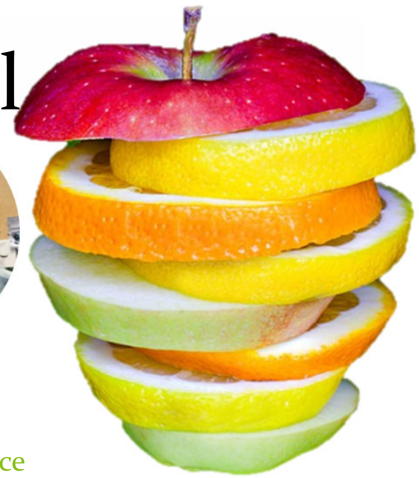
Postharvest Pathololology - Environmental Factors & Control



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Revised from a lecture by Jerry Bartz, UF/IFAS Plant Pathology Dept.

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General strategy

- Although thermo processing will stop most decay pathogens, who wants to eat cooked lettuce, etc.???
- Therefore, we rely on creating "hurdles" that inhibit decays—as many as necessary to achieve our marketing goals.
- Hurdles are selected that avoid visible chemical residues and are compatible with measures that minimize the potential for contamination by human pathogens.

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Individual hurdles remove or shorten one or more of the three legs of the disease triangle

- Making the environment unfavorable is the #1 hurdle because it includes measures that:
  - Inhibit disease development
  - Inhibit development of hazardous microorganisms
  - Protect product quality
  - Are compatible with storage and marketing
  - Avoid regulatory issues
  - Are consumer friendly

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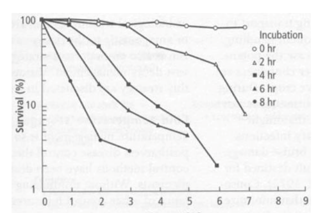
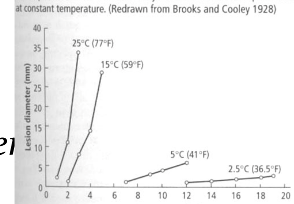
Cooling, the most important hurdle for protecting perishable crops



- Noel Sommer at U.C., Davis, noted that refrigeration is so important for controlling postharvest decays that all other measures may be regarded as supplements.
- Cold or even cool creates stasis among decay pathogens— cold doesn't kill most pathogens although germinating spores of *Rhizopus stolonifer* are irreversibly inhibited by exposure to ≤ 5°C.
- Cold delays ripening and senescence which helps to preserve host resistance.
- Cold delays disease onset and development

Development of brown rot caused by *Monilinia fructicola* in peach fruits at constant temperature. (Redrawn from Brooks and Cooley 1928)



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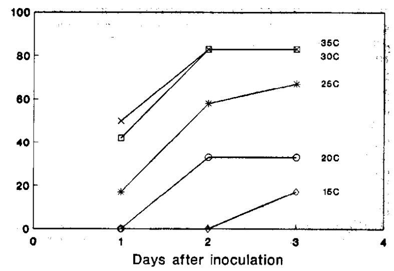
Bacterial soft rot in tomato fruit as affected by storage temperature



Fruit were wound inoculated—note that decay incidence among fruit stored at 20°C doesn't keep increasing such as those stored at higher temperatures

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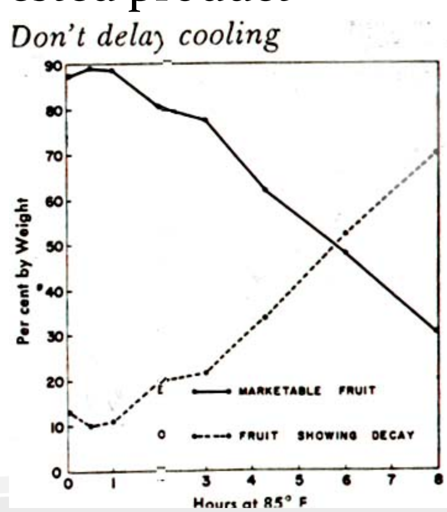
Don't delay cooling a freshly harvested product

