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

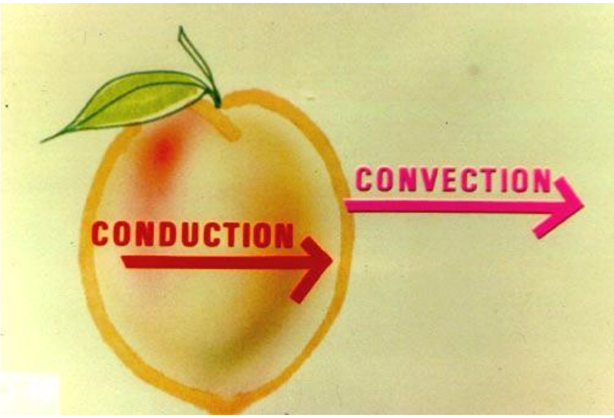
Heat sources

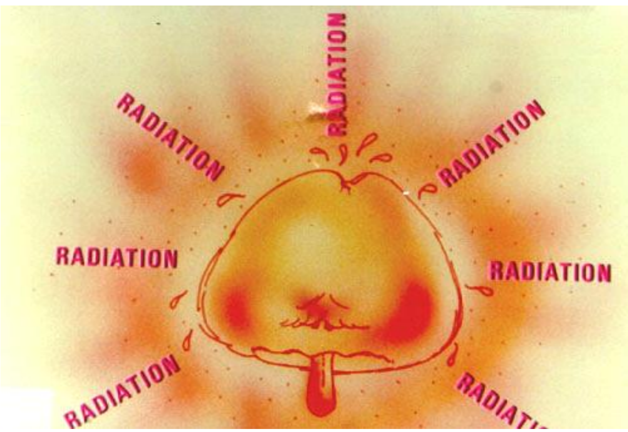
- Filed heat

- Vital heat (respiration)

- Others; container, operation,
  facility (bulb, storage wall etc.)

Heat transfer



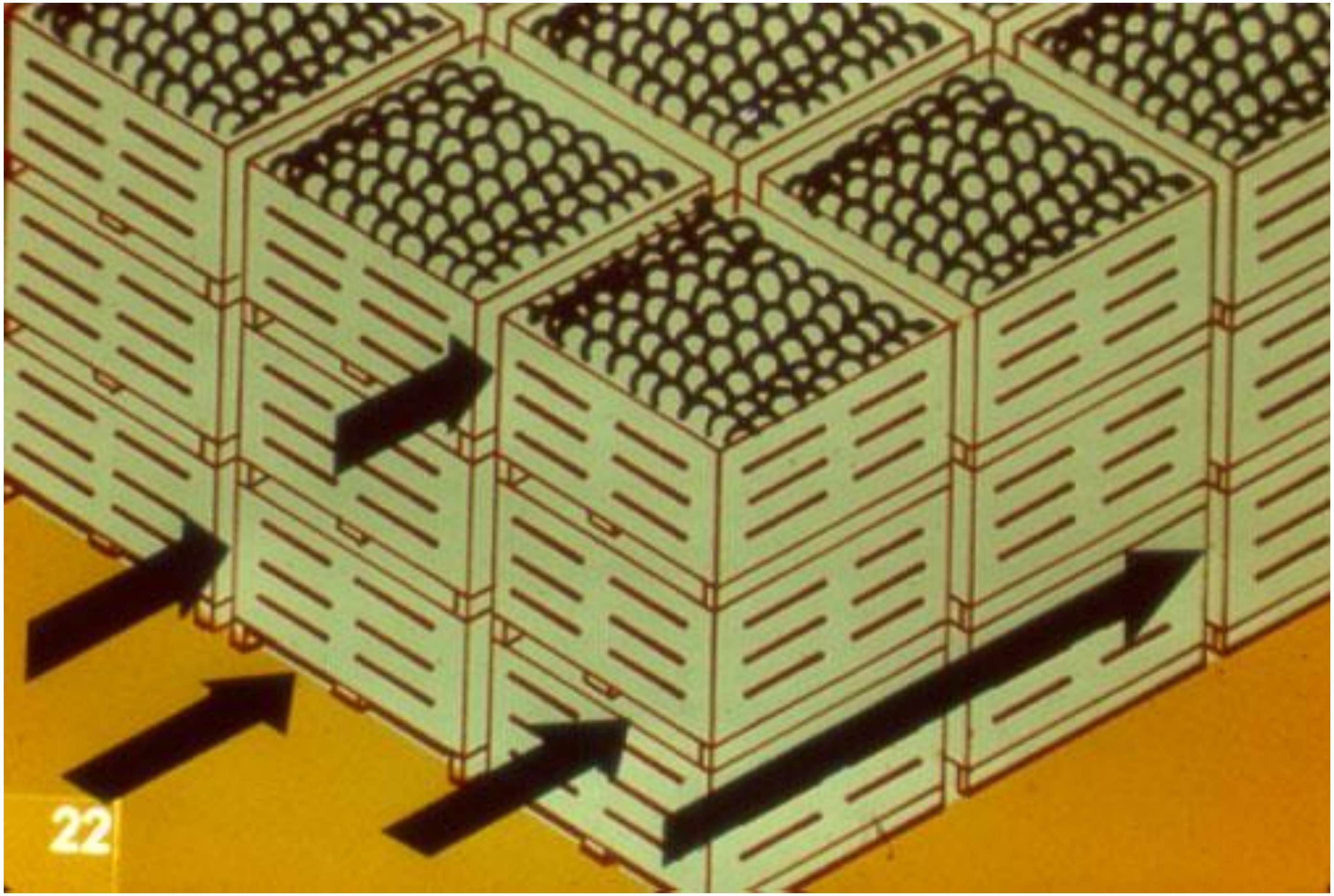


- Conduction
- Convection
- Radiation
- Evaporation

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

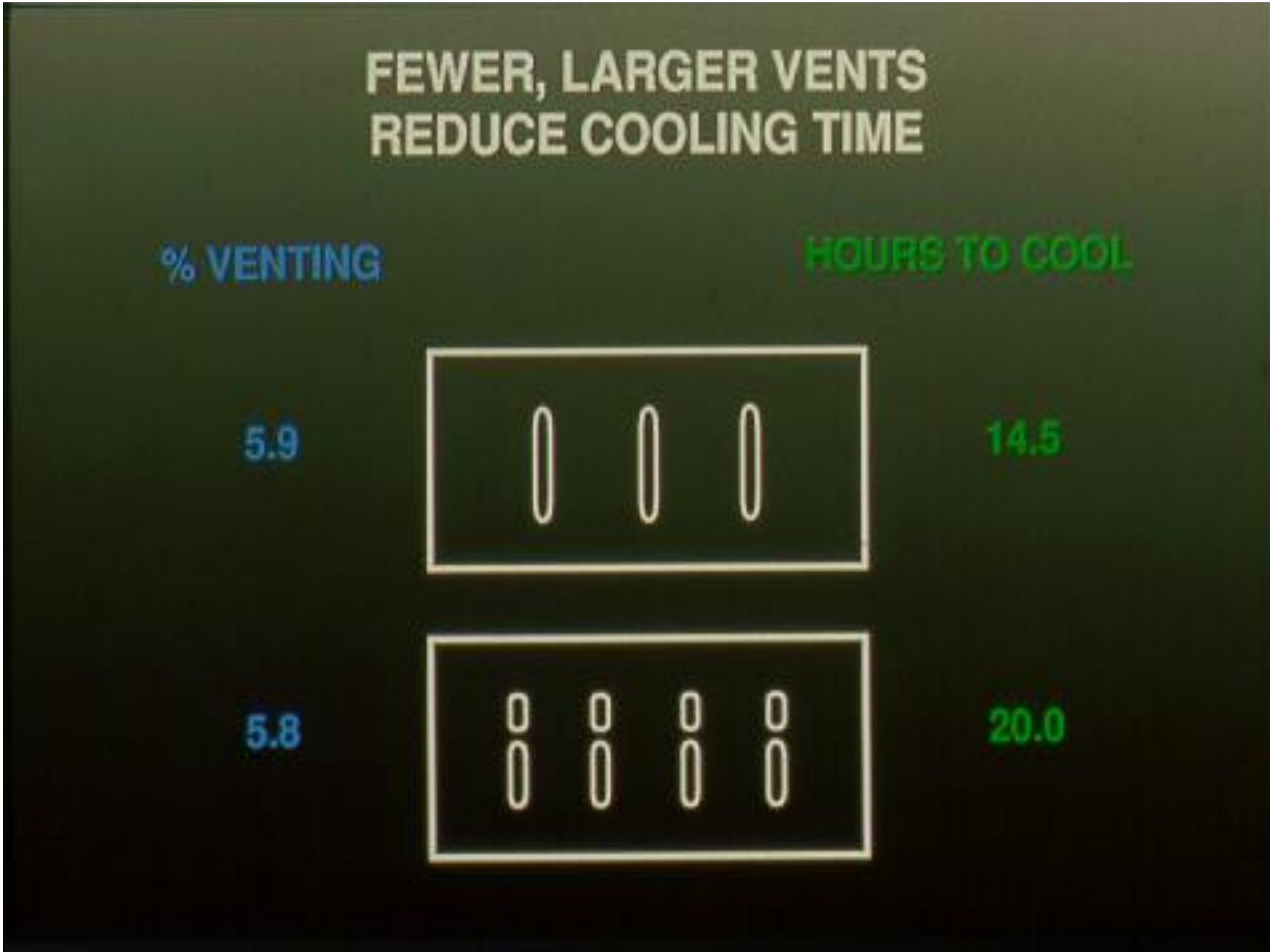
- Using cold air as a cooling medium
  - Low thermal capacity and conductivity

