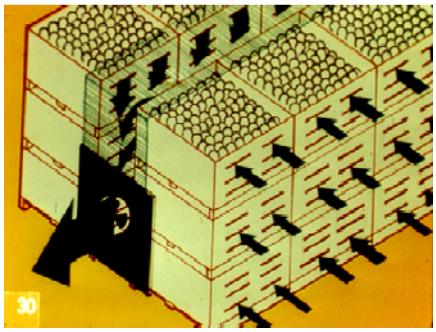
http://hort.ku.ac.th

Sloped sides

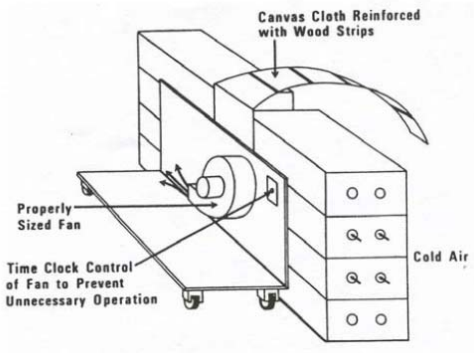
Vents

http://hort.ku.ac.th

2. Forced air cooling



http://hort.ku.ac.th



http://hort.ku.ac.th

Tunnel-type forced-air cooling

http://hort.ku.ac.th

http://pre-coolers.net/tarp.html

Portable tunnel-type forced-air cooling

Advantages

- Very efficient (2-5 times faster than room cooling)
- Reasonably clean and sterile

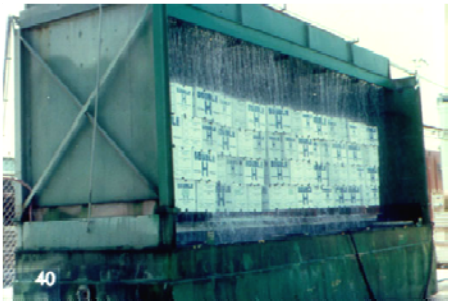
Disadvantages

- Moisture loss
- Forced air cooler is a separate room from cold storage room

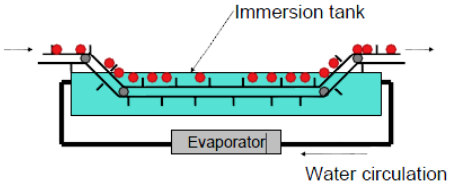
Most common used for

stone fruit, pome fruit, subtropical fruit, berries, kiwifruit, grape, cabbage, cauliflower, kale, collards, leaf vegetable, mushroom, melon, okra, cut flowers

3. Hydro cooling



Immersion Hydrocooler



http://hort.ku.ac.th

Advantages

- Very fluid
- Most effective method to cool produce
- Avoid water loss

http://hort.ku.ac.th

Disadvantages

- Container must be water tolerant
- May require drying process after cooling

http://hort.ku.ac.th

Increase cooling rate

- Reduce water temperature
- Increase water circulation (13.6-17 L $sect^{-1}$ m^{-2}) of surface area
- Increase product exposure

http://hort.ku.ac.th

Considerations

- Moisture loss: gian 0.5 % to lose 0.05%
- Water Beating Damage
- Control pH and chlorine levels
- Cooling time depends on size of produces

http://hort.ku.ac.th

http://hort.ku.ac.th

http://hort.ku.ac.th

Most common used for

stone fruit, pome fruit, subtropical fruit, carrot, potatoes, asparagus,

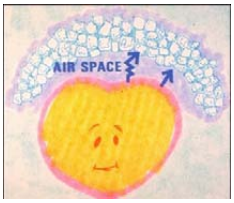
4. Package-icing

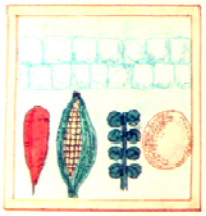
http://hort.ku.ac.th

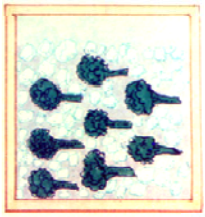
http://hort.ku.ac.th

Considerations

Ice solidifies & melts away from product




PACKAGE-ICING


LIQUID ICING

http://hort.ku.ac.th

Disadvantages

- Container must be water tolerant
- Weight or ice is an issue
- Need vehicle insulation
- problem with mixed load with other water intolerant box/produce

