**Ethylene Inhibition and Control**

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(Modified from a presentation prepared by Mike Reid, UC Davis)

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**Ethylene Effects in Postharvest Horticulture**

<table>
<thead>
<tr>
<th>Desirable</th>
<th>Deleterious</th>
</tr>
</thead>
<tbody>
<tr>
<td>Promotes faster, more uniform fruit ripening</td>
<td>Promotes ripening &amp; softening of fruits</td>
</tr>
<tr>
<td>Used for degreening of citrus</td>
<td>Hastens senescence &amp; yellowing of plant tissues</td>
</tr>
<tr>
<td>Loosens fruits &amp; nuts for mechanical harvest</td>
<td>Promotes abscission of leaves and flowers</td>
</tr>
<tr>
<td></td>
<td>Promotes phenolic metabolism related to lignification and oxidative browning</td>
</tr>
<tr>
<td></td>
<td>Causes/promotes some physiological disorders</td>
</tr>
</tbody>
</table>

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**Ethylene - an important factor**

- **Useful:**
- **A problem:**

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**Senescence & Yellowing**

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**Russet Spotting**

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Ethylene-induced damage to harvested fruit.

Ripe ‘Millionaire’ watermelon fruit stored in ethylene or air for 6 d at 20 °C.

Source: Don Huber, UF
**Where does ethylene come from?**

- Smoke
- Vehicle exhausts
- Ripening rooms
- Ripening climacteric fruit
- Decaying produce
- Fluorescent ballasts
- Rubber exposed to heat or UV light

**The ultimate undesirable ethylene effect!!**

Explosion, fire destroy banana ripening facility

**Overcoming Ethylene Effects**

- Low temperature
- Avoidance
- Removal
- Inhibition of production
- Inhibition of action
- Germplasm selection/engineering

**Effects of temperature**

1 ppm ethylene, 1 day

**Effect of Temperature on Ripening Rate of Stone Fruits Exposed to 100 ppm Ethylene for 48 Hours**

<table>
<thead>
<tr>
<th>Tempeature (°C)</th>
<th>Nectarine</th>
<th>Peach</th>
<th>Plum</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>6.9</td>
<td>5.6</td>
<td>5.6</td>
<td>6</td>
</tr>
<tr>
<td>20</td>
<td>4.3</td>
<td>3.8</td>
<td>3.7</td>
<td>4</td>
</tr>
<tr>
<td>25</td>
<td>3.2</td>
<td>2.7</td>
<td>2.7</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: Mike Reid

**Fluctuation of Ethylene Levels Corresponding to Forklift Activity**

Fluctuation of Ethylene Levels Corresponding to Forklift Activity

**Effect of Temperature on Ripening Rate of Stone Fruits**

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Ripening Rate (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>30</td>
<td>7</td>
</tr>
<tr>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
</tr>
</tbody>
</table>

Source: Calif. Tree Fruit Agreement
Avoiding Exposure to Ethylene

- Exclusion of ethylene from storage rooms
  - Use of electric forklifts
  - \(\text{C}_2\text{H}_4\) absorber on forklift exhaust
  - Avoiding other pollution sources
  - Avoiding mixing ethylene-producing and ethylene-sensitive crops
    - Storage rooms
    - Mixed loads

Avoiding Exposure to Ethylene

- Avoid stresses
  - Physical damage, diseases, fumigation, irradiation, etc. are all stresses that stimulate ethylene production

Removal of Ethylene

- Use of adequate ventilation (1 air exchange per hour with fresh air)
- Use of ethylene absorbers
  - Potassium permanganate (alkaline \(\text{KMnO}_4\) on inert pellets = “Purafil,” “Ethysorb,” “Ethylene Control,” etc.)
  - Activated and brominated charcoal +/− \(\text{KMnO}_4\) = “Stayfresh” absorbers

Effect of impacts on respiration and ethylene production of tomatoes damaged at the mature-green stage and held at 20°C.