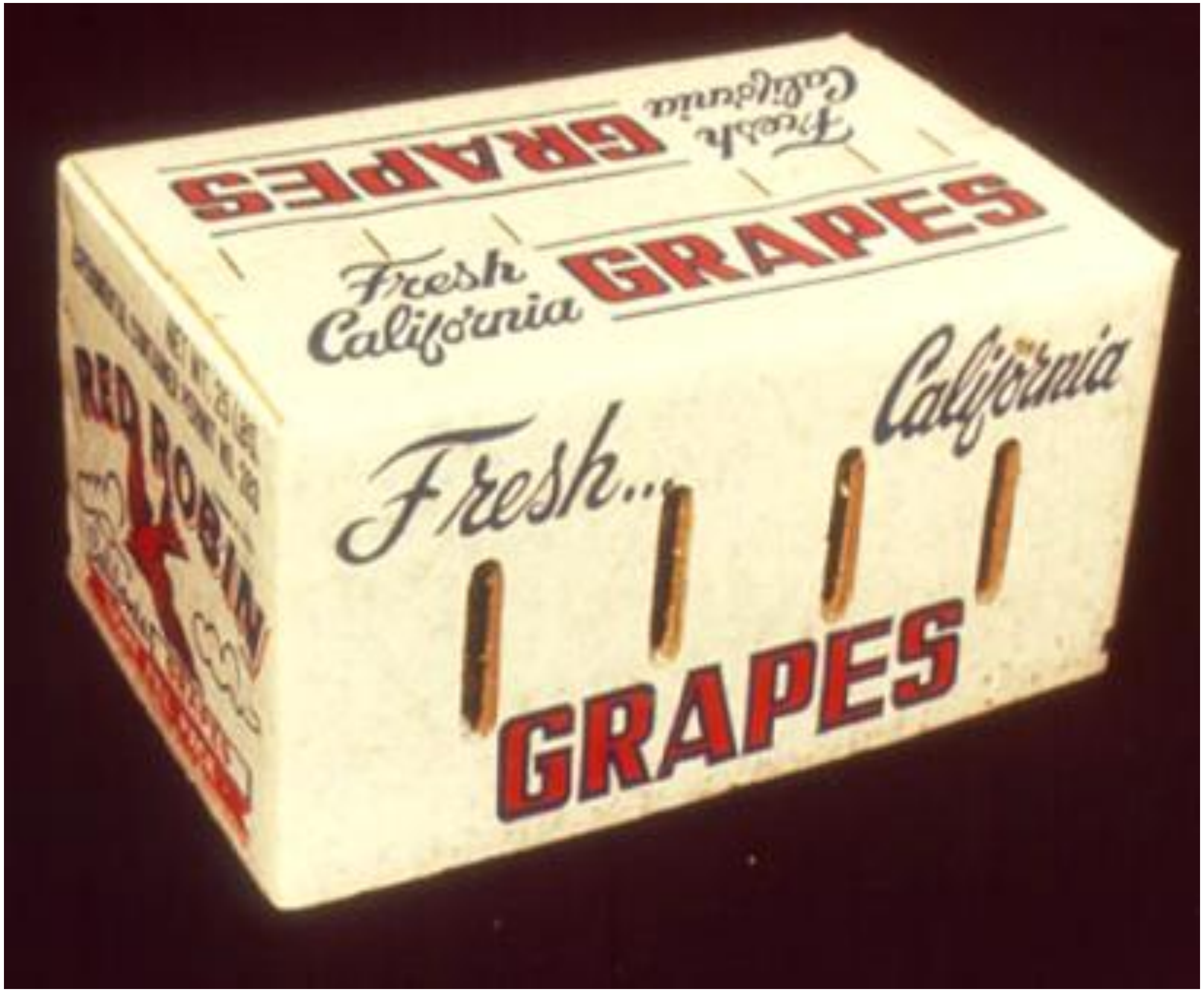
Most common used for

- produces with a **relatively long storage life** which stored in the same room
- **potatoes, dried onion**

Increase cooling rate

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


FEWER, LARGER VENTS
REDUCE COOLING TIME
% VENTING
HOURS TO COOL
5.9
14.5
5.8
20.0



Containers has airflow channel~ 5%

(<2% give similar result to closed-container)

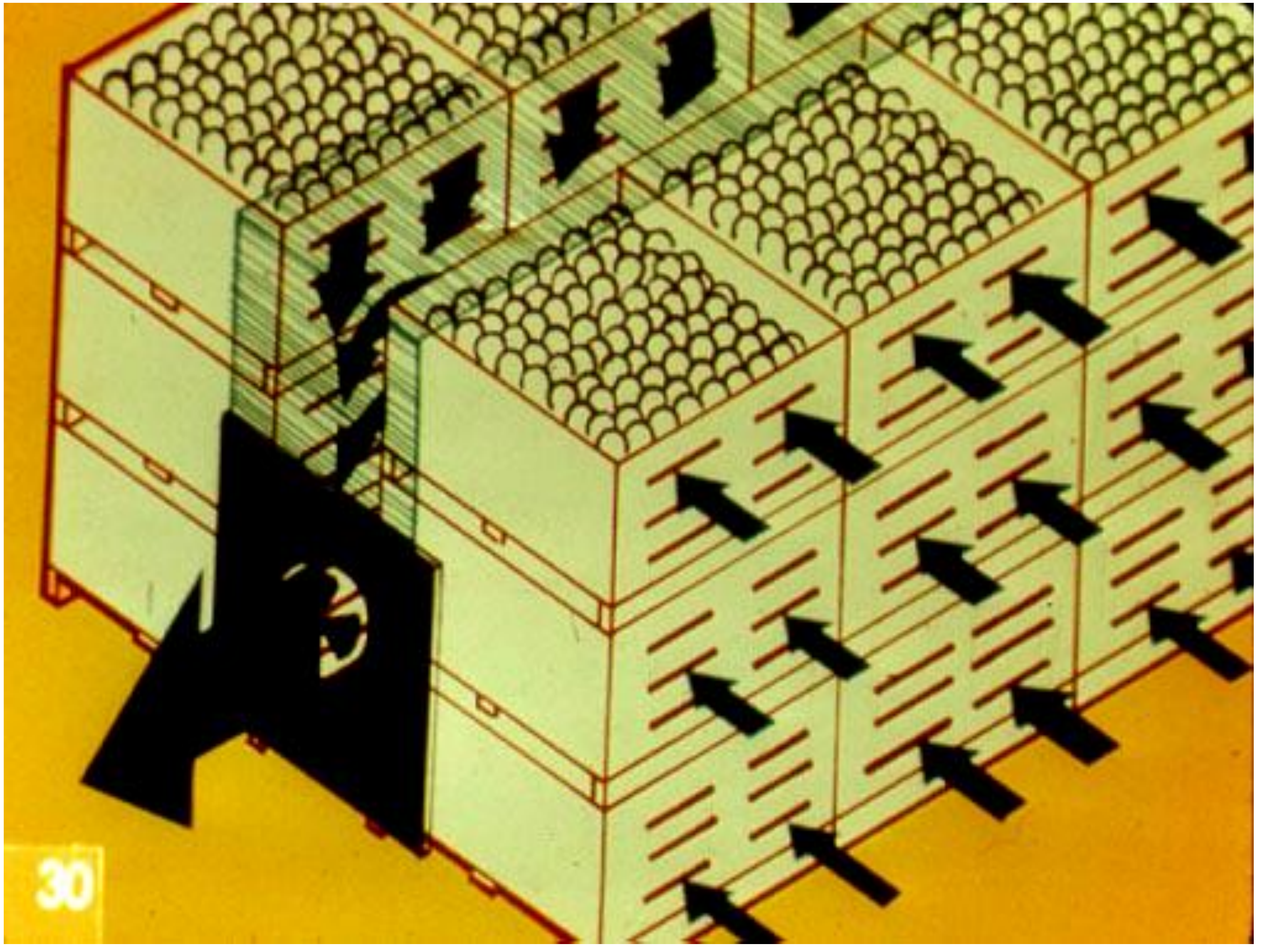
4 -6” between lanes

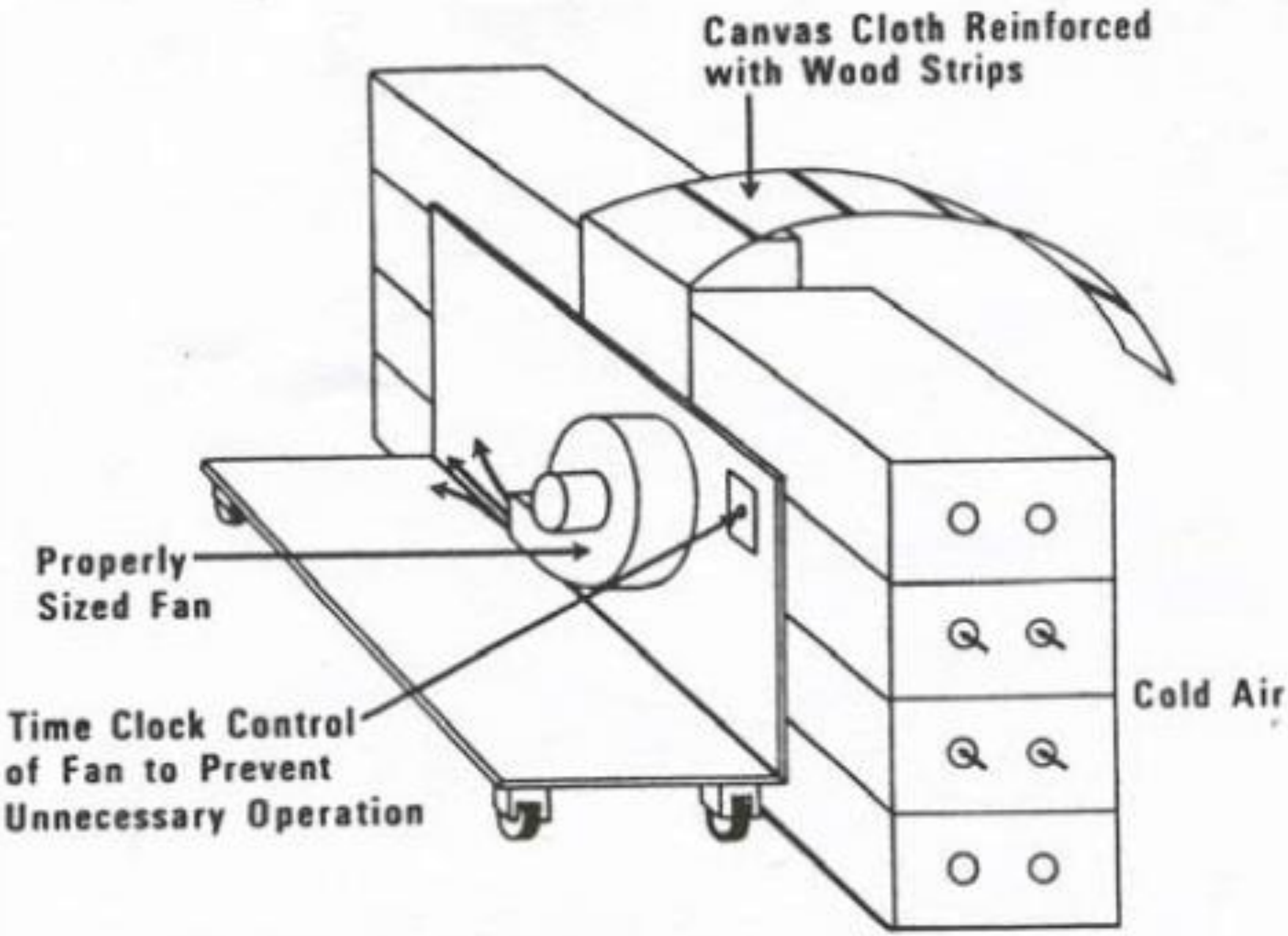
Sloped

sides

Vents

2. Forced air cooling




Canvas Cloth Reinforced
with Wood Strips
Properly
Sized Fan
Time Clock Control
of Fan to Prevent
Unnecessary Operation
Cold Air

