I. Processes Associated with Fruit Ripening

- Change in $\text{C}_2\text{H}_4$ production (climacteric fruits only)
  - increase in endogenous ethylene concentration until adequate to initiate ripening
  - autocatalytic ethylene production
- Increased sensitivity to $\text{C}_2\text{H}_4$ (climacteric fruits only)

II. Factors Influencing Climacteric Fruit Ripening

- Factors that affect $\text{C}_2\text{H}_4$ production and action can all be manipulated to control ripening

- Seed maturation
  - ability of seeds to germinate successfully
- Development of wax
- Abscission of fruit

I. Processes Associated with Fruit Ripening

- Change in respiration rate
  - increased $\text{O}_2$ consumption and $\text{CO}_2$ production in climacteric fruits
- Membrane and cell wall changes
  - increased membrane permeability \(\rightarrow\) juice leakage
  - depolymerization of pectins and other cell wall polysaccharides \(\rightarrow\) softening

- Protein and nucleic acid changes
  - synthesis of enzymes involved in compositional changes
- Compositional changes
  - starch to sugar conversion
  - pigmentation synthesis (anthocyanins & carotenoids) and degradation (chlorophyll)
  - polymerization of tannins and resulting loss of astringency
  - formation of flavor volatiles
II. Factors Influencing Climacteric Fruit Ripening

- Ethylene treatment
  - promotes faster and more uniform ripening by coordinating the onset of ripening
  - reduced time between harvest and consumption can mean better quality and nutritive value

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

<table>
<thead>
<tr>
<th>Temperature (°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>

Ethylene Effects on Fruit Ripening as Indicated by Flesh Firmness of Stone Fruits

<table>
<thead>
<tr>
<th>Days at 30°C</th>
<th>Treatment</th>
<th>Nectarine (kg)</th>
<th>Peach</th>
<th>Plum</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>At harvest</td>
<td>5.3 ± 0.9</td>
<td>6.9 ± 0.7</td>
<td>2.8 ± 0.9</td>
</tr>
<tr>
<td>4</td>
<td>Without added ethylene</td>
<td>1.0 ± 0.5</td>
<td>1.3 ± 0.5</td>
<td>1.7 ± 1.0</td>
</tr>
<tr>
<td>4</td>
<td>With 20 ppm ethylene</td>
<td>0.8 ± 0.2</td>
<td>1.0 ± 0.3</td>
<td>0.8 ± 0.5</td>
</tr>
</tbody>
</table>

III. Undesirable Ethylene Effects

- Undesired ripening and softening of fruits in storage
- Accelerated senescence and loss of green color in leafy and immature fruit vegetables (e.g., cucumbers)
- Abscission of leaves (e.g., cauliflower, cabbage, foliage plants, etc.)
- Sprouting (stimulation or retardation)

III. Undesirable Ethylene Effects (cont.)

- Induction of phenolic synthesis
  - bitter principle (isocoumarin) in carrot roots
  - toxic ipomeamarone in sweet potato roots
  - russet spotting on lemon
  - lignification of asparagus
III. Undesirable Ethylene Effects (cont.)

- Physiological disorders of ornamental crops
  - 'sleepiness' of carnations (failure of bloom to open)
  - flower and leaf abscission
  - inhibition of shoot and root elongation; gummosis; bud necrosis and flower bud blasting in bulb crops

III. Undesirable Ethylene Effects (cont.)

- The ultimate undesirable ethylene effect!!

Explosion, fire destroy banana ripening facility

The Packer
July 12, 1999

IV. Postharvest Sources and Levels of Ethylene in Lettuce Handling

- Fluctuation of Ethylene Levels Corresponding to Forklift Activity

Fig. 2: Fluctuations of ethylene concentration in a cold room used for holding lettuce after cooling, where propane-fueled forklifts were operated during a 3-day period.

