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Cooling

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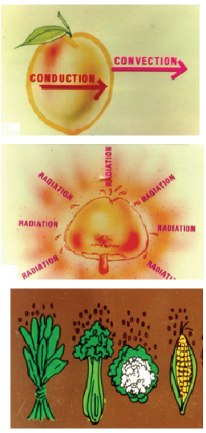
Heat sources

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



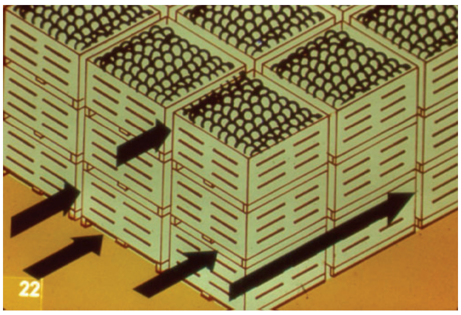
Heat transfer

- 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**

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Increase cooling rate

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

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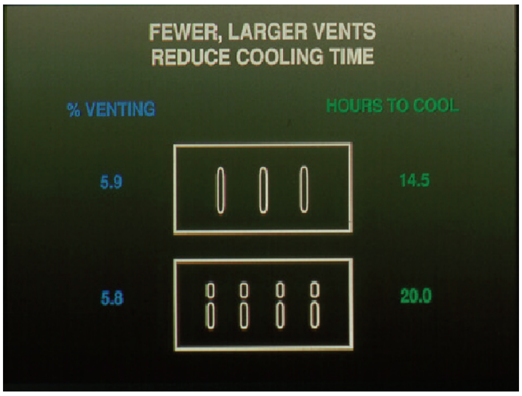

Containers has airflow channel~ 5%
(<2% give similar result to closed-container)

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4 -6” between lanes

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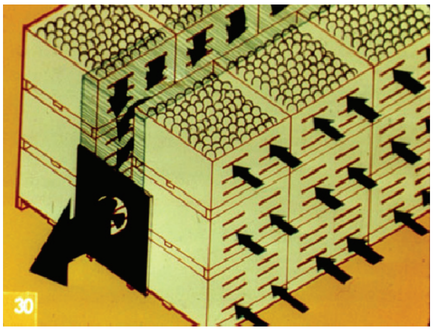
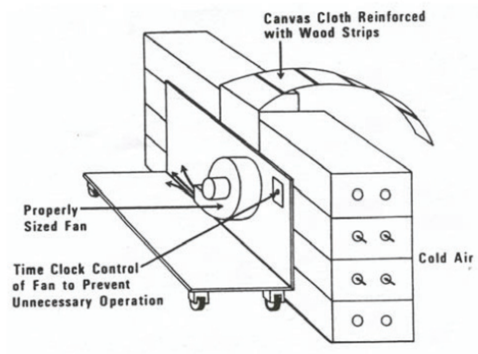
Sloped
sides
Vents

2. Forced air cooling





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

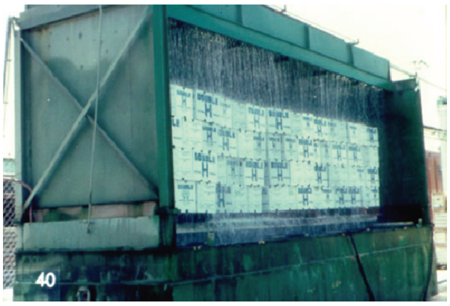
Increase cooling rate

- 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

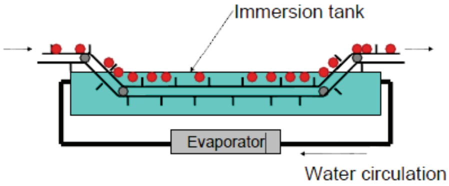
Most common used for

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



Advantages

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

Disadvantages

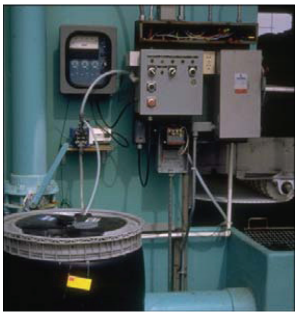
- Container must be water tolerant
- May require drying process after cooling