Tunnel-type forced-air cooling

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

Increase cooling rate

- Air flow **0.001-0.002 m^3 sec^{-1} kg^{-1}** of produce

- Well vented boxes

  (5-6% side or end wall venting with **few larger vents** rather than **many small vents**)

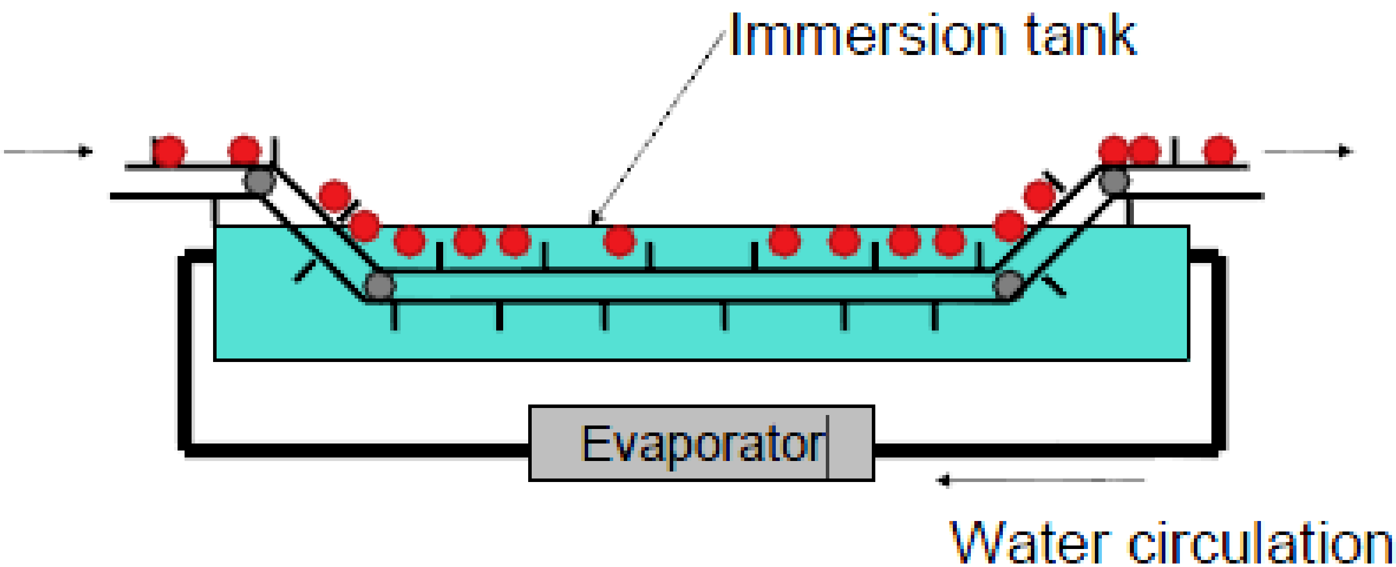
- Lowest possible air temperature

Most common used for

- Fruit-type vegetable: pepper, tomato, mushroom, okra, cauliflower
- Leafy vegetable: cabbage, kale, collards,
- Cut flowers

3. Hydro cooling

Immersion Hydrocooler



http://hort.ku.ac.th

Advantages

- Very fluid
- Most effective method to cool produce (water has greater heat capacity than air)
- Avoid water loss

Disadvantages

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

Increase cooling rate

- Reduce water temperature
- Increase water circulation of surface area
- Increase product exposure