- Delay in cooling strawberries leads to increased decay and decrease in marketable fruit among fruit in cold storage (4.4 C.) From Mitchell, et al. 1978. Cal Ag. Exp. Station. Circ 527



Field temperature was 85 F (29 C)

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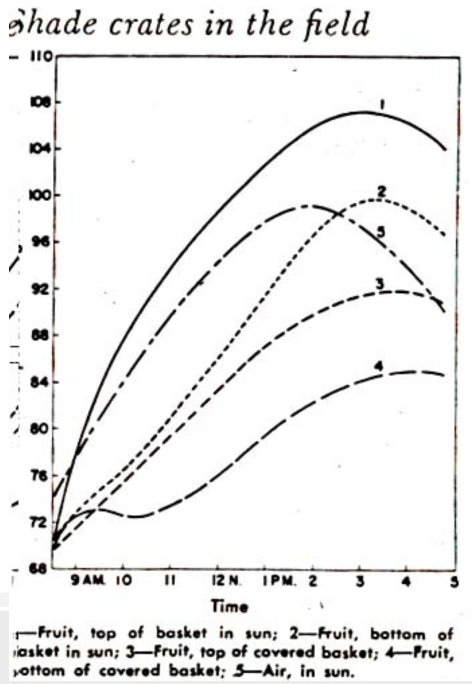
Exposure to sunlight in the field increases cooling costs, especially with fruits or vegetables directly exposed to the sun.



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Atmosphere composition hurdle (MA/CA)

- Affects all three legs—weakens pathogen, maintains host resistance and makes environment less favorable
  - Modified atmosphere--product respiration maintains atmosphere when stored under a differentially permeable cover
    - High CO_2 (>10 to 15%) or low O_2 (<2%) slows pathogen growth and commodity senescence—reduces respiration and inhibits activity of ethylene
    - Reduction in senescence slows decay onset
    - Most fresh fruits and vegetables require at least 2% O_2
    - Only a few fruits and vegetables will tolerate ≥15% CO_2
  - Controlled atmosphere—more precise control of atmospheres—used for long term storage of pome fruits
  - Carbon monioxide (CO) – 5 – 10%; synergistic with <5% O_2 for control of fungi, but CO alone can mimic ethylene
  - Hypobaric storage (reduced atmospheric pressure)– looked promising but equipment was expensive and now company out of business!

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Resistance hurdle

- Use cultivars with decay resistance.
- Anticipate field environment at time of expected harvest—avoid planting such that product matures during rainy or cold periods (note that the market may lead growers to take chances).
- Avoid rough harvests—resistance is compromised by injury—includes journey from field to packinghouse
- Use appropriate storage conditions if wound-healing (curing) is needed.
- Treat plants preharvest or postharvest with calcium salts

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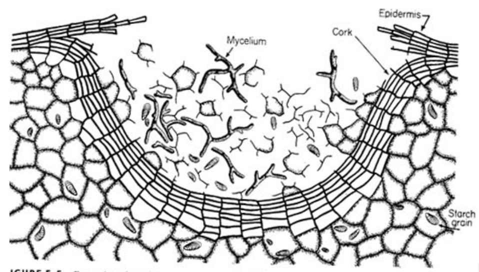
Examples of using host resis

That bucket should be lowered to the pile surface before being emptied

- Rough handling at harvest
- Promote wound healing
- Calcium treated potatoes

Increased calcium in tissues = resistance to soft rots



IGURE 5-5 Formation of a cork layer on a potato tuber following infection with *Rhizoctonia*. [After G. E. Ram- ›y (1917), *J. Agric. Res.* 9, 421–426.]

