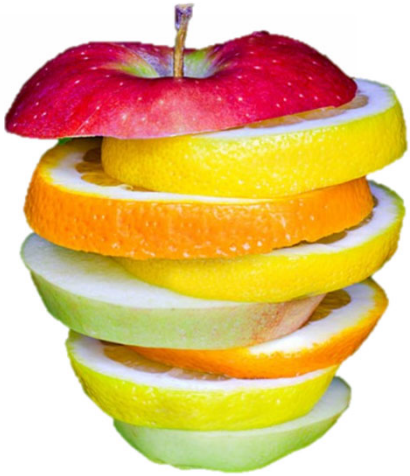
Quarantine Treatments

Postharvest Control of Insects & Other Pests



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Quarantine Pests

Follett & Neven, 2006

"A quarantine pest is a plant pest of potential economic importance to an area that is not yet present there or that is present but not widely distributed and officially controlled"

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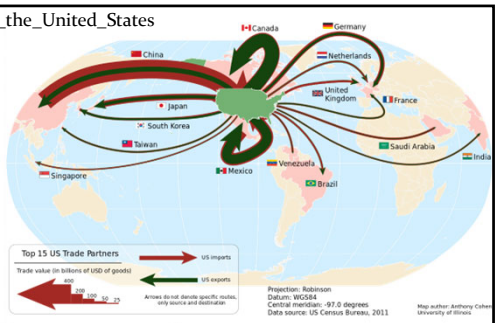
https://en.wikipedia.org/wiki/List_of_the_largest_trading_partners_of_the_United_States

Overview



- World trade in agricultural commodities continues to increase
- Phytosanitary restrictions protect the agriculture in a region – Keeps bad bugs out
  - Should be based on a risk assessment, and not a zero risk
  - Should be based on scientific data, and not politics
- At times, phytosanitary regulations, without sound scientific support, are used as trade barriers

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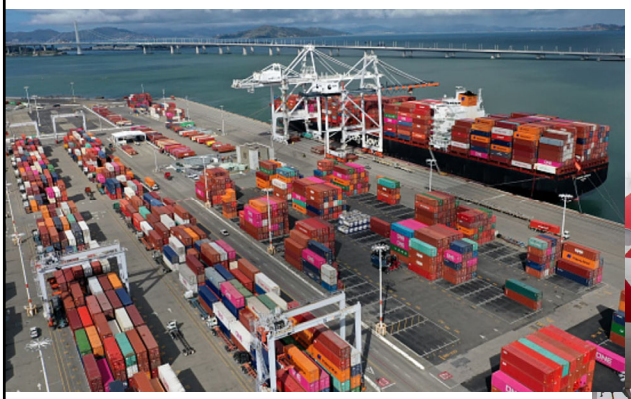

https://www.cnbc.com/2021/03/15/carriers-rejected-at-least-1point3-billion-in-potential-us-agricultural-exports.html

https://www.aircargonews.net/cargo-airport/stansted-flower-power/

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Overview

- If accepted disinfestation measures are not available, quarantine pests will prohibit marketing of fresh agricultural products
  - Between countries
  - Between geographical areas within countries (e.g., between Florida and other states)

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Overview

- Quarantine or phytosanitary treatments eliminate, sterilize, or kill regulatory pests in exported commodities to prevent their introduction and establishment to new areas

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Overview

- Quarantine or phytosanitary treatments eliminate, sterilize, or kill regulatory pests in exported commodities to prevent their introduction and establishment to new areas

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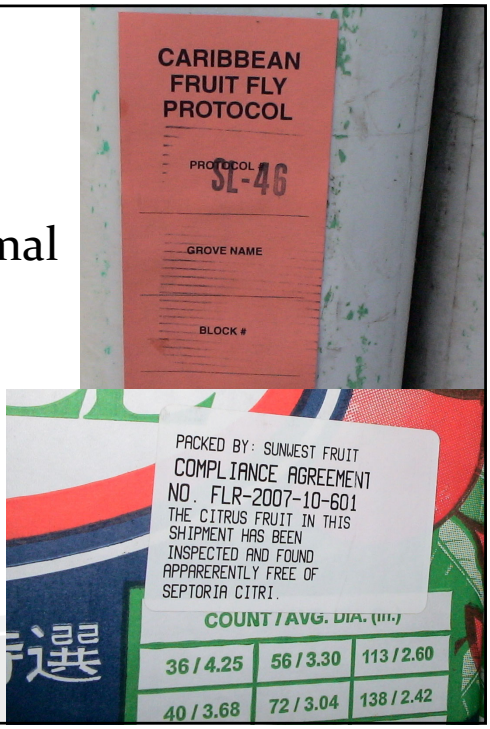
Treatments