V. Commercial Use of Ethylene

- Methods of application
  - Cylinders of ethylene or banana gas (C₂H₄ in CO₂) with flowmeters
V. Commercial Use of Ethylene

- Methods of application
  - Ethylene generators
    (liquid ethanol plus
    catalyst \(\rightarrow C_2H_4\))

- Ethylene-releasing chemicals (e.g.,
  Ethephon = 2-chloroethane-phosphonic acid)

- Intended for field application, but sometimes used
  postharvest

V. Commercial Use of Ethylene (cont.)

- Ethylene concentration and duration of treatment
  - physiological response saturated at 100 ppm
  - mature climacteric fruits should initiate endogenous
    ethylene production within no more than 72 hours
  - degreening should continue for no more than 72
    hours or risk increased peel senescence and decay

V. Commercial Use of Ethylene (cont.)

- Used for ripening of climacteric fruits
  - Bananas
  - Tomatoes
  - Avocados
  - Mangoes
  - Papayas
  - Persimmons
  - Casaba & Honeydew melons

V. Commercial Use of Ethylene (cont.)

- Ripening climacteric fruits
- Recommended conditions (tomatoes)
  - 20 to 21°C
  - 90 to 95% RH
  - 100 to 150 ppm \(C_2H_4\)
  - Air circulation = 20-40 ft\(^3\) per minute per ton of
    product
  - Ventilation = 1 air change per 6 hours or open room for
    0.5 h twice per day (prevent CO\(_2\) build-up)
V. Commercial Use of Ethylene (cont.)

- Degreening of citrus fruits
- Recommended conditions (Florida)
  - 28 to 29°C
  - 90 to 96% RH
  - 5 ppm C₂H₄
  - Air circulation = 10 ft³ per min. per box
  - Ventilation = 1 air change per hour or sufficient to maintain <0.2% CO₂

VI. Avoiding Exposure to Ethylene

- Exclusion of ethylene from storage rooms
  - use of electric forklifts
  - C₂H₄ absorber on forklift exhaust
  - avoiding other pollution sources
  - avoiding mixing ethylene-producing and ethylene-sensitive crops
VI. Avoiding Exposure to Ethylene (cont.)

- Removal of ethylene from storage rooms
  - use of adequate ventilation (air exchange)
  - use of ethylene absorbers
    - Potassium permanganate (K\textsubscript{2}MnO\textsubscript{4} on inert pellets)
    - Activated and brominated charcoal
    - Palladium-impregnated zeolite
    - Potassium permanganate (alkaline KMnO\textsubscript{4} on inert pellets = “Ethylene Control,” etc.)
    - Activated and brominated charcoal + KMnO\textsubscript{4} = “Stayfresh” absorbers
    - Palladium-impregnated zeolite (It’s Fresh! - the most effective)

- Removal of ethylene from storage rooms
  - use of ozone or UV radiation to oxidize ethylene:
    1. O\textsubscript{2} + UV \rightarrow O\textsubscript{3}
    2. C\textsubscript{2}H\textsubscript{4} + [O] \rightarrow CO\textsubscript{2} + H\textsubscript{2}O
  - ozone may also be produced by corona discharge
  - must remove excess O\textsubscript{3} to avoid injury to fruits & vegetables

Source: Applied Ozone Systems

VI. Avoiding Exposure to Ethylene (cont.)

- Removal of ethylene from storage rooms
  - low pressure system (i.e., hypobaric CA storage)
    - 1/10 atm = 1/10 gas concentrations in storage atmosphere (e.g., 21% O\textsubscript{2} becomes 2.1% O\textsubscript{2})
    - low pressure also facilitates gas (i.e., C\textsubscript{2}H\textsubscript{4}) diffusion from fruit tissue

Source: KES Science & Technology, Inc.

VII. Inhibiting Ethylene Biosynthesis & Action

- Biosynthesis inhibition
  - AVG (aminoethoxyvinylglycine)
  - inhibits ACS (i.e., SAM \rightarrow ACC)
  - the commercial product = “Briarlie”

- Action inhibition
  - 1-MCP (1-methylcyclopropene)
    - Irreversibly binds to ethylene receptors
    - “EthylBloc” for ornamentals and “SmartFresh” for fruits (“Harvista” for preharvest)