Considerations

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


44

Most common used for

Sweet corn, snap beans, cucumbers, carrot, potatoes, asparagus

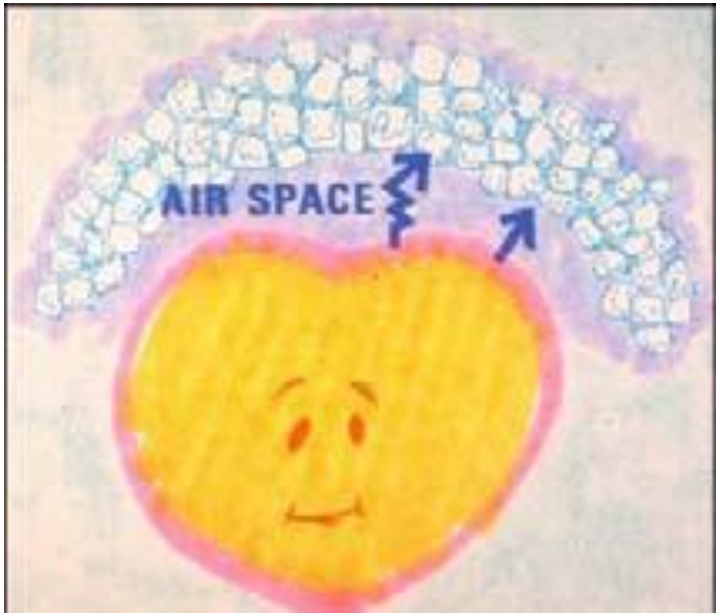
4. Top/Package-icing

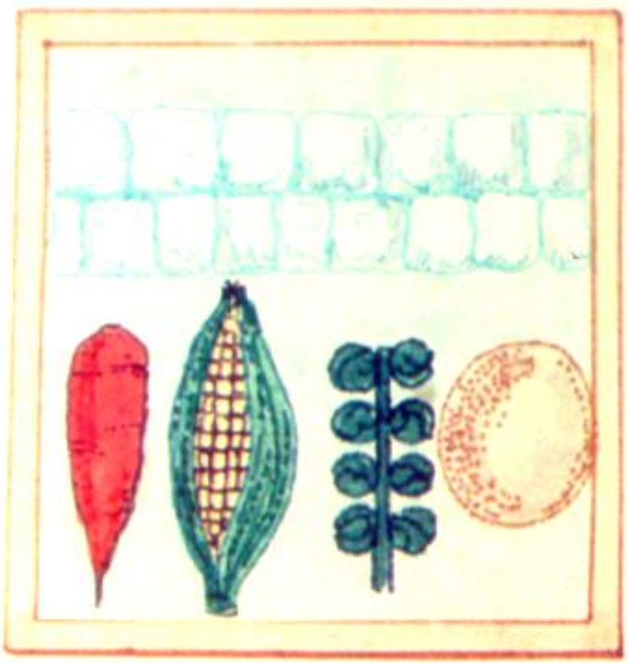

PERIN


RiverRanch

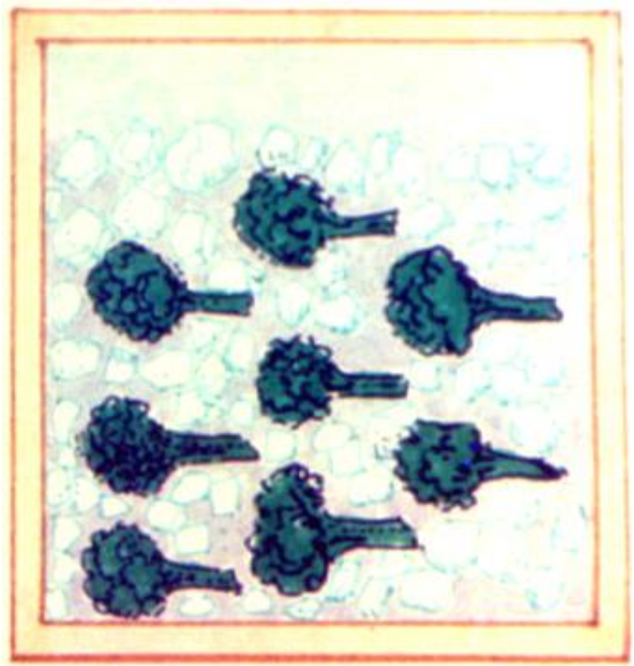
Considerations

Ice solidifies & melts away from product





PACKAGE-ICING



LIQUID ICING

Heat of fusion for ice = 80 cal/g

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

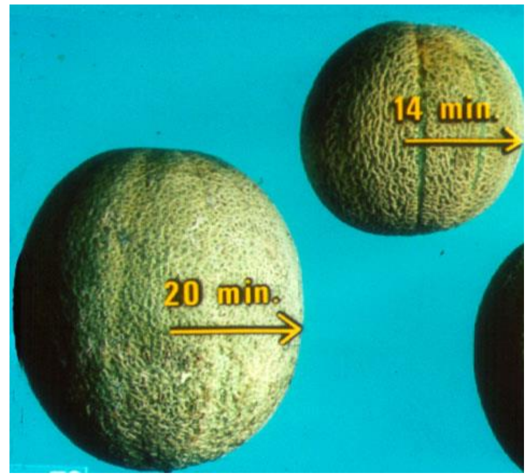
Most common used for

carrot, artichokes, green onions,

peas, sweet corn, broccoli

Factors affecting cooling efficiency

- Packaging
- Product size
- Product density



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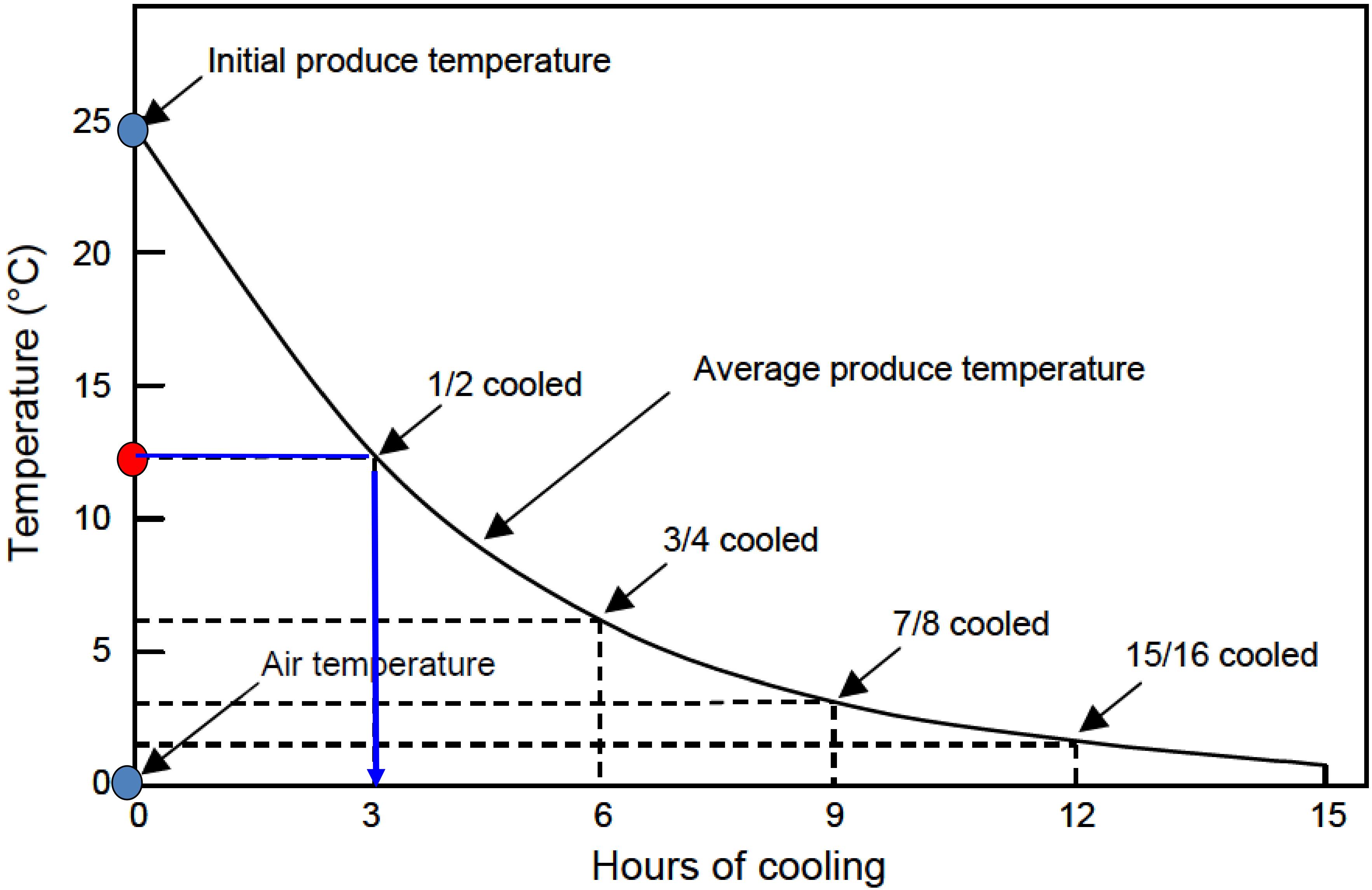
Selecting a Cooling System

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

You can help!!

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

Half cooling time



BTU calculation

I. Total heat

= Field heat + vital heat + environmental/facility heat

Field heat

= specific heat of the produce (cal/g·°C) × weight of fruit (g) × Δ temp (°C)

= X cal

[1 BTU = 252 cal]

so Field heat = $\frac{X}{252}$ BTU

Vital heat

$$= \text{respiration rate } (\text{mgCO}_2/\text{kg}\cdot\text{hr}) \times 220 \ (\text{BTU/tonE}\cdot\text{day}) \times \frac{\textbf{fruit weight (kg)}}{\textbf{907} \ (\frac{\textbf{kg}}{\textbf{ton}})}$$

$$= \text{Y BTU/day}$$

$$= \frac{\textbf{Y}}{\textbf{24}} \text{ BTU/hr}$$

Ton refrigeration

1 ton refrigeration = 288,000 BTU/day

= 12,000 BTU/hr

Then the size of refrigeration needed to cool down the product

$$= \frac{X\ BTU + \frac{Y}{24}\ BTU/hr}{12,000\ BTU/hr}$$

= Z ton refrigeration

Example

The company want to build the cold room for precooling mango fruit before export.

The mango fruit (**10 Ton/day**) needs to be cooled down from **30°C to 15°C** within **12 hr**

How big the refrigeration this cold room should be?

Field heat

= specific heat of the produce (cal/g·°C) × weight of fruit (g) × Δ temp (°C)

= 0.9 (cal/g·°C) × [10 ton × 1000 kg/ton × 1000 g/kg) (g) × [30-15](°C)

= 135,000,000 cal

[1 BTU = 252 cal]

so Field heat = $\frac{135{,}000{,}000}{252}$ BTU

= 535,714 BTU

Vital heat

$$= \text{respiration rate } (\text{mg}CO_2/\text{kg}\cdot\text{hr}) \times 220 \ (\text{BTU}/\text{tonE}\cdot\text{day}) \times \frac{\text{fruit weight (kg)}}{907 \ (\frac{\text{kg}}{\text{ton}})}$$

$$= 75 \ (\text{mg}CO_2/\text{kg}\cdot\text{hr}) \times 220 (\text{BTU}/\text{tonE}\cdot\text{day}) \times \frac{10{,}000 (\text{kg})}{907 \ (\frac{\text{kg}}{\text{ton}})}$$

= 181,918 BTU/day

= 90,954 BTU/12hr

Ton refrigeration

Total heat = field heat + vital heat

= 535,714 BTU + 90,954 BTU

= 626,668 BTU

1 ton refrigeration = 288,000 BTU/day

= 144,000 BTU/12 hr

size of refrigeration = $\frac{626{,}668 \text{ BTU}}{144{,}000 \text{ BTU/hr}}$

= 4.35 ton refrigeration

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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

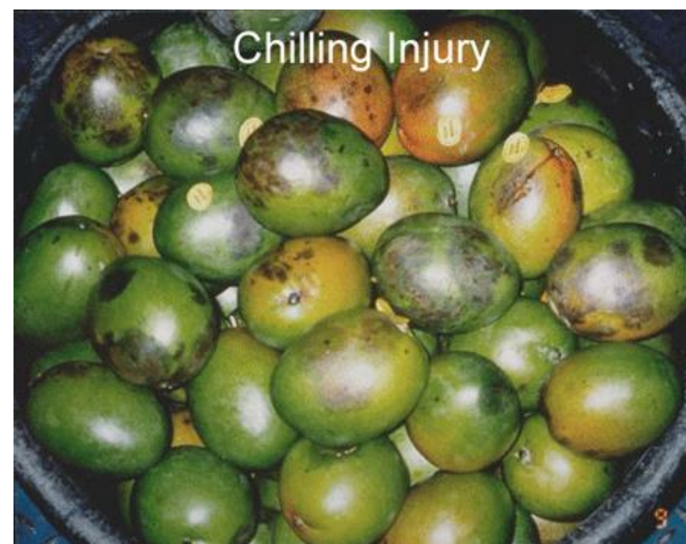
I. Refrigerated Storage

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)

