Controlling Postharvest Diseases

Jerry Bartz, postharvest pathologist

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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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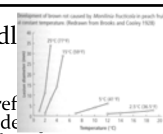
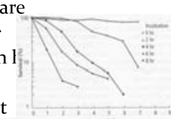
Cooling, the most important hurdl[e in] protecting perishable crops



- Noel Sommer at U.C., Davis, noted that ref[rigeration is] so important for controlling postharvest de[cay that] 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 h[elps] preserve host resistance.
- Cold delays disease onset and development



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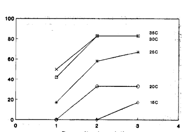
Bacterial soft rot in tomato fruit as affected by storage temperature



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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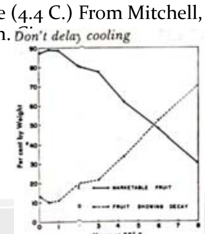
Don't delay cooling a freshly harvested product

- 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. Cal Ag. Exp. Station.



Field temperature assumed to be 85 F (29 C)

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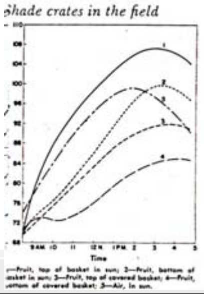
Exposure to sunlight in field increases cooling costs especially with fruit or vegetables directly exposed to the sun.

Shade crates in the field



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Atmosphere composition hurdle

- 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
  - CO – (5 – 10%) synergistic with <5% O_2 for control of fungi, but CO alone can mimic ethylene
  - Hyperbaric 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 pre-harvest or post-harvest with calcium salts

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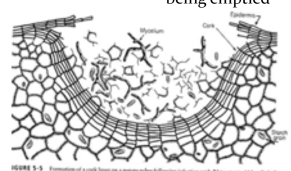
Examples of using host resistance

That picking bucket should be lowered to surface of pile before being emptied

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

Increased calcium in tissues = resistance to soft rots



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

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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 /Na or LiOCl/$Ca(OCl)_2$
  - 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
- Produced from sachets that contain sodium chlorite and a proprietary reactant when RH > 30%

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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
- No easy "on-line" way to measure ozone residual
- Has been tested as space treatment but phytotoxicity has been a problem

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Ozone damage on head lettuce

Immediately after ozone treatment

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 biofilms
  - Breakdown products include acetic acid in addition to water and oxygen
  - Much more expensive than chlorine (used at 80 ppm)
  - Not as effective on fungal spores as bacteria

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Reactive oxygen species

- Atmosphere in treatment chamber contains treated with ozone and free radicals
- Ozone comes out of the treatment chamber
- 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

- Warmed air
  - Tomato fruit stored for 3 days at 38°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°C for 60 min, 51 to 55°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 saprophyte that lives epiphytically on plants
  - Colonizes plant surfaces and especially wounds thereby competing with pathogen
  - Does not produce antibiotic
  - Either sequesters essential compound or uses available nutrition before pathogen begins colonizing host tissues
  - Parasitizes pathogen
- Actual
  - Must usually be present at concentrations 2 logs greater than pathogen
  - Are examining applying 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
    - Large volumes must be produced
    - Uniform application
    - Stability on shelf
  - Current products = Bio-save 10, Bio-save 11--*P. syringae* strs. 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
    - Certain commodities are field packed
    - 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
  - Preharvest applications
    - Fenheximide, captan or thiram applications to strawberries in peak bloom protects against Botrytis fruit rot in storage
    - Regular applications of captan to strawberries during season reduces 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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Fungicides--II

- Postharvest applications
  - Sodium orthophenyl phenate – applied to citrus to control Penicillium (green and blue mold), some efficacy against sour rot. Enters wounded tissues where it is converted to orthophenyl phenol, which is phytotoxic
  - Fludioxonil–low risk fungicide, a pyrrolnitrin compound derived antibiotic produced by *Pseudomonas* now *Burkholderia cepecia* –excellent activity in citrus, stone, and pome fruits
  - Azoxystrobin –low risk fungicide, derived from antibiotic produced by mushroom produced by fungus growing on pine-cone litter, has locally systemic activity

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Essences (short for essential oil) and extracts of plants (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. caravcrol
- 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
- Remember—"All things are poison and nothing is without poison; only the dose makes a thing not a poison." Quote from 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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