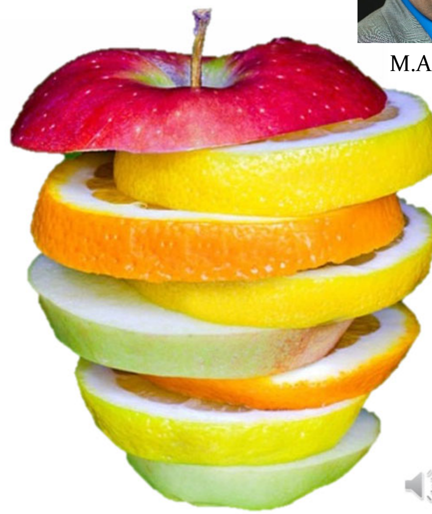
# Ethylene and Fruit Ripening


Dr. Mark A. Ritenour

Indian River Research and Education Center, Fort Pierce

Dr. Jeffrey K. Brecht

Horticultural Sciences Department, Gainesville

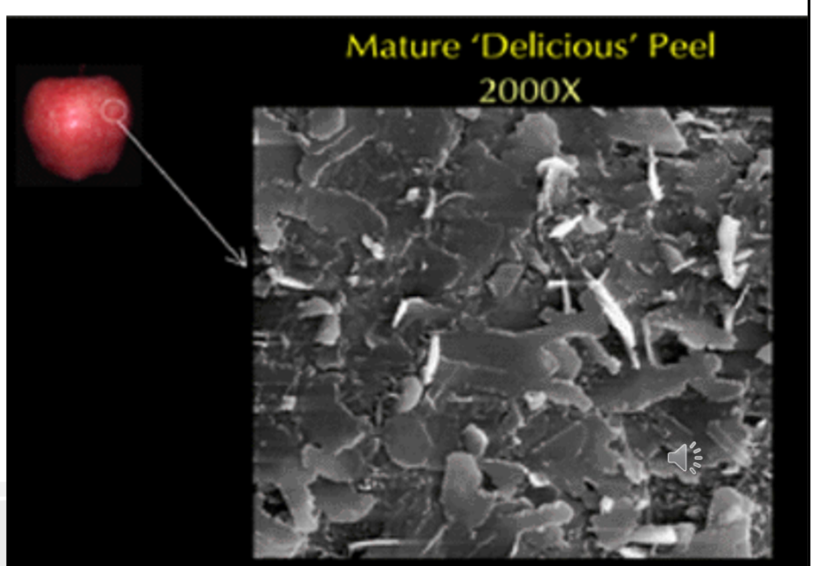


UNIVERSITY OF FLORIDA IFAS

1

## Processes Associated with Fruit Ripening

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

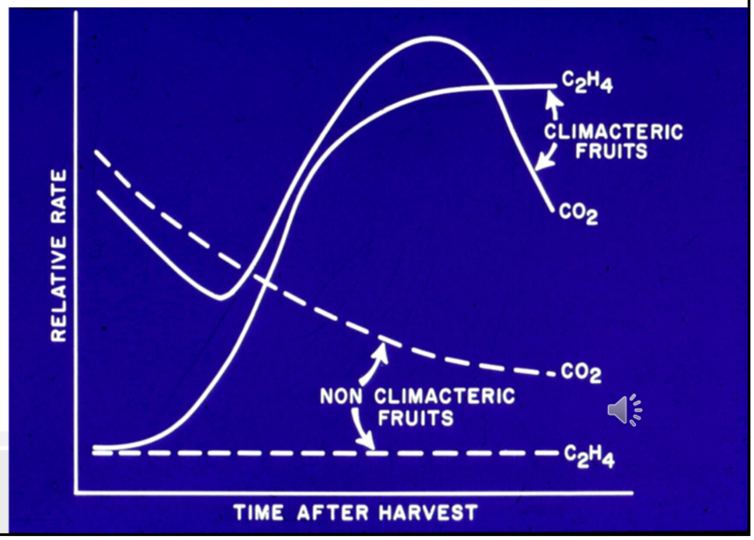



Source: Curry, 2000
http://postharvest.tfrec.wsu.edu/pgDisplay.php?article=PC2000AA#s2

2

# Processes Associated with Fruit Ripening

- Change in $C_2H_4$ production (climacteric fruits only)
  - increase in endogenous ethylene concentration until adequate to initiate ripening
  - autocatalytic ethylene production
- Increased sensitivity to $C_2H_4$ (climacteric fruits only)