Maintaining High Humidity

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

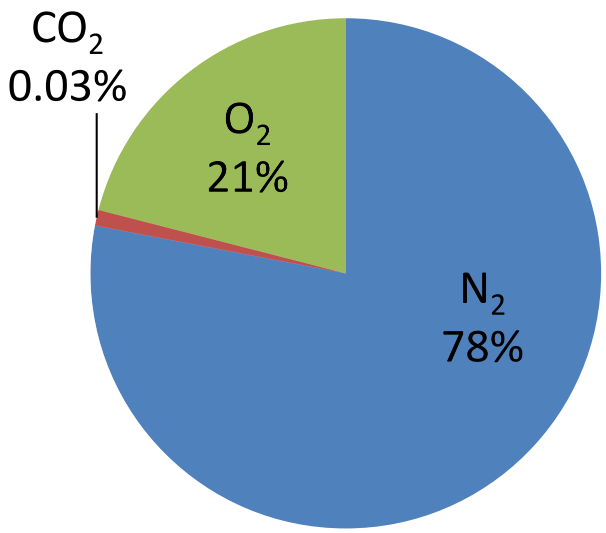
Minimize paper & wood packaging

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

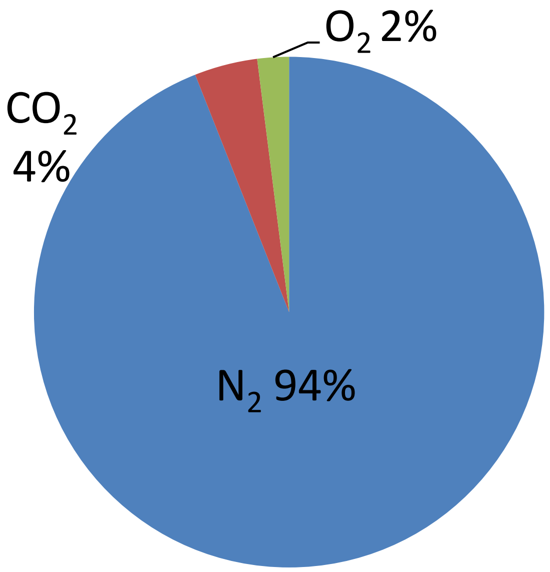
Minimize ethylene

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

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



Normal Atmosphere

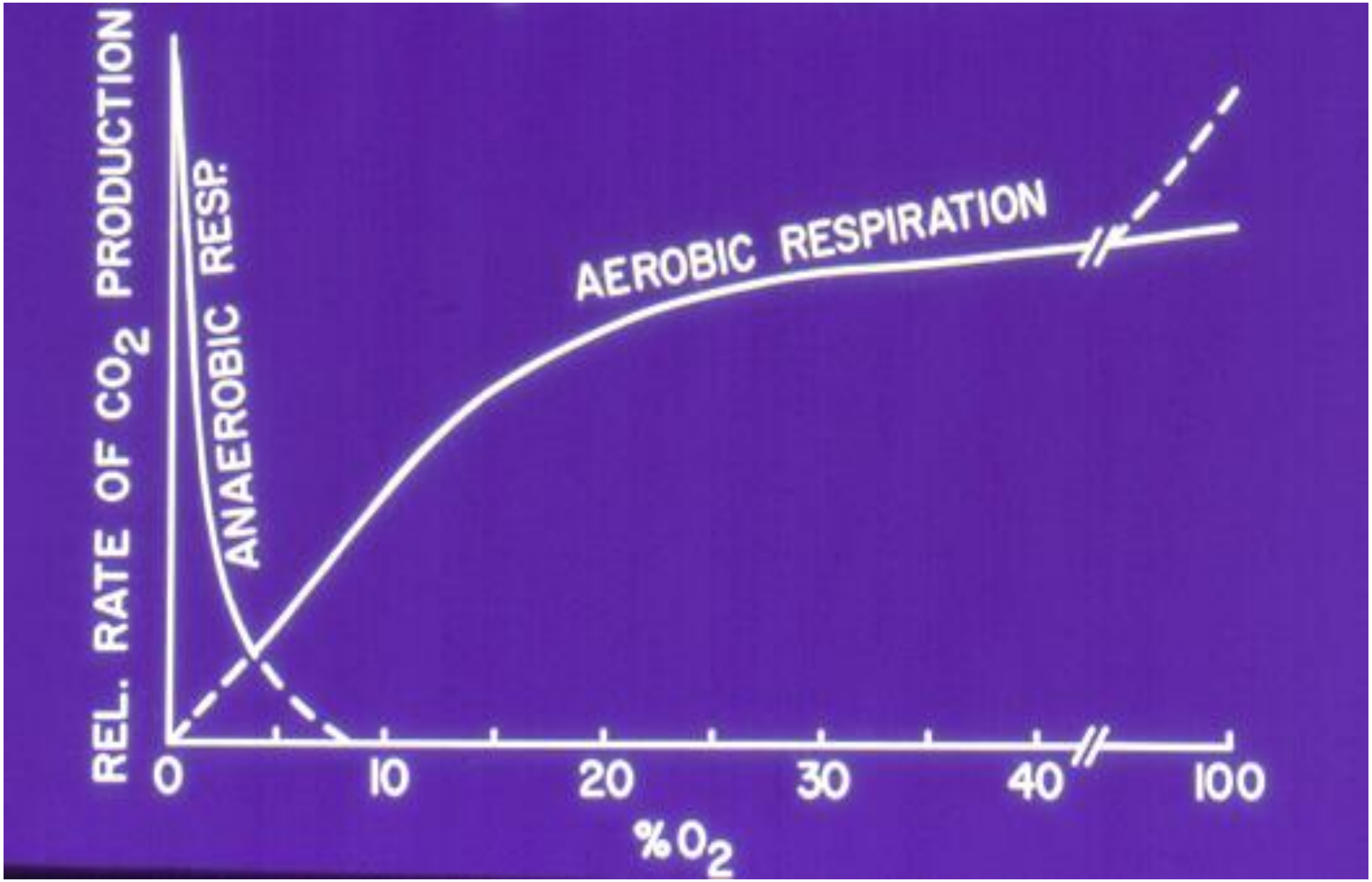


Typical Desired Atmosphere

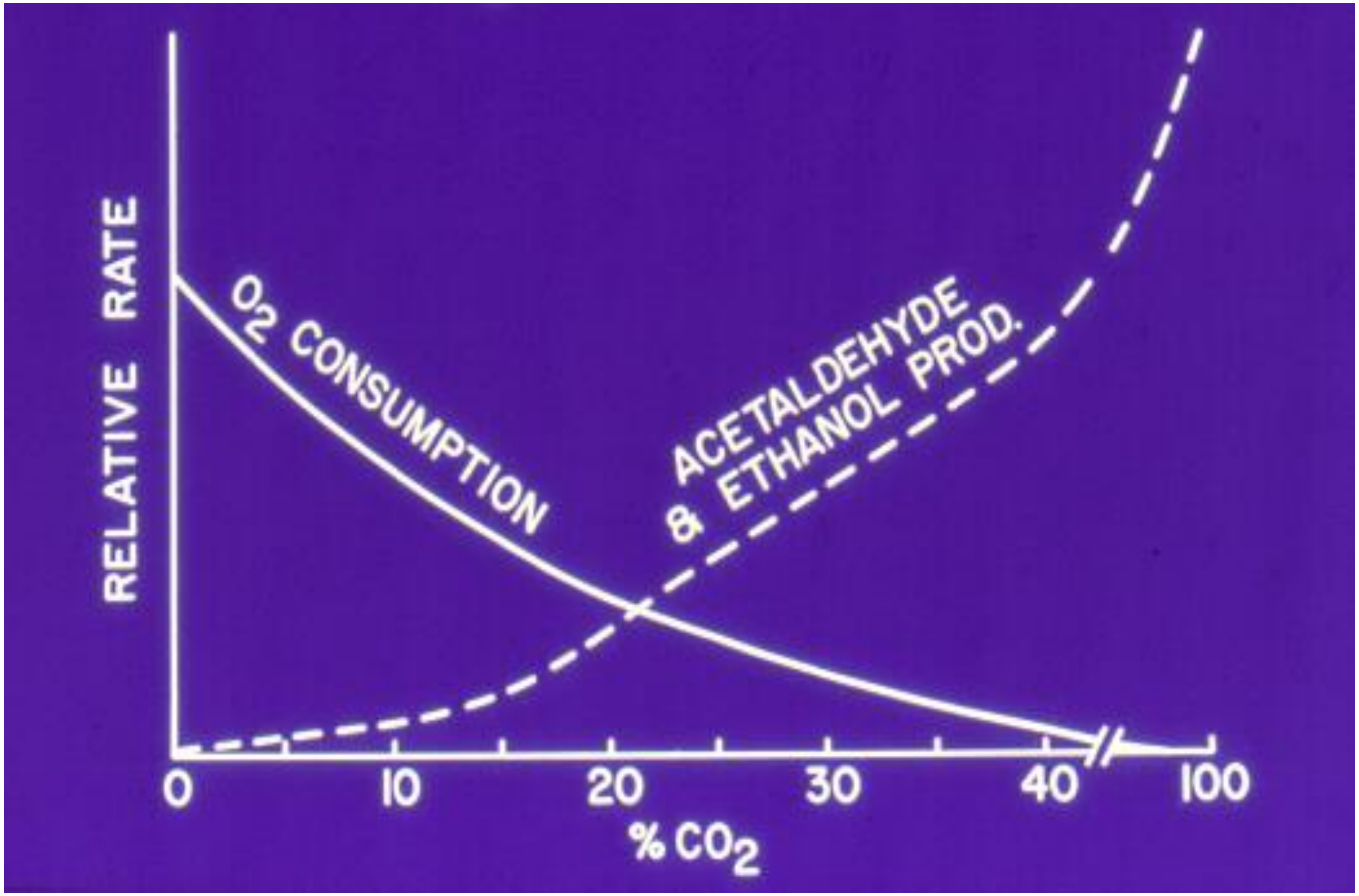
MA or CA

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

How Does CA/MA Affect the Product?



REL. RATE OF CO2 PRODUCTION
ANAEROBIC RESP.
AEROBIC RESPIRATION
0
10
20
30
40
100
%O2


RELATIVE RATE
O2 CONSUMPTION
ACETALDEHYDE
& ETHANOL PROD.
0
10
20
30
40
100
% CO2

Potential Benefits

Low O_2 delays ripening of Bartlett Pears

6 Months Storage

Low O_2 delays ripening of 'Santa Rosa' plums

Air

$1\%O_2 + 5\% CO_2$

5 weeks at $10^{\circ}C$

CA Reduces Chilling Injury and Resulting Decay

Air $\quad$ 2% O_2 + 10%CO_2

21 days at 5°C

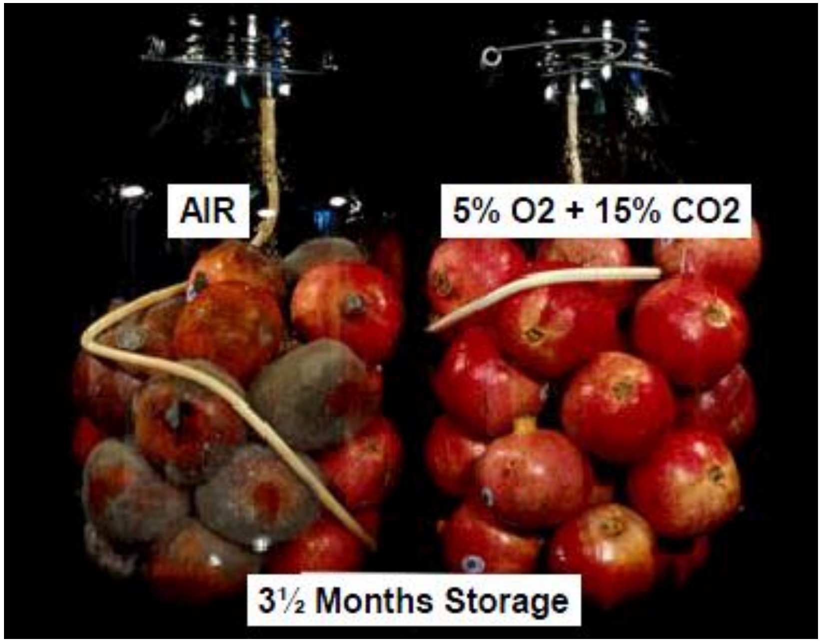
CA Reduces Chilling Injury and Resulting Decay