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



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Most common used for

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

4. Package-icing

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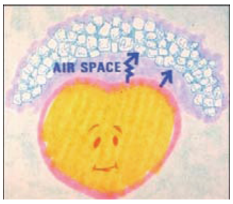
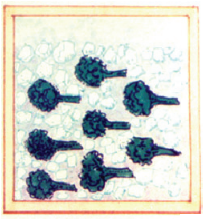
Considerations

Ice solidifies & melts away from product



PACKAGE-ICING



LIQUID ICING

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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

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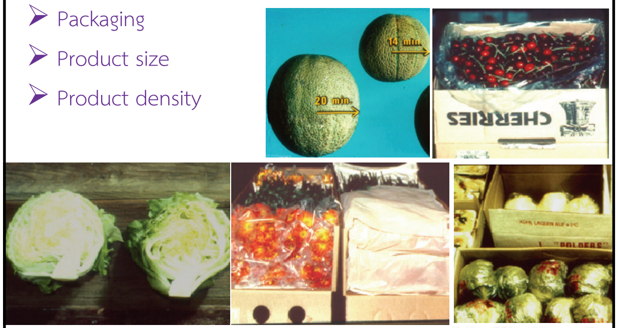
Most common used for

carrot, artichokes, green onions,

leeks, 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

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You can help!!

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

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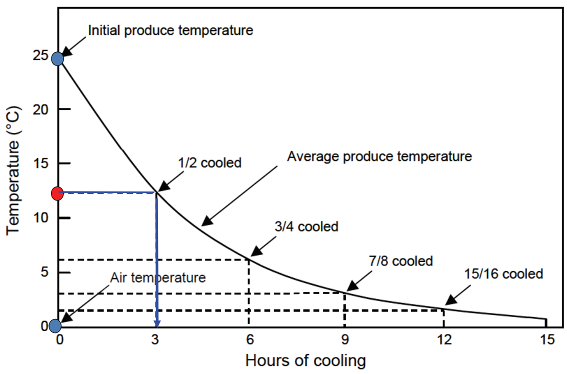
Half cooling time



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Storage

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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

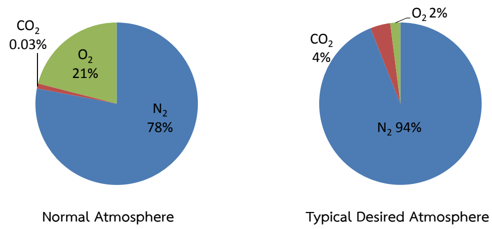
Minimize paper & wood packaging

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

Minimize ethylene

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

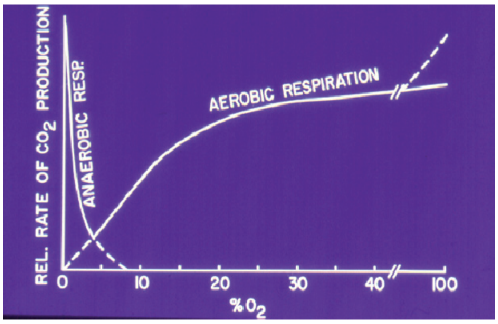
II. Modified or Controlled- Atmosphere Storage (MA or CA)

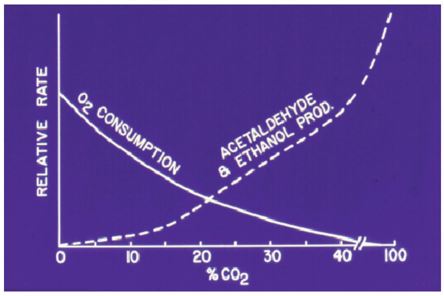


MA or CA

- 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?