Wound periderm forms walling off wound with cork cells to the outside—prevents moisture loss and direct exposure of unprotected cells to

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Shorten pathogen leg of triangle

- Remove potential sources of pathogens from field, production area or around packinghouse—never dump culls near or upwind of field, greenhouse or high tunnel
- Clean and sanitize picking containers—surfaces must be clean before they can be adequately sanitized
- Teach field crews to avoid decayed material
- Never pick up a fruit or vegetable that has fallen on the soil or mulch surface
- Use approved sanitizer to keep wash/handling water from dispersing pathogens

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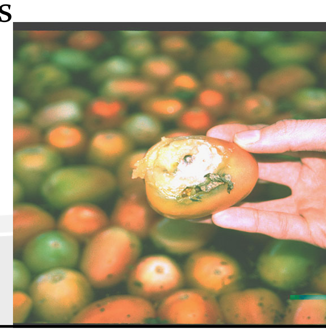
Tomatoes as an example of sanitizing handling water

- Unloading gondola of tomatoes into water flume
- Flume moves tomatoes to packingline—due to volume of water required, the water is recirculated. Microbes of various types accumulate in the water
- A sample of “pre-ripened” Roma tomatoes



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Sanitizers - chlorine

- Chlorine gas/solution of hypochlorite salt/pellet of hypochlorite salt -- Cl_2 or $Na(OCl)_2$ or $Ca(OCl)_2$
  - Active ingredient = HOCl—20 to 300× more toxic than OCl^-
  - pH most important in controlling ratio of ion to acid
  - Not volatile at appropriate pH—Can use in heated water—Chlorine odors are actually DBPs (disinfection by products)
  - No residual left on product
  - Highly reactive particularly with NH groups
  - Add make-up product to maintain necessary concentration—measure free chlorine or ORP
  - Add buffers to maintain pH in range of 6.0 to 7.5
    - More corrosion at lower pH levels-off gas at very low pH levels <ca. 5.0.
    - Noticeably slower activity at 7.5 versus 6.0
  - Disinfection by products are concerns—chloramines, trihalomethanes
  - Removes lignin from wood—weakens wooden truck bodies when used as a pre-dump drench
  - Doesn't penetrate well—embedded microbes are protected
  - Florida tomato rules call for 150 to 200 ppm free available chlorine

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--Chlorine dioxide

- Can be used in water but concentration is much lower than chlorine (ca. 5 ppm)
- As a "dry treatment", gas produced in enclosed area
- Much more soluble in water than chlorine or ozone
- Since microbes are coated with water, chlorine dioxide gas dissolves and oxidizes surface of microbe
- Used to decontaminate US Senate Office Building
- Gas will penetrate common paper goods
- Produced from sachets that contain sodium chlorite and a proprietary reactant when RH > 30%
- Can be explosive

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--Ozone

- Much more reactive than chlorine or chlorine dioxide
- Not very soluble in water with a half-life of about 20 min (20 ppm in air/10 h or 1.5 ppm in water)
- Must be produced on site and system must be closed—more toxic to workers than chlorine dioxide (0.3 ppm OSHA limit)
- No easy "on-line" way to measure ozone residual
- Has been tested as space treatment but phytotoxicity has been a problem (e.g., lenticel bleaching, tissue browning)

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Ozone damage on head lettuce

Immediately after ozone treatment (200 ppm)

5 days after ozone treatment

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Peroxides

- Hydrogen peroxide
  - Not volatile
  - Higher oxidation reduction potential than chlorine
  - Does not penetrate into microbes
  - Breaks down into water and oxygen
  - Not nearly as effective as other oxidizers (applied at concentrations up to 5%)
- Peroxyacetic acid
  - Mixture of hydrogen peroxide and acetic acid yields peroxyacetic acid
  - Used in vegetable processing plants to control biofilims
  - Breakdown products include acetic acid in addition to water and oxygen (odor issue)
  - Much more expensive than chlorine (used at 80 ppm)
  - Not as effective on fungal spores as on bacteria

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Reactive oxygen species (ROS)

- Atmosphere in treatment chamber contains ozone plus oxygen free radicals (ROS)
- Ozone comes out of the treatment chamber in the emitter type units
- General effect on products is the same as ozone

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Maintaining oxidants in process water

- Since oxidants are depleted by contact with fruit and vegetables as well as debris and other reducing agents, measure active levels with periodic "hand" tests using a kit or indicator strip.
- Measure oxidation-reduction potential (ORP)—usually continuous
  - Slower to equilibrate but can be wired to pumps that add product and stabilizers (buffers, acids or bases).
  - Probes (like a pH probe) can become fouled so the ORP should be compared with kit readings hourly.