9 weeks at 5°C

CA Reduces Browning

CA Treatments for Decay Control

- $O_2 < 1\%$
- $CO_2 > 10\%$



Polyethylene Liner develops MA

Delay ripening

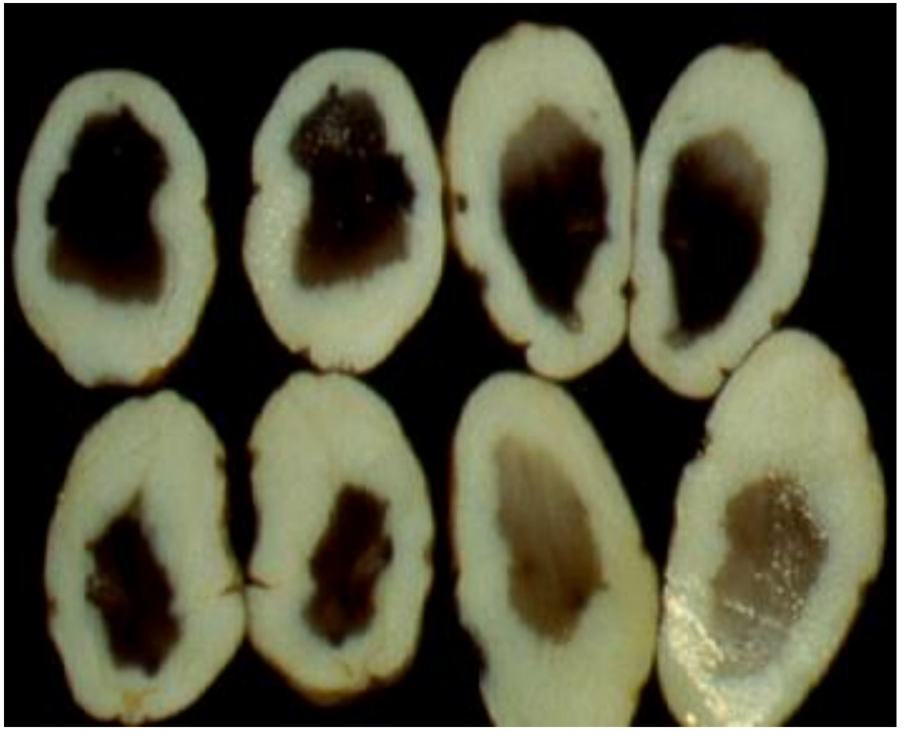
Reduce decay and keep stems green

Pallet Covers for Carbon Dioxide Treatment during Transport

Potential Hazards

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

black heart in potato




A
B
C
D
E

Low O_2 Stimulates Sprouting and Increases Decay

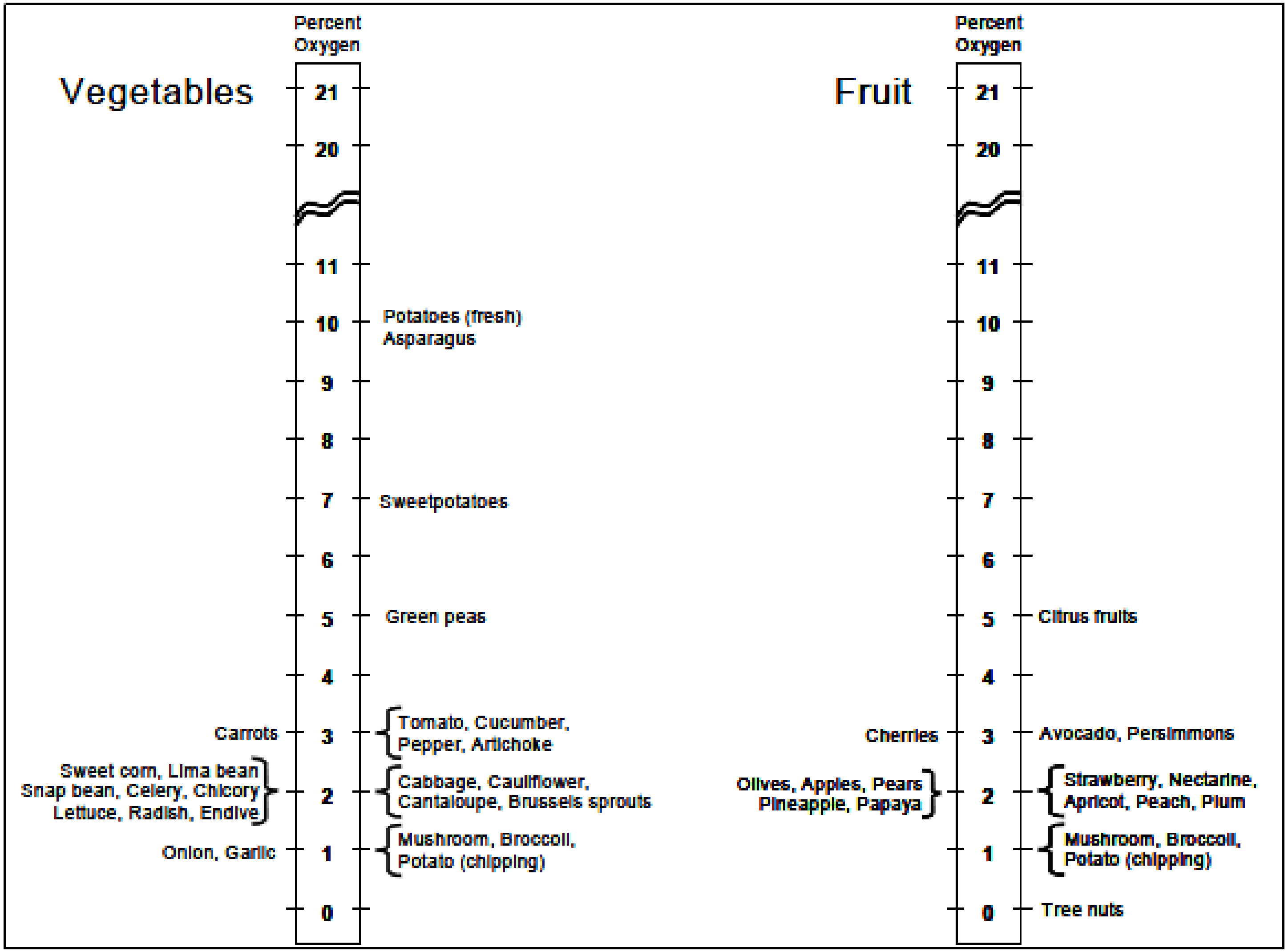
Air 2%O_2 0.2%O_2

$2\%\ O_2 + 5\%\ CO_2$ at $0^{\circ}C$ for 1 week

Potential for Benefit or Hazard ?

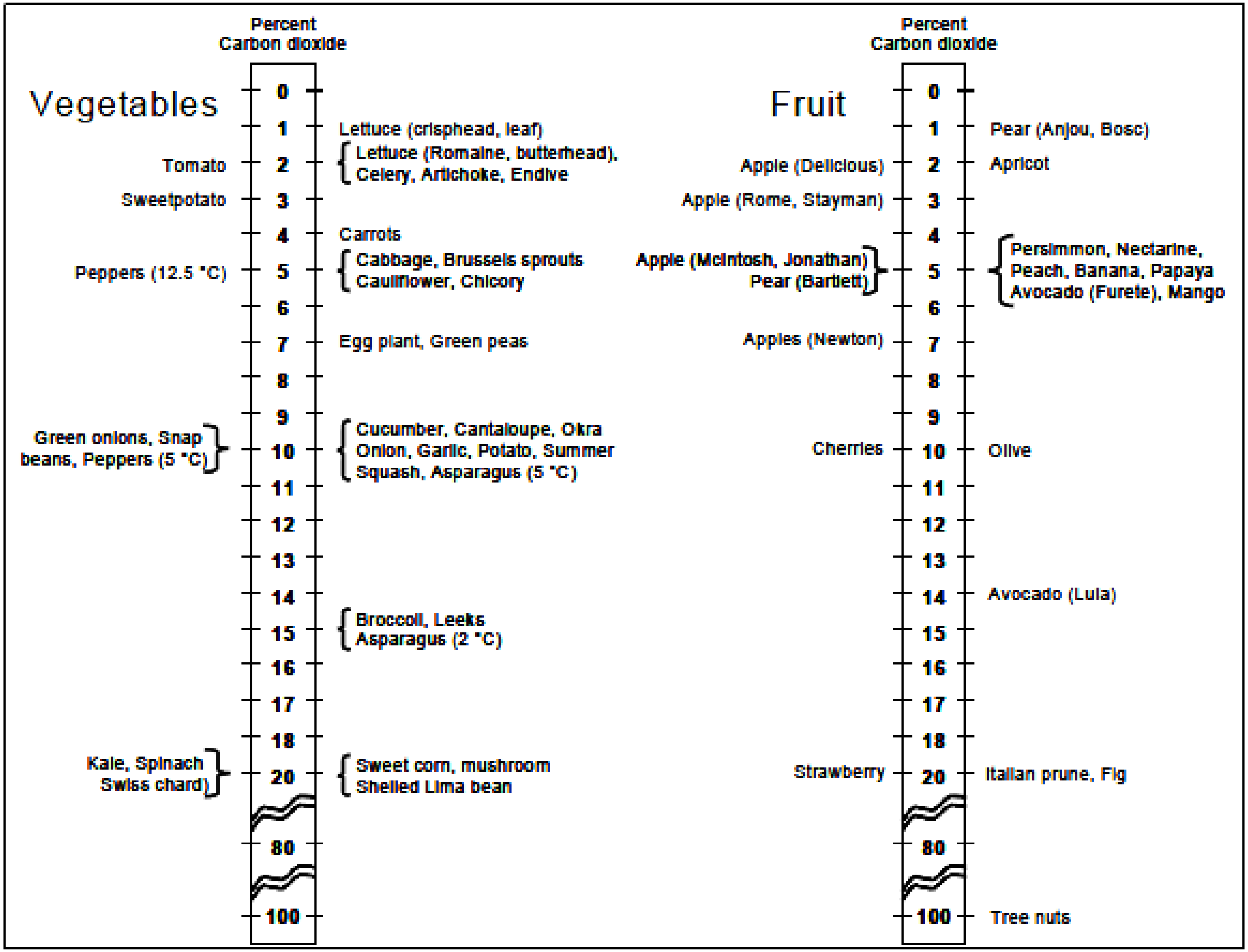
- Commodity
- Cultivar
- Physiological age
- Atmospheric composition
- Temperature
- Duration