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°C

CA Reduces Chilling Injury and Resulting Decay

Air 2% O_2 + 10%CO_2

21 days at 5°C

CA Reduces Chilling Injury and Resulting Decay

9 weeks at 5°C

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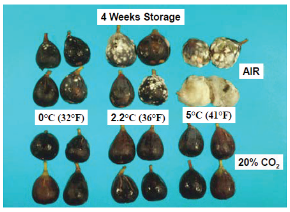
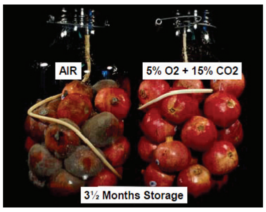
CA Reduces Browning

http://hort.ku.ac.th

CA Treatments for Decay Control

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





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Polyethylene Liner develops MA

Delay ripening

Reduce decay and keep stems green

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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

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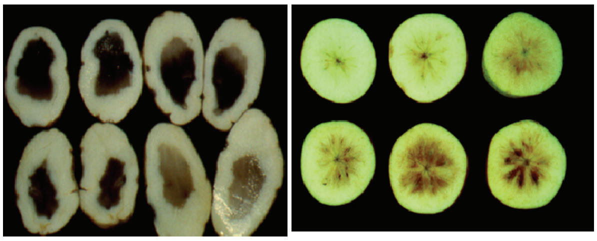
black heart in potato



Low O_2 Stimulates Sprouting and Increases Decay

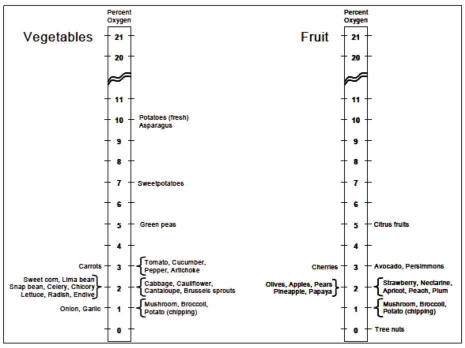
Air   2%O_2 0.2%O_2

2% O_2 + 5% CO_2 at 0°C for 1 week

Potential for Benefit or Hazard ?

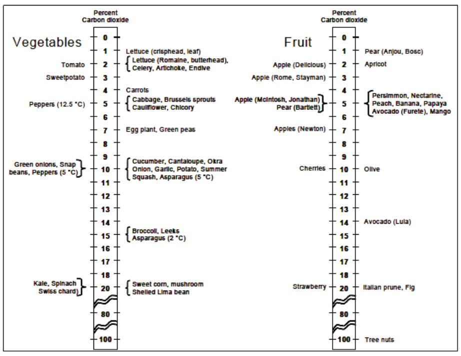
- Commodity
- Cultivar
- Physiological age
- Atmospheric composition
- Temperature
- Duration

Minimum O_2 level



Kader and Morris, 1997

Maximum CO_2 level



Kader and Morris, 1997

WVTR, OTR, CO_2 TR of selected films

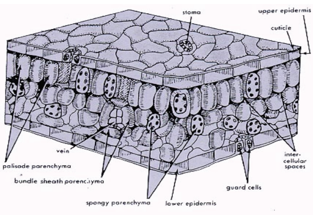
Film	WVTR g/m^2day @23°C, 90%RH	OTR cm^3/m^2day atm @23°C, 90%RH	CO_2TR cm^3/m^2 day atm @23°C, 0%RH
PE	8.66	5,918	
PP	6.59	3,026	7,765
PVC (stretch film)	32.1	14,661	> 30,000
PS	2.82	1,418	3,470
Breathable film	21.94	12,887	> 30,000

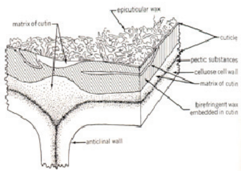
Thai Packaging Centre
Thailand Institute of Scientific and Technological Research