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Heat

- Hot air
  - Tomato fruit stored for 3 days at $38^{\circ}C$ for control of Botrytis fruit rot
  - Hot-air treatment of mangoes for control of anthracnose
    - Therapeutic
    - Difficult to control temperatures
    - Air is inefficient conductor of heat
    - Margin between killing pathogen and damaging host is narrow
- Hot-water treatment (mangoes, stone fruits)
    - $46^{\circ}C$ for 60 min, 51 to $55^{\circ}C$ for 5 to 30 min
    - Therapeutic
    - Prone to damage fruit
    - Not compatible with cooling, modern packinglines

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"Biocontrol" agents

- Theoretical
  - Safe, naturally occurring saprophytes that live epiphytically on plants
  - Colonize plant surfaces and especially wounds, thereby competing with pathogens
  - Does not produce antibiotic (no residue issues)
  - Either sequesters essential compounds or uses available nutrients before pathogen begins colonizing host tissues
  - May parasitize the pathogen
- Actual
  - Must usually be present at concentrations 2 logs greater than pathogen
  - Apply antagonist with antagonist-specific nutrition?—still experimental, no actual products available
  - Some interest in combining fungicide resistant antagonists with fungicide application
  - Problems with formulation
    - Microorganisms tend to change during mass culture (adapt to grow on culture rather than plant)
    - Large volumes must be produced
    - Uniform application is necessary
    - Stability on shelf may be an issue
  - Current products = Bio-save 10, Bio-save 11--*P. syringae* strains, apple and citrus
  - Aspire -- *Candida oleophila* in apples and citrus

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Fungicides

- Theoretical
  - Apply fungicide preharvest to prevent infection of fruit or vegetable (where pathogens become quiescent)
    - Difficult to protect senescing plant tissues such as flower petals
    - Exposure of pathogen in field (variation in dose and long period in contact) creates ideal conditions for fungicide resistance
  - Apply fungicide on packingline (less common than preharvest application)
    - Certain commodities are field packed and not amenable to fungicide application
    - Liquid applications don't penetrate well—can't have visible residue
    - Mix fungicide with wax and apply wax to fruit—wax may or may not be heated

- Practical examples
  - Preharvest applications up to last possible date as per label re-entry date before harvest
    - Fenheximide, captan or thiram applications to strawberries at peak bloom protects against Botrytis fruit rot in storage
    - Regular applications of captan to strawberries during season reduce Botrytis fruit rot postharvest
    - Various fungicides applied to citrus for control of Penicillium spp, stem-end decay, and blossom drop/anthracnose

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Essential oils (part of a plant's defense against pathogens and parasites)

- Extensive research but few commercial products
  - Thyme, cinnamon, eucalyptus, clove, oregano, lemongrass, cilantro
  - Some of these oils include the same active ingredients (e.g., carvacrol)
- Inhibitory levels in growth medium or on plant tissues for postharvest pathogens are generally higher than those of commercial fungicides
- Difficult to obtain an effective residual on fruits and vegetables (they're volatile)
- Remember—"All things are poison, and nothing is without poison; only the dose makes a thing not a poison." Paracelsus

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Putting hurdles together

- When decays are slow to develop, control measures are more effective because pathogen populations are smaller and less vigorous.
- Wider array of alternative measures can be used.
- Inoculated commodities do not become diseased before they are consumed
- Commodities may be successfully shipped to more distant markets.
- Arguably, products are fresher because the turnover is more rapid.

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