Minimum O_2 level



Kader and Morris, 1997

Maximum CO_2 level



Kader and Morris, 1997

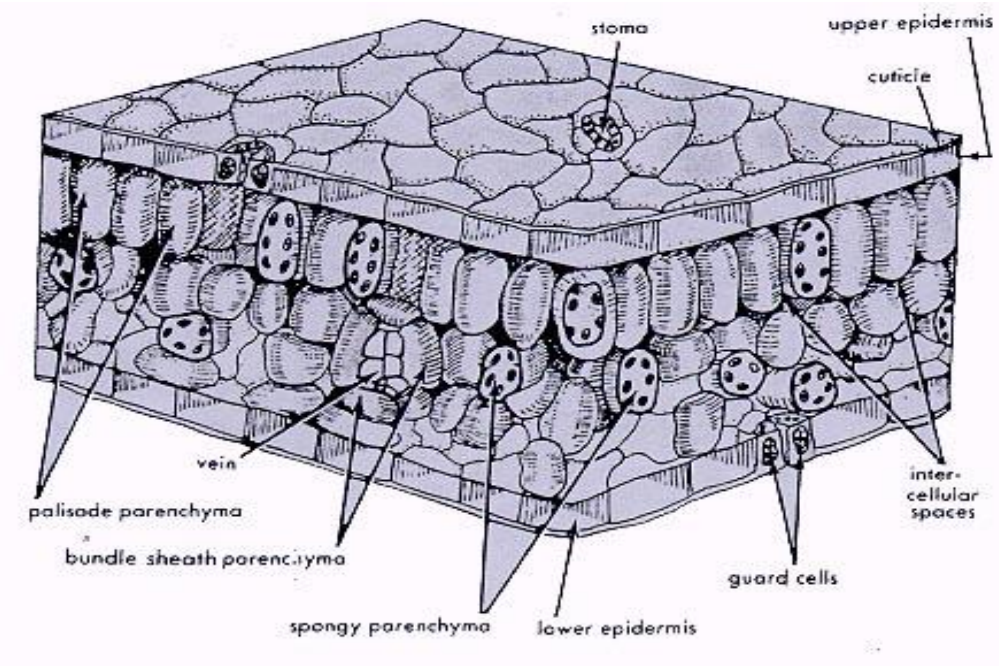
WVTR, OTR, CO_2 TR of selected films

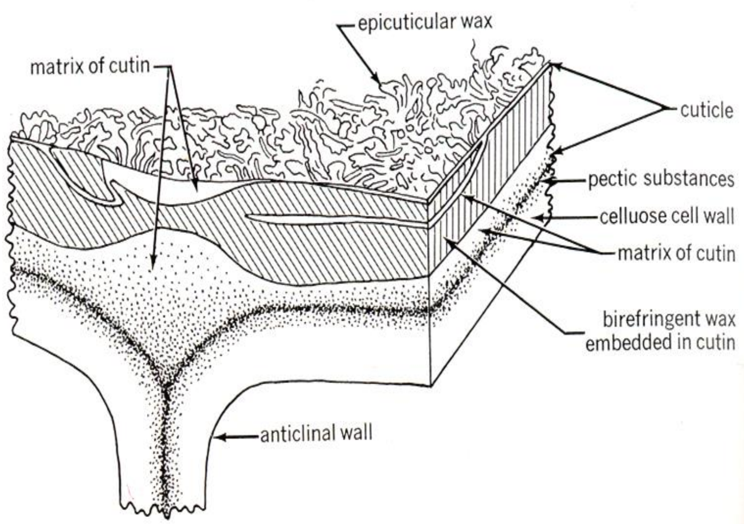
Film	WVTR g/m^2day @23°C, 90%RH	OTR cm^3/m^2day atm @23°C, 90%RH	CO_2TR cm^3/m^2 day atm @23°C, 0%RH
PE	8.66	5,918	
PP	6.59	3,026	7,765
PVC (stretch film)	32.1	14,661	> 30,000
PS	2.82	1,418	3,470
Breathable film	21.94	12,887	> 30,000

Waxing

Surface structure : epidermis cutin , wax , stomates

periderm lignin , suberin , lenticel





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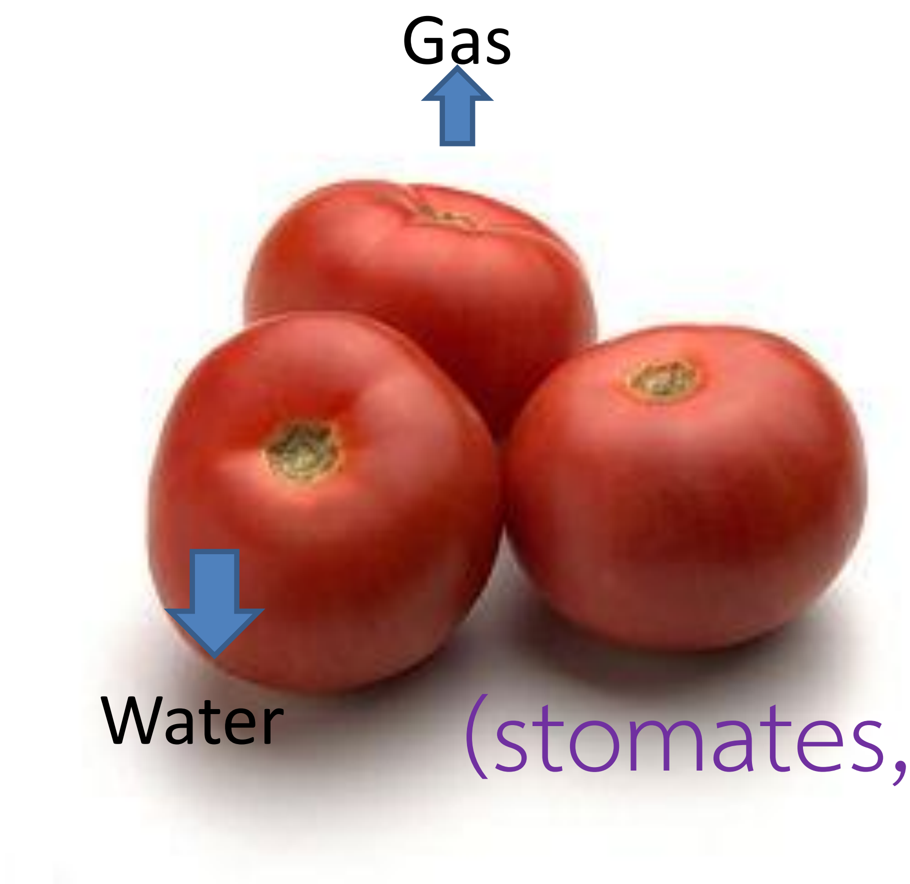

Gas through pores

(stomates, lenticel, wound scar)

Water through skin

(stomates, lenticel, cuticle)

Problems : surface wax in nature

postharvest treatment

Aim : water loss , shrinkage, gas barrier

appearance, others

Criteria to select wax application

Consumer Need

Appearance, weight loss, gas barrier

Wax properties

Vapor & gases barrier, gloss , solubility

Produce

Climacteric-non climacteric fruit or vegetable

1. Room temperature sensor

2. Plug Frost sensor into the fin

3. Connect A/C temperature sensor to coolbot heater

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Pest control

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

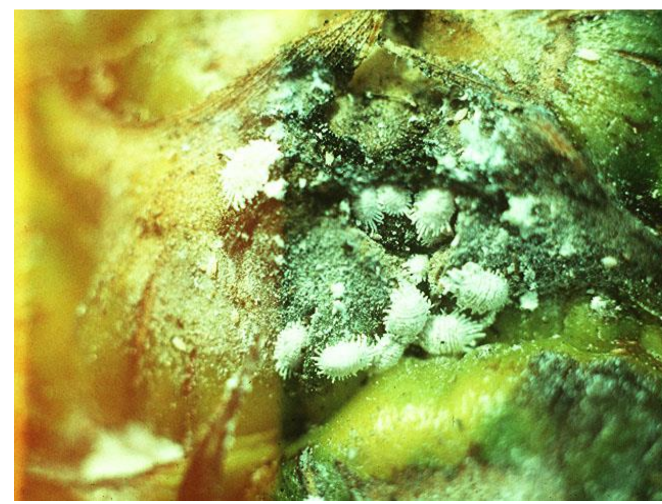
1. SURFACE INSECTS

Thrips in avocado

Scales in apple

Aphids in Rosy apple

Mealy bugs



Pineapple mealy bug:

Dymicoccus brevipes

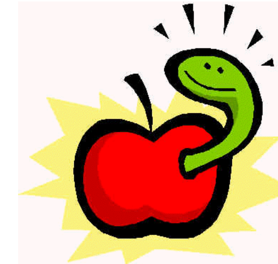
Aphids (***Periphyllus testudinaceus***)

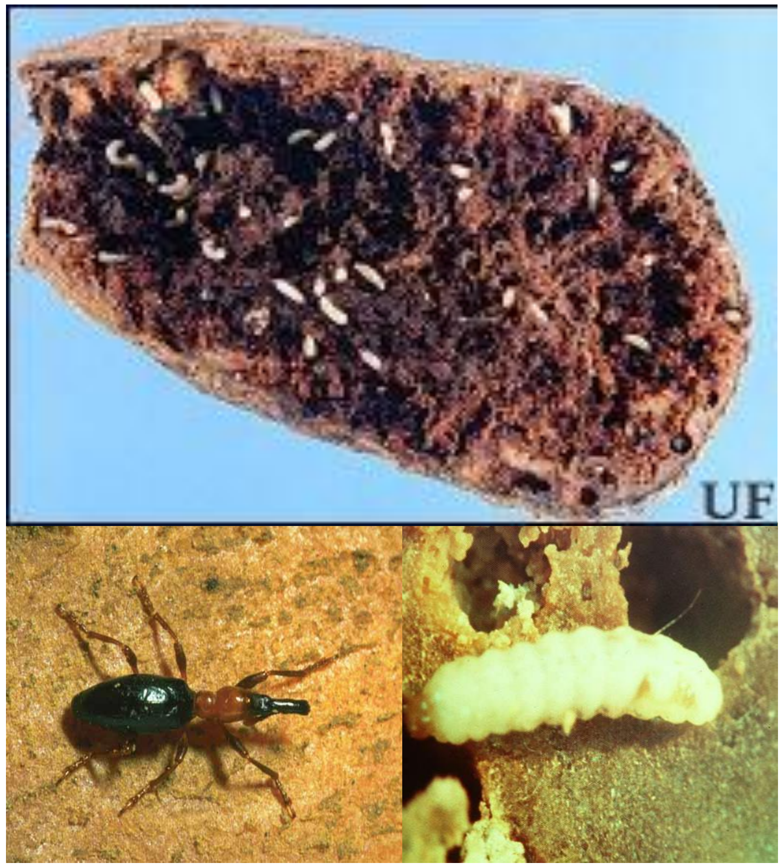

Thrips infection
2
6


Mealy bugs

2. <u>INTERNAL INSECTS</u>

Beetles (boring, souring, seed)