- Treatment protocols are under the authority of the USDA Animal and Plant Health Inspection Service (APHIS)
- This includes overseeing treatment application



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Treatments

- Phytosanitary restrictions
  - Often a very high degree of insect control is required before commodities are allowed in
  - "Probit 9 mortality" = the treatment kills or sterilizes 99.9968% of the insect pests
    - ~ 3 survivor in 100,000 insects, or no survivors in 93,613 insects
- See http://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/treatment.pdf for a list of approved treatments

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Treatments Protocol Strategy

1. Kill the most resistant life stage of the pest (insect, etc.)
2. Cause NO physiological injury to the host commodity

- That's a TALL order! And it doesn't always work…

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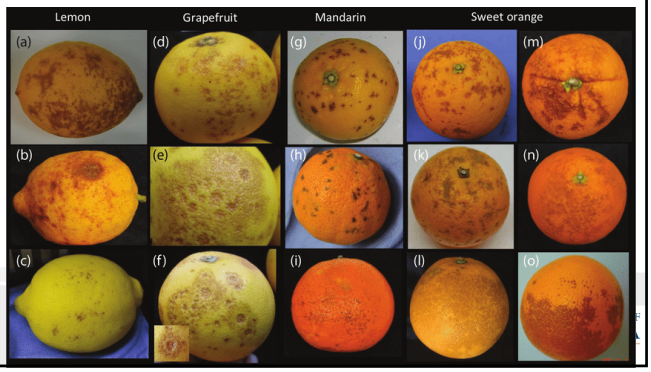
Unfortunately for Fresh Produce

- The most important aspect of any treatment(s) is
  - **Preventing pest introductions**
  - **NOT** on the impacts of those treatments on product quality!



https://www.researchgate.net/publication/330945775_Citrus/figures?lo=1

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Treatments

- Postharvest quarantine treatment factors are related to horticultural commodity differences
  - –Maturity
  - –Variety
  - –Source
  - –Handling procedures
  - –Cost

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Treatments

- Chemical
  - –Fumigation
  - –Detergent washes
  - –Insecticides
- Physical
  - Temperature
    - Cold treatments
    - Heat treatments
  - Irradiation
  - Controlled Atmospheres

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RA1

Fumigation

- Most common type of postharvest insect control
  - –both for disinfestation & storage
- Often easy to use and relatively inexpensive
- Future availability of some fumigants is questionable
  - –Human health issues
  - –Environmental impacts

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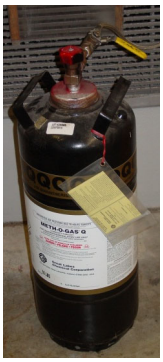
Methyl Bromide (MeBr)

- Most commonly used (general biocide)
- Under the Montreal Protocol (UN treaty):
  - – 2005 phase out for developed countries
  - – 2015 phase out for developing countries
  - – Quarantine treatments & "critical uses" are exempt
- In general, there is a time temperature relationship
  - – Higher temperatures require shorter exposure to the fumigant
- Many approved protocols may cause injury to the commodity



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Slide 17

RA1 Ritenour,Mark A, 10/3/2018

Commodities approved for methyl bromide fumigation:

grape	sweetpotato	yam
avocado	cut flowers	root crops
citrus	ornamentals	beans/lentils
pome fruit	leafy vegetables	berries
stone fruit	okra	celery
tomato	asparagus	cucumber
garlic/onion	kiwifruit	melons
pineapple	squash	sweetcorn
nuts	banana/plantain	potato