http://hort.ku.ac.th

Most common used for

carrot, artichokes, green onions,
leeks, peas, sweet corn, broccoli

Factors affecting cooling efficiency

- Packaging
- Product size
- Product density




http://hort.ku.ac.th

Selecting a Cooling System

- Products to be cooled
- Compatibility with present facilities
- Initial capital investment
- Operation costs
- Labor costs
- Maintenance costs

http://hort.ku.ac.th

You can help!!

- Harvest in coolest part of day
- Keep delays short
- Park in shade to prevent heat accumulation and water loss

http://hort.ku.ac.th




http://hort.ku.ac.th

Durian

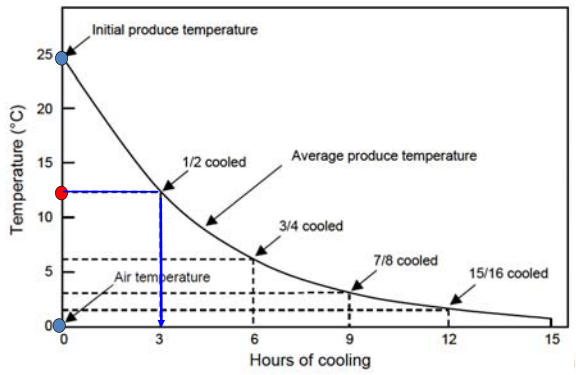








Half cooling time



Department of Horticulture
Faculty of Agriculture at Kamphaeng Saen
Kasetsart University, Kamphaeng Saen campus
Hort.ku.ac.th

Storage

Kietsuda Luengwilai
agrkdl@ku.ac.th or kietsuda@hotmail.com

Considerations

- Preharvest factor
- Maturity and developmental stage
- Quality of produce before storage
- Pre-cooling

- Temperature
- Humidity
- Atmosphere

Storage methods

I. Refrigerated Storage

II. Modified or Controlled-Atmosphere Storage (MA or CA)

I. Refrigerated Storage

- Maintaining optimum temperature (variation < 1°C)
- Maintaining optimum humidity to reduce water loss (> 90-95%)
- Uniform of air circulation
- Minimize ethylene

Chilling Injury

Maintaining Temperature

- Refrigeration capacity
- Evaporator coils
- Insulation
- Controls/thermostat
- Air mixing volume (usually above fruit)

http://hort.ku.ac.th

Maintaining High Humidity

- Large evaporator surface
- High evaporator temperature
- Reduce refrigeration load
- Humidifier

http://hort.ku.ac.th

Minimize paper & wood packaging

A 2lb fiberboard box can absorb water equal to 1% of fruit weight

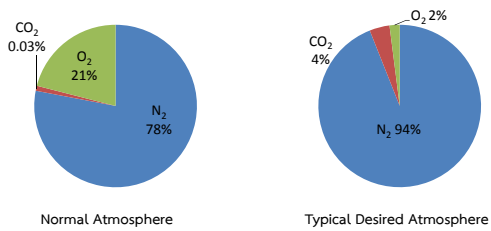
http://hort.ku.ac.th

Minimize ethylene

- Ventilation
- Activated charcoal
- Bromine
- Ozone
- $KMnO_4$

http://hort.ku.ac.th

II. Modified or Controlled- Atmosphere Storage (MA or CA)



Normal Atmosphere | Typical Desired Atmosphere

http://hort.ku.ac.th

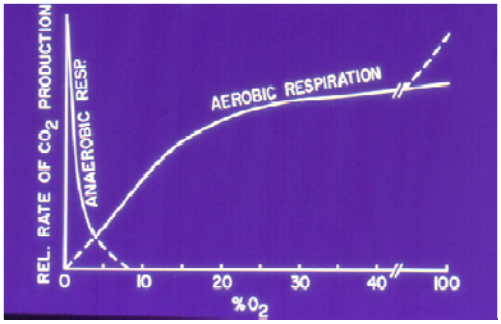
MA or CA

- Reduced oxygen
- Increased carbon dioxide
- Removing ethylene and other volatiles
  ($KMnO_4$, activated charcoal, O_3)
- Degree of precision differentiates MA and CA

