

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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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

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



- 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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Overview

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




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Inspections: USDA APHIS




<https://www.cnbc.com/2021/09/15/carriers-rejected-at-least-4point3-billion-in-potential-us-agricultural-exports.html>

<https://www.aircargonews.net/cargo-airport/stansted>



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Quarantine Treatments

- Treatment protocols are under the authority of the USDA Animal and Plant Health Inspection Service (APHIS)
- This includes overseeing the treatment application, even done in the exporting country

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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 <https://acir.aphis.usda.gov/s/treatment-hub#a1X3dooooo04zk6EAA-9> for a list of approved treatments

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Treatment 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 quarantine treatment is:
 - Preventing pest introductions**
 - NOT the impact of the treatment on product quality!**




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

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Treatments


- Chemical**
 - Fumigation
 - Detergent washes
 - Insecticides
- Physical**
 - Temperature
 - Cold treatments
 - Heat treatments
 - Irradiation
 - Controlled atmosphere



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Fumigation


- Most common** type of postharvest insect control
- Often **easy to use and relatively inexpensive**
- Very effective in terms of distribution and penetration
- Future availability 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):
 - Phased out for other uses
 - 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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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


Scheduled with tar



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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 conditioning treatments to help protect the crops from CI




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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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Conditioning Treatments (before cold tmnt. 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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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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Cold treatments are sometimes applied during marine transport


- The transit time may already be as long as the cold treatment protocol
- However, if the temperature exceeds the maximum allowable temperature, even by a fraction a degree at one reading, the treatment must be started over



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Heat Treatments


- Hot water, 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


- Mostly 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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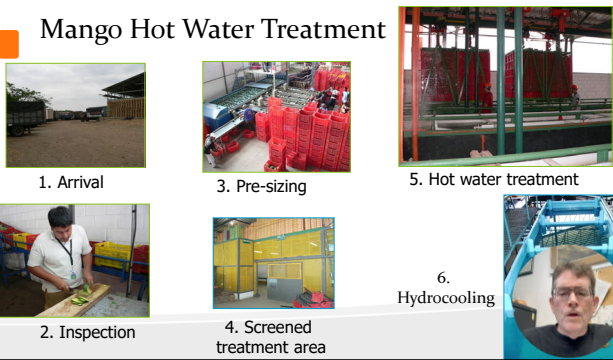
Mango Hot Water Treatment

- 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 hydrocooled after hot water tmnt. in water that is max. of 21°C (70°F)
- If hydrocooled, must: a) wait 30 minutes, or b) hot water treatment must be extended 10 minutes




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Mango Hot Water Treatment



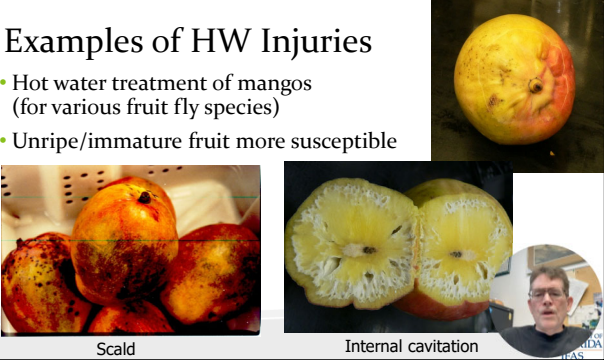
1. Arrival
2. Inspection
3. Pre-sizing
4. Screened treatment area
5. Hot water treatment
6. Hydrocooling




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Examples of HW Injuries

- Hot water treatment of mangos (for various fruit fly species)
- Unripe/immature fruit more susceptible




Scald Internal cavitation



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Irradiation Treatments

- Sterilize versus kill insects
- Gamma rays: cobalt-60 or cesium-137
- X-rays
 - Electrically driven machine source
- Electrons from E-beam



Nuclear Isotopes	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	50 years ¹	80 days ²	70-100 days ³	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 (combination)	10 days	18 years	7 days	64 d		
Organs and tissues where radioactive materials accumulate	Whole body	Bones	Thyroid			


Effective half-life: The time required for the amount of radioactive material to be reduced to one-half of its original amount. Biological half-life: The time required for the amount of a substance to be reduced to one-half of its original amount. Physical half-life: The time required for the amount of a substance to be reduced to one-half of its original amount. The effective half-life is the time required for the amount of a substance to be reduced to one-half of its original amount when both biological and physical decay are occurring. The effective half-life is always less than either the biological or physical half-life.

<https://www.epa.gov/jp/cn/chemi/rhm/basic-info/ut/02-02-04.html>

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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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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 2-3-fold the minimum C60 or Cs137 dose
- E-beam requires treatment of individual cartons



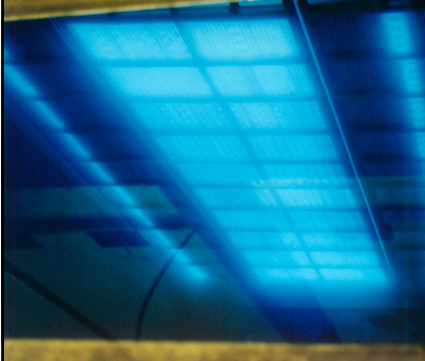
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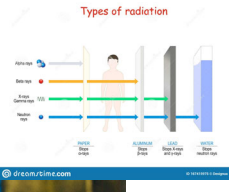

An irradiation facility in Dover, Florida



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Types of radiation

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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

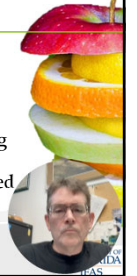
Minimal damage	Inconsistent results	Significant damage
Apple	Apricot	Avocado
Cherry	Banana	Cucumber
Guava	Citrus	Grape
Longan/rambutan	Fig	Green bean
Mango	Litchi	Olive
Muskmelon	Pear	Pepper
Papaya	Pineapple	Sapodilla
Peach/nectarine	Plum	Squash
Strawberry	Loquat	Soursop
Tomato		



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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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Controlled Atmospheres

- CA quarantine treatments involve raising the level of CO₂ and/or lowering the level of O₂ in combination with heat or cold to reduce the duration of the lethal treatment and help maintain commodity quality
- More common for grains than produce



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Controlled Atmospheres


- Insects vary in susceptibility to CA
- Commodities tend to tolerate low O₂ better than high CO₂
 - >60% CO₂ and/or <0.5% O₂ 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 and package liners or wraps 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 **Non-host** 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 non-host 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 susceptibility) barriers



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Experimental Treatments

- New fumigants
 - e.g., methyl 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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