Schedule varies with target pest

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Phosphine

- Used limited to dried fruit and nuts
  - –Fresh commodities often injured
- Slower to act than MeBr and does not penetrate as well
- On dried products, its use is often alternated with MeBr
- Phosphine is a potential carcinogen & its future is in doubt

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Hydrogen Cyanide (HCN)

- Many commodities are injured by HCN exposure
- HCN is also very hazardous to people
- Thus, HCN is not used very often
  - Has been used for citrus

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Physical Treatments

Temperature

- Advantages:
  - No residue left on the commodity
  - Relatively safe for workers
- Disadvantages:
  - Possible product injury
  - Higher energy costs
  - Treatment times potentially longer

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Cold Treatments

- Approved for a variety of insects on many commodities
- Most effective on insects from subtropical and tropical environments
  - –However, crops from these areas are chilling sensitive
  - –Potential used of other conditioning treatments to help protect the crops from CI

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Commodities approved for cold treatment:

Plum	Apple	Pomegranate
Nectarine	Pear	Persimmon
Peach	Grape	Passionfruit
Apricot	Citrus	Kiwifruit

Schedule varies with target pest

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Example Cold Treatment Protocol
(Mediterranean Fruit Fly)

Days	Temperature*
10	0°C (32°F)
11	0.55°C (33°F)
12	1.11°C (34°F)
14	1.66°C (35°F)
16	2.22°C (36°F)

*Maximum allowable temperature

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Cold treatments can be applied during marine transport

However, if the temperature exceeds the maximum allowable, even by a fraction a degree at one reading, the treatment must be started over

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Conditioning Treatments
(for chilling sensitive commodities)

Commodity	Duration	Temperature (C)
Grapefruit	3-7 days	10-30
Mango	1-4 days	36-40
Tomato	<60 minutes	40-55
Avocado	10 hours	38

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Heat Treatments

- Hot water dips, vapor heat, and high-temperature forced air treatments
  - e.g., mango, lychee, papaya, citrus
- Vapor heat was one of the first postharvest insect control methods (1920's)

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Heat Treatments

- Often shorter treatments than cold treatments
  - –Size of commodity will affect the rate of heating
  - –Therefore, different protocols may exist for different varieties of the same commodity or the same variety produced in different countries.

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Mango Hot Water Treatment

- Min. pulp temp. at start of tmnt. 21°C (70°F)
- Fruit must be submerged >4 inches
- Water must circulate constantly and be min. of 46.1°C (115°F)
- Duration 65 to 90 min. depending on fruit origin, size and shape (variety)
- Fruit may be hydocooled after hot water tmnt. in water that is max. of 21°C (70°F)
- If hydrocooled: a) wait 30 minutes, or b) hot water treatment must be extended 10 minutes

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Mango Hot Water Treatment

1. Arrival

3. Pre-sizing

5. Hot water treatment

2. Inspection

4. Screened treatment area

6. Hydrocooling

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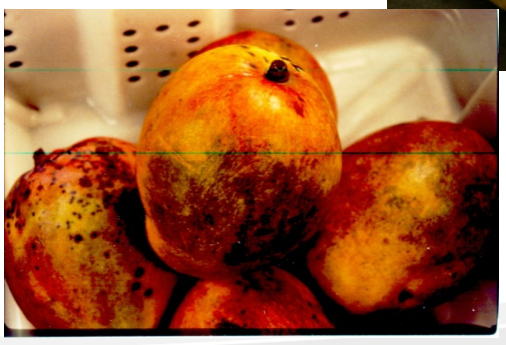
Examples

- Hot water treatment of mangos (various fruit fly species)

Internal cavitation



Scald

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Irradiation Treatments

- Gamma rays
  - –Isotopic sources: cobalt-60 or cesium-137
- X-rays
  - –Electrically driven machine source
- Electrons from E-beam

https://www.env.go.jp/en/chemi/rhm/basic-info/1st/02-02-04.html

Nuclear Disaster — **Radioactive Materials Derived from Nuclear Accidents**

	H-3 Tritium	Sr-90 Strontium-90	I-131 Iodine-131	Cs-134 Cesium-134	Cs-137 Cesium-137	Pu-239 Plutonium-239
Types of radiation	β	β	β, γ	β, γ	β, γ	α, γ
Biological half-life	10 days *1 *2	50 years *3	80 days *2	70-100 days *4	70-100 days *3	Liver: 20 years *4
Physical half-life	12.3 years	29 years	8 days	2.1 years	30 years	24,000 years
Effective half-life (calculated from biological half-life and physical half-life)	10 days	18 years	7 days	64-88 days	70-99 days	20 years
Organs and tissues where radioactive materials accumulate	Whole body	Bones	Thyroid	Whole body	Whole body	Liver and bones