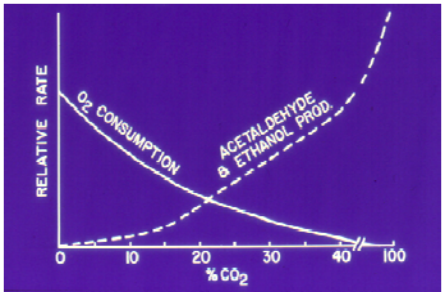
http://hort.ku.ac.th

How Does CA/MA Affect the Product?

http://hort.ku.ac.th



http://hort.ku.ac.th



http://hort.ku.ac.th

Low O_2 delays ripening of Bartlett Pears

6 Months Storage

http://hort.ku.ac.th

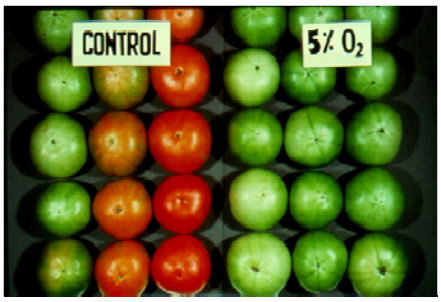
Low O_2 delays ripening of 'Santa Rosa' plums

Air $1\%O_2 + 5\% CO_2$

5 weeks at 10°C

http://hort.ku.ac.th

Low O_2 Retards Ripening of Partially Ripe Tomato Fruit



14 days at 12.5°C

http://hort.ku.ac.th

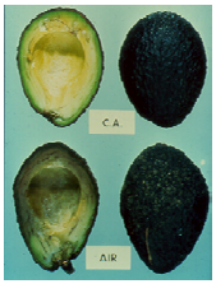
CA Reduces Chilling Injury and Resulting Decay

Air 2% O_2 + 10%CO_2

21 days at 5°C

http://hort.ku.ac.th

CA Reduces Chilling Injury and Resulting Decay



9 weeks at 5°C

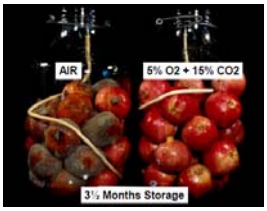
http://hort.ku.ac.th

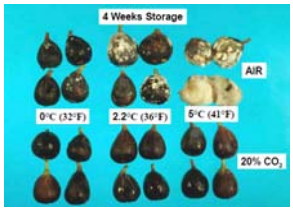
CA Reduces Browning

http://hort.ku.ac.th

CA Treatments for Decay Control

- O_2 < 1%
- CO_2>10%





http://hort.ku.ac.th

Polyethylene Liner develops MA

Delay ripening

Reduce decay and keep stems green

http://hort.ku.ac.th

Pallet Covers for Carbon Dioxide Treatment during Transport

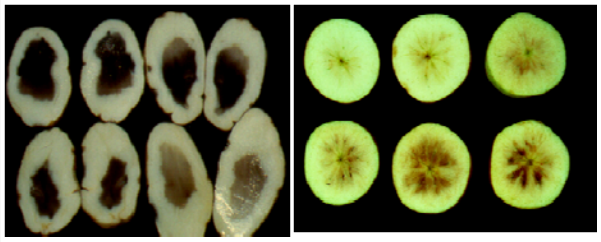
http://hort.ku.ac.th

Potential Hazards

- Causes or aggravates physiological disorders in product
- Causes irregular ripening
- Induces off-flavors/odors
- Increases decay susceptibility

http://hort.ku.ac.th

black heart in potato



http://hort.ku.ac.th

http://hort.ku.ac.th

Low O_2 Stimulates Sprouting and Increases Decay

Air 2%O_2 0.2%O_2

http://hort.ku.ac.th

2% O_2 + 5% CO_2 at 0°C for 1 week

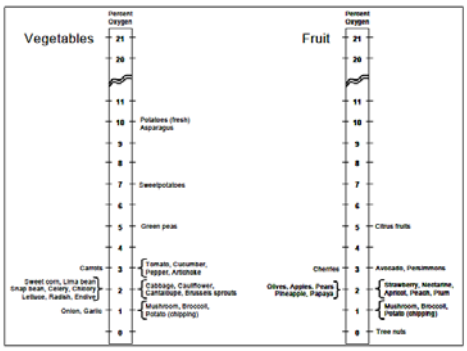
http://hort.ku.ac.th

Potential for Benefit or Hazard ?