Source: MacLeod et al., 1976, HortScience

Source: Mike Reid

Source: Ethylene Control, Inc.
**Removal of Ethylene**

- Use of ozone or UV radiation to oxidize ethylene:
  - Ozone may be produced by corona discharge
  - UV reacts with oxygen to produce ozone
    - May need to remove excess O$_3$ to avoid injury to fruits & vegetables
    1. O$_2$ + UV $\rightarrow$ O$_3$
    2. C$_2$H$_4$ + [O] $\rightarrow$ CO$_2$ + H$_2$O

**Removal of Ethylene**

- Use of low pressure systems (i.e., hypobaric CA storage)
  - 1/10 atm = 1/10 gas concentrations in storage atmosphere (e.g., 2.1% O$_2$)
  - Low pressure also facilitates gas (i.e., C$_2$H$_4$) diffusion from fruit tissue

**Removal of Ethylene**

- Removal of ethylene from storage rooms
  - Oxidation of ethylene with Pt or oxide catalysts + heat (200-300°C)
  - Low temperature catalysis (e.g., TiO$_2$ + UV radiation at ~100°C)

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**Inhibiting Ethylene Production & Action**

- Controlled and modified atmospheres
  - Low oxygen and high CO$_2$ inhibit ethylene production and action

**Factors Affecting Ethylene Production & Action**

- Oxygen level
  - reduced O$_2$ (<8%) reduces ethylene action and production rates
  - Elevated O$_2$ (>21%) stimulates ethylene production and action
- CO$_2$ level
  - CO$_2$ competitively inhibits ethylene action, consequently, it can also inhibit autocatalytic ethylene production
**Inhibiting Ethylene Production & Action**

- **Biosynthesis inhibition**
  - AVG (aminoethoxyvinylglycine)
  - Inhibits ACS (i.e., SAM → ACC)
  - Retain
- **Action inhibition**
  - 1-MCP (1-methylcyclopropene)
  - Irreversibly binds to ethylene receptors
  - ‘SmartFresh’

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**1-MCP - a new ethylene inhibitor**

- Ed Sisler, NCSU
- Mimics ethylene, blocks the binding site
- Marketed for fruits and vegetables as ‘SmartFresh’
- First marketed for ornamentals as ‘EthylBloc’

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**Already in use to extend life of fruits and vegetables**

Fresh-cut ripe ‘Sunrise Solo’ papaya fruit derived from either air-treated fruit or fruit treated with an ethylene antagonist (1-MCP)

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**1-MCP effects may be transient**

Plants were treated with 1-MCP on day 0, then exposed to ethylene on days 1, 2 or 3

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**Avoiding Ethylene Effects**

- Selection of ethylene-resistant germplasm
Avoiding Ethylene Effects

- Understanding ethylene action
- Ethylene binds to a number of different receptors in several “families”
  - receptor-kinase complexes act to prevent constitutive ethylene responses in the absence of ethylene
  - ethylene binding “de-represses” the response pathways

Ethylene Action

- In other words, ethylene responses are always ready to go, being held back by the receptors (negative regulators)
- When ethylene binds to receptors, it is like pulling a plug, allowing an almost instantaneous cascade of responses to proceed

Mechanism of Ethylene Action

- etr1 mutation revealed by lack of triple response

Avoiding Ethylene Effects

- Biotechnology to interfere with the action cascade
Biotechnology!

Use of the Ethylene Receptor Gene

• Insert mutated gene in a sensitive plant - it becomes insensitive

Use of the Ethylene Receptor Gene

• Use tissue-specific, or stage-specific ‘promoter’ - ethylene action is inhibited only in that tissue or at that time (e.g., mature flowers, ripe fruits)
  • Already done with petunias, carnations, kalanchoes, campanulas
• Use ‘inducible’ promoters to engineer plants where ethylene can be inhibited at will

Manipulating genes inducible promoter

DNA

RNA

Protein

Cell
Nucleus

Dexamethasone
Ecdysone
Alcohol
Heat shock
Copper ions

Questions?

Thank you!