Effective half-life: The time required for the amount of radioactive materials in the body to reduce to half through biological excretion (biological half-life) and the physical decay (physical half-life) of the radioactive materials; The values are cited from the "Emergency Exposure Medical Text" (Iryo-Kagaku Sha).
Effective half-lives are calculated based on values for organs and tissues where radioactive materials accumulate as indicated in the table of biological half-lives.
*1: Tritium water; *2: ICRP Publication 78; *3: JAEA Technical Manual (November 2011); *4: Assumed to be the same as Cesium-137; *5: ICRP Publication 48

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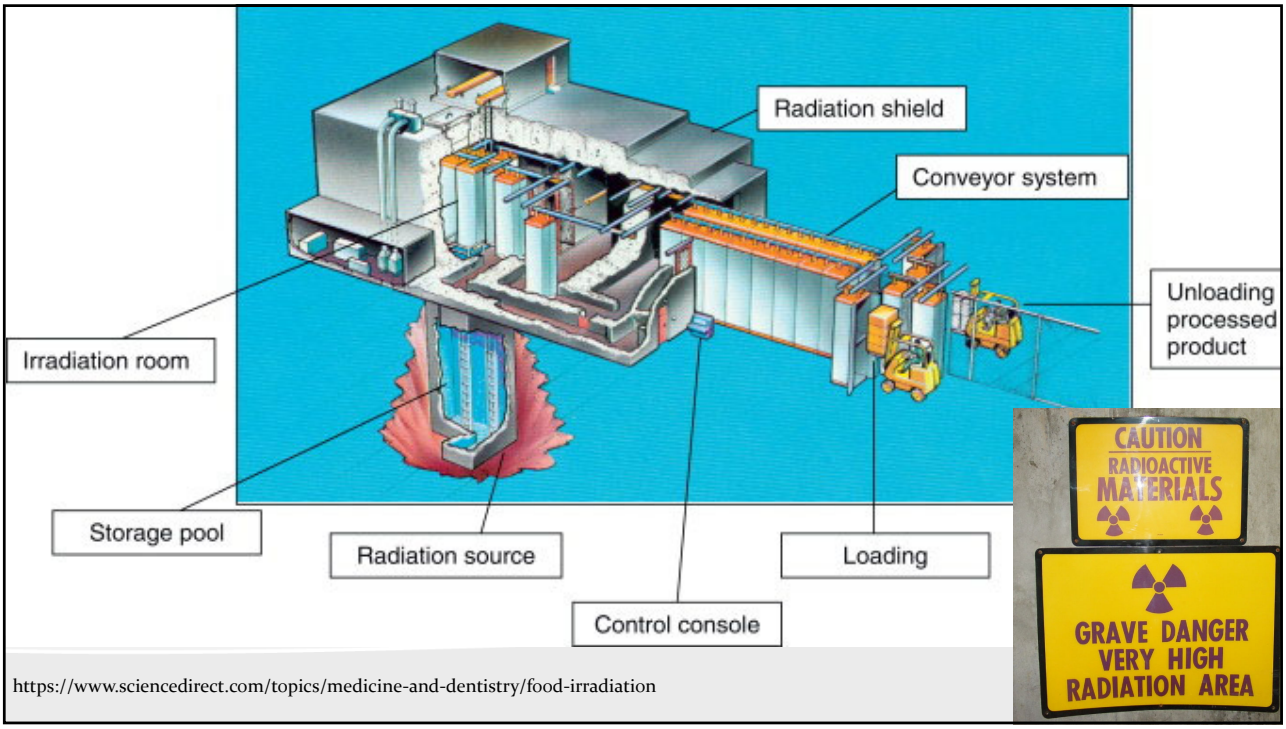

https://www.sciencedirect.com/topics/medicine-and-dentistry/food-irradiation

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Irradiation as a Quarantine Treatment