Sweet potato weevil:

Cylas formicarius

Mango seed weevil: *Sternochaetus mangiferae*

Mango seed weevil: *Sternochaetus mangiferae*

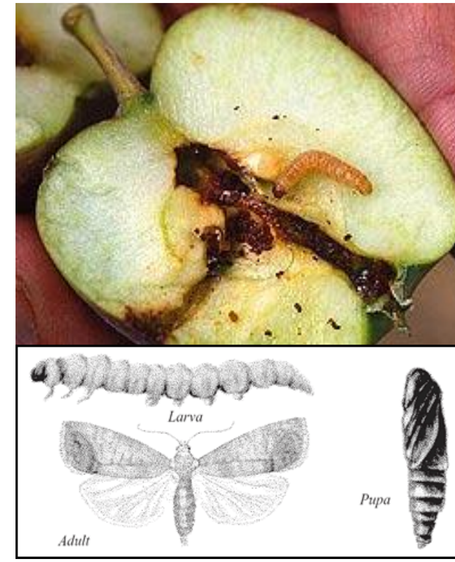
Moths

Tomato Fruitworm:

(*Heliothis sp.*)

Oriental fruit moth:

Grapholita molesta



Codling moth:

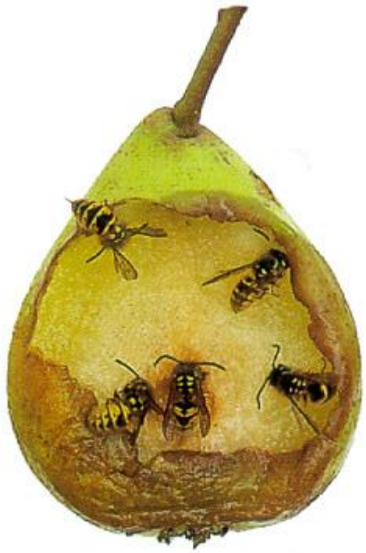
Cydia pomonella

Corn Earworm: (*Heliothis sp.*)

Armyworms:

(*Spodoptera sp.*)

Tephritid fruit flies



Oriental fruit fly:

Bactrocera dorsalis

Melon fly:

Bactrocera cucurbitae

POSTHARVEST DISINFESTATION PROCEDURES

WASHING TREATMENT

water, soap and brush

CHEMICAL TREATMENT

Fumigation :

- carbon disulphide
- hydrogen cyanide
- ethylene dibromide (EDB) US 1984, Japan 1987
- methyl bromide (MB)

  developed countries 0% by 2010

  developing countries freeze at 95-98 by 2002
- phosphine
- ethylformate

Dip : dimethoate

fenthion

methoprene


Mealy bugs

TEMPERATURE TREATMENTS

HEAT TREATMENTS :

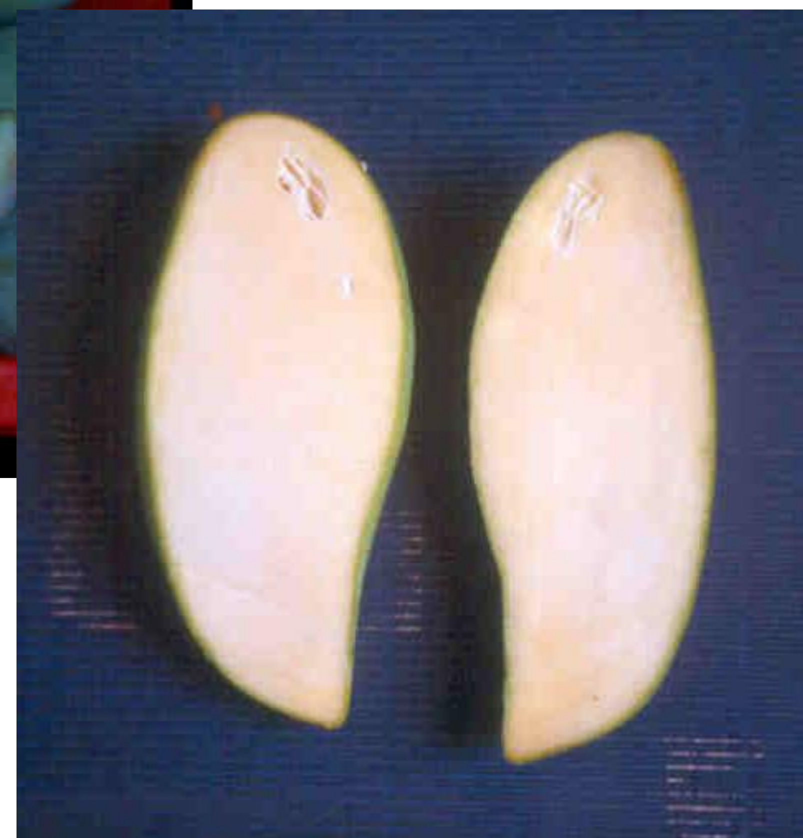

Vapor heat treatments

- Hot water treatments
- Vapor heat treatments
- Hot air treatment
- Microwave heat treatment

Quarantine disinfestation schedules with heat against eggs or larvae of fruit flies in various fruits

Pest species	Fruit	Method	Temp (°C)	Time	Reference
Anastrepha distincta	Mango	HW	46	1.5 h.	Sharp et al.(1990) (
A.obliqua (Macquart)	Mango	HA	48	1.5-3.5 h.	Msngan and Ingle(1992)
(West Indian fruit fry)	Mango	HW	46	1.5 h.	Sharp et al.(1989)
A.serpentina (Wiedemann) (Sapodilla fruit fly)	Mango	HW	46	1.5 h.	Sharp et al.(1990)
A.ludens (Loew) (Mexican fruit fly)	Mango	HW	46	1.5 h.	Sharp et al.(1990)
A.suspensa (Leow)	Carambora	Vapour heat	43.5-46.5	1-2 h.	Hallman (1990)
(Caribbean fruit fly)	Mango	HW	46-47	1-2 h.	Sharp et al.(1989)
Ceratitis capitata(Wiedemann)	Mango	VH	43.5	14 h.	Balock and Starr (1945)
(Mediterranean fruit fly)	Papaya	HA	46-47	5 h.	Armstrong et al.(1989)

Pest species	Fruit	Method	Temp (°C)	Time	Reference
Dacus cucurbitae(Coquillett)	Papaya	HA	45-46	5 h.	Armstrong et al. (1989)
(Melon fly)	Momordica	VH	45	30 m	Sunagawa et al.(1988)
	Egg Plant	VH	-	-	Furusawa et al.(1984)
D. dosalis (Hendel)	Papaya	VH	44.5	20 h.	Seo et al.(1974)
	Mango	VH	46	2 h.+10m	Merinoet al.(1985)
	Mango	VH	46.5	2 h.+10m	Unahawutti et al.(1986)
	Papaya	HW	42, 49	30 + 20m	Couey and Hayes(1986)
Bactrocera tryoni (Froggatt) (Queensland fruit fly)	Mango	VH	46.5	2 h+10m	Heather(unpublished)
B.cucumis French (Cucumber fly)	Zucchini	VH	45	2 h.+ 30m	Corcoran et al.(1993)



TEMPERATURE TREATMENTS

COLD TREATMENTS :

Time and temperature

On land VS in transit

CONTROLLED ATMOSPHERE TREATMENT

Oxygen

Carbon dioxide

Carbonmonoxide

Film wraps

Studies of film wraps used to kill insects inside different fruits.

Insect	Fruit	Film	Mortality at	Temp	Reference
Drosophila melanogaster	Mango	Cryovac D-955	100% at 3d	24-25 C	Shetty at el.(1989)
Bactrocera dorsalis	Papaya	Cryovac D-955	>95% at 6d	27 C	Shetty at el.(1989)
Bactrocera cucurbitae	Papaya	Cryovac D-955	>85% at 6d	22-24 C	Jang(1990)
Ceratilis capitata	Papaya	Cryovac D-955	~90% at 6d	22-24 C	Jang (1990)
Anastrepha suspensa	Mango	Clysar EHC-150	99.95% at 15d	24-26 C	Gould and Sharp (1990)
Anastrepha suspensa	Grapfruit	Clysar EHC-50-F	92.2% at 35d	24-26 C	Sharp(1990)
Anastrepha suspensa	Grapfruit	Clysar EHC-150-F	97.5% at 35d	24-26 C	Sharp(1990)

Possible controlled atmosphere quarantine treatment

Commodity	Pest	Percentage O_2	Percentage CO_2	Temp (°C)	Time (days)	Reference
Apple	San Jose scale	<1	>90	>12	2	Morgan and Gaunce(1975)
Apple	Codling moth larvae	1.5-2	<1	0	91	Toba and Moffitt(1991)
Asparagus	Green peach aphid and New Zealand flower thrips	8.4	60	0-1	4.5	Carpenter and Potter (1994)
Strawberry	Western flower thrips	1.9-2.3	88.7-90.6	2.5	2	Anaroni et al.(1981)
Sweet potato	Sweet potato weevil	4	60	25	7	Delate et al. (1990)
Walnut	Codling moth larvae	8.4	60	25	>14	Soderstrom et al. (1990)

Irradiation

Technology : g-ray, x-ray

dose ≤ 1000 grey

Regulation : IAEA, WHO, FAO, CODEX, WTO

(Plant quarantine agencies)

Treatment combinations

Heat and controlled atmosphere

Heat and irradiation

Effect of Gamma Irradiation at the Absorbed Dose of 150 Gy on 5 days Old Oriental Fruit Fly Larvae in Nang Klangwan Mangoes

Trial	No. fruit	Treated			
		No. Insect		No. survivors	
		Formation of Pupae	Formation of adults	Pupae	Adults
I	496	109,715	96,472	100,823	1
II	336	62,059	25,603	21,541	0
III	336	8,568	5,275	9,086	0
IV	336	16,699	11,188	14,459	0
	Total	197,041	138,538	145,912	1

As of 2007 Thailand can export:

- rambutan
- papaya
- mango
- mangosteen
- litchi
- longan

to USA using irradiation treatment

Plant protection and quarantine treatment manual; USDA

http://www.cdpr.ca.gov/docs/license/pubs/excerpts_usda_treatment_manual.pdf