Waxing

Surface structure : epidermis — cutin , wax , stomates

periderm — lignin , suberin , lenticel





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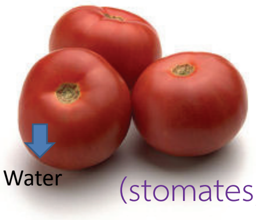

Gas through pores

(stomates, lenticel, wound scar)

Water through skin

(stomates, lenticel, cuticle)

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Problems : surface wax in nature

postharvest treatment

Aim : water loss , shrinkage, gas barrier

appearance, others

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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

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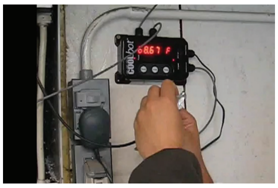
1. Room temperature sensor

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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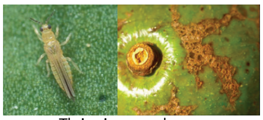
1. SURFACE INSECTS

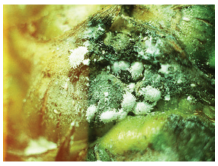


Thrips in avocado

Scales in apple

Aphids in Rosy apple

Mealy bugs



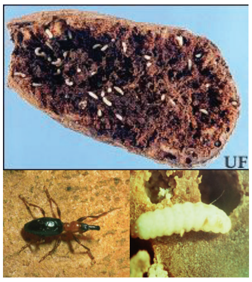
Pineapple mealy bug:

Dymicoccus brevipes

Aphids (*Periphyllus testudinaceus*)

2. INTERNAL INSECTS

Beetles (boring, souring, seed)



Sweet potato weevil:
Cylas formicarius

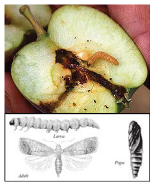
Mango seed weevil: *Sternochaetus mangiferae*

Mango seed weevil: *Sternochaetus mangiferae*

Moths

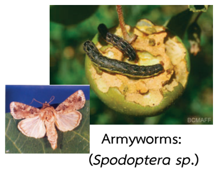
Tomato Fruitworm:
(*Heliothis sp.*)

Oriental fruit moth:
Grapholita molesta



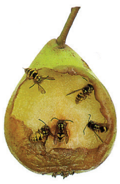
Codling moth:
Cydia pomonella

Corn Earworm: (*Heliothis sp.*)

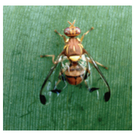


Armyworms:
(*Spodoptera sp.*)

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

TEMPERATURE TREATMENTS

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

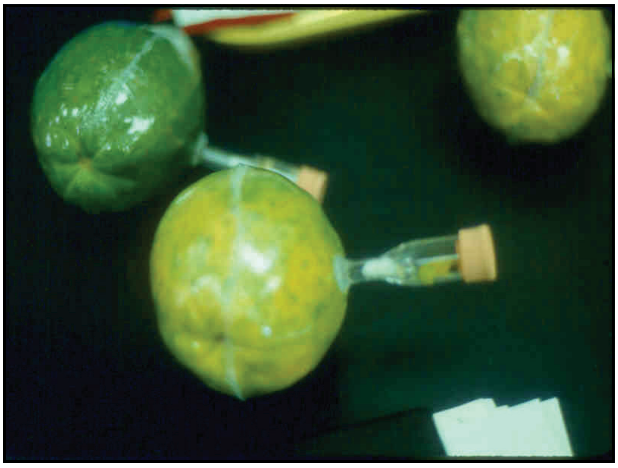
CONTROLLED ATMOSPHERE TREATMENT

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	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 Orental Fruit Fly Larvae in Nang Klangwan Mangoes

Trial	No. fruit	Treated: No. Insect, Formation of Pupae	Treated: No. Insect, Formation of adults	No. survivors: Pupae	No. survivors: 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