- Irradiation is approved for fruits and vegetables up to **1,000 Grays (Gy)** (FDA 1986)
- APHIS requires generic minimum doses of 70-400 Gy for various Tephritid fruit flies and other arthropod plant pests
  - *'Generic'* in that the required dose is not dependent on the commodity that is being treated, just the pest species

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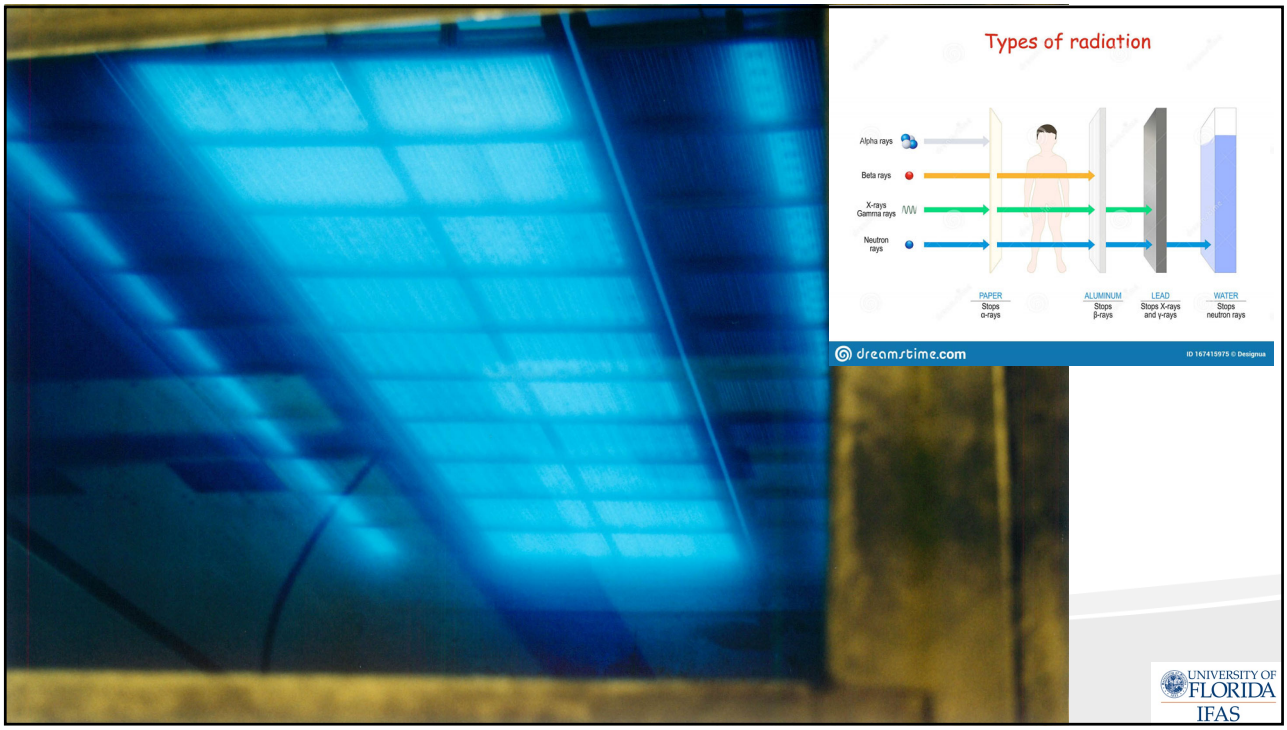

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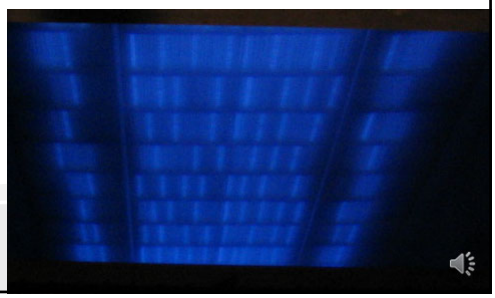
Irradiation Treatments