- Commodity
- Cultivar
- Physiological age
- Atmospheric composition
- Temperature
- Duration

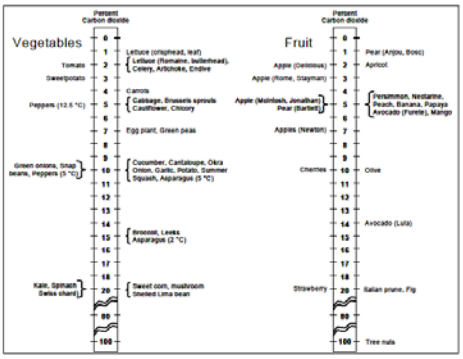
http://hort.ku.ac.th

Minimum O_2 level



Kader and Morris, 1997

Maximum CO_2 level

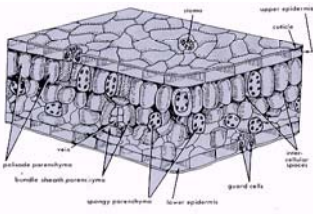


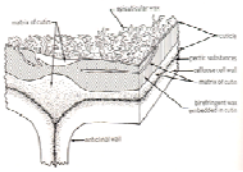
Kader and Morris, 1997

Waxing

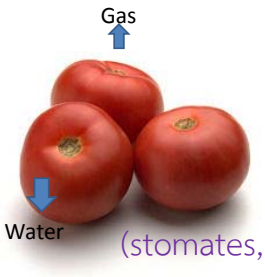
Surface structure : epidermis cutin , wax , stomates

periderm lignin , suberin , lenticel





http://hort.ku.ac.th



Gas through pores (stomates, lenticel, wound scar)

Water through skin (stomates, lenticel, cuticle)

http://hort.ku.ac.th

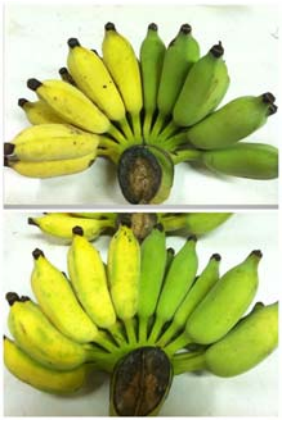
Problems : surface wax in nature

postharvest treatment

Aim : water loss , shrinkage, gas barrier

appearance, others

http://hort.ku.ac.th



1-MCP 1/8 tablet

~0.15 g release

1-MCP 112.5 nl

Dept. of Horticulture, KU

10% CO_2

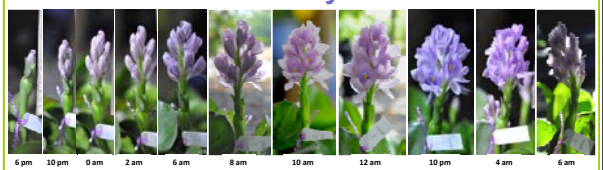
1-MCP+10% CO_2

7 days at 25±2°C

Dept. of Horticulture, KU

Dept. of Horticulture, KU

Water Hyacinth



Harvesting Stage

Flower bud

Open flower

Long Kong

- 13DPF
- Dip in Ca 0.25 %, Carbendazim 1000 ppm และ NAA 200 ppm 3 min before pack
- $Al_2O_3/KMnO_4$ 4 g/kg
- 1-MCP @ 1000 ppb
- store at 18°C
- air flow rate 1.0 room hr^{-1}

1. Room temperature sensor

2. Plug Frost sensor into the fin

3. Connect A/C temperature sensor to coolbot heater