- Insect sterilization often requires doses < 300 Gy
- Decay control (esp. fungi) often requires doses > 1,000 Gy
- For required levels of irradiation to the center of pallets, outside product must receive 2-3X the minimum C60 or Cs137 dose
- E-beam requires treatment of individual cartons



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Sterilizing Dose versus Lethal Dose

- Sterilization Dose
  - 150 Gy for fruit flies
  - 300 Gy for other insects
- Lethal Dose - varies with species
  - 750 - 1000 Gy

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Irradiation Treatments

- When irradiation is used to sterilize insects, the receiving country must trust the exporters that the live insects they see are really harmless
- Social considerations:
  - US consumers are accepting more. Acceptance by other countries (not Japan, limitations for EU)?
  - Acceptance of irradiation facilities?

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Irradiation Effects on Ripening and Senescence

- Inhibits ripening of subtropicals and tropicals at 250-350 Gy
- Accelerates lemon degreening at >500 Gy
- May see uneven ripening and accelerated deterioration after treatment

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Relative tolerance of selected commodities to doses <1000 Gy

Minimal damage	Inconsistent results	Significant damage
Apple	Apricot	Avocado
Cherry	Banana	Cucumber
Guava	Citrus	Grape
Longan/rambutan	Fig	Green bean
Mango	Litchi	Olive
Muskmelon	Pear	Pepper
Papaya	Pineapple	Sapodilla
Peach/nectarine	Plum	Squash
Strawberry	Loquat	Soursop
tomato		

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Examples of injury (<1000 Gy) which may occur with storage

Commodity	Type of Injury
Avocado	Internal browning; skin discoloration
Lemon / Limes	Formation of cavities along segment walls
Oranges / Grapefruit	Peel damage, including pitting
Table Grapes	Stem darkening
Peppers	Calyx discoloration; accelerated discoloration

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Considerations pertaining to adoption of irradiation

- Some hosts are injured at <1000 Gy
- Sterilization dose vs. lethal dose
- Dosimetry
- Not a substitute for good handling
- Cost and Logistics
- Social Issues

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Controlled Atmospheres

- CA quarantine treatments involve raising the level of CO_2 and/or lowering the level of O_2 in combination with heat or cold to reduce the duration of the lethal treatment and help maintain commodity quality

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Controlled Atmospheres

- Insects vary in susceptibility to CA
- Commodities tend to tolerate low O_2 better than high CO_2
  - >60% CO_2 and/or <0.5% O_2 appear to be the best treatments
- Treatment duration is temperature dependent (higher temps = shorter duration)
- May be used in combination with heat or cold to reduce the duration of the lethal treatment and help maintain commodity quality
- Could be applied during marine transport

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Waxes and Other Coatings

- Presence of coatings can have dramatic effects on responses to quarantine treatments
- Probably due to internal tissue modified atmosphere effects

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Alternative Methods

- Systems Approach
  - Integration of numerous biological & physical factors with operational procedures to provide overall quarantine security
    - Can be time-consuming & costly to develop
  - Developed so that if one of the mitigating measures fail, built in safeguards keep the overall risk to negligible levels
- Eradication
  - Removal of all target pests from a geographical area, with little chance of normal re-infestation

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Alternative Methods

- Declaration as a Nonhost for all or part of its growth cycle
  - E.g., Unblemished, mature green 'Cavendish' bananas from Hawaii can be harvested and shipped to the mainland as a nonhost commodity even though ripe bananas are a preferred host for fruit flies
    - Fruit flies will not lay eggs on mature green bananas
  - This can be difficult because the physiological basis for host non-preference or non-suitability by a pest is often not understood

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Alternative Methods

- Establishment of Pest Free Areas (PFAs)
  - Officially identified or established areas in which a target pest does not occur and is maintained as such
  - The identity of the commodity must be maintained throughout to prevent mixing with non-certified product
  - Enhanced by geographic (e.g., mountains or large bodies of water) or temporal (i.e., developmental period of sysceptibility) barriers

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Experimental Treatments

- New fumigants
  - E.g. methyle iodide, carbonyl sulfide, sulfuryl fluoride, & ozone
- New temperature treatments
  - E.g. used of radio frequency (RF) & conditioning treatments
- Hyperbaric pressure & Vacuum

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