3

# Processes Associated with Fruit Ripening

- Change in respiration rate
  - increased $O_2$ consumption and $CO_2$ production in climacteric fruits
- Membrane and cell wall changes
  - increased membrane permeability → juice leakage
  - depolymerization of pectins and other cell wall polysaccharides → softening

UNIVERSITY OF FLORIDA IFAS

4

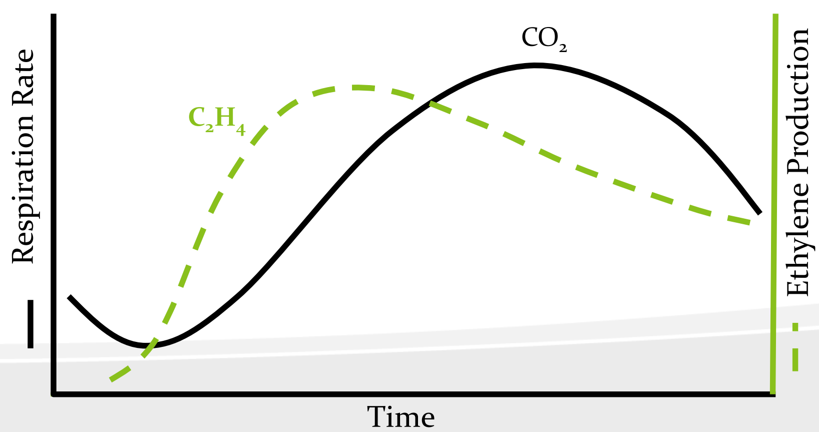
## Processes Associated with Fruit Ripening

- Protein and nucleic acid changes
  - synthesis of enzymes involved in compositional changes
- Compositional changes
  - starch to sugar conversion; loss of acids
  - pigment synthesis (anthocyanins & carotenoids) and degradation (chlorophyll)
  - polymerization of tannins and resulting loss of astringency
  - formation of flavor volatiles

5

## Factors Influencing Climacteric Fruit Ripening

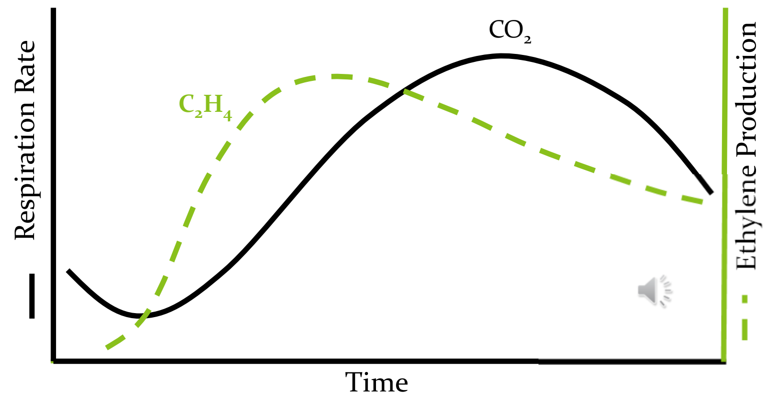
- Factors that affect $C_2H_4$ production and action can all be manipulated to control ripening




6

## 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




7

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

| Days at 20°C | Treatment | Flesh Firmness (kg) | | |
|---|---|---|---|---|
| | | Nectarine | Peach | Plum |
| 0 | At harvest | 5.3 ± 1.0 | 6.9 ± 0.7 | 2.8 ± 0.9 |
| 4 | Without added ethylene | 1.0 ± 0.5 | 1.3 ± 0.5 | 1.7 ± 1.0 |
| 4 | With 20 ppm ethylene | 0.8 ± 0.2 | 1.0 ± 0.3 | 0.8 ± 0.5 |

UNIVERSITY OF FLORIDA IFAS

8

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

| Temperature (°C) | Mean Number of Days to Ripen | | | |
|---|---|---|---|---|
| | Nectarine | Peach | Plum | Mean |
| 15 | 6.9 | 5.6 | 5.6 | 6 |
| 20 | 4.3 | 3.8 | 3.7 | 4 |
| 25 | 3.2 | 2.7 | 2.7 | 3 |

9

## 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)

10

## Senescence



## & Yellowing


UNIVERSITY OF FLORIDA IFAS

11

## Undesirable Ethylene Effects (cont.)

- Induction of phenolic synthesis
  - bitter principle (isocoumarin) in carrot roots
  - toxic ipomeamarone in sweetpotato roots
  - **russet spotting** on lettuce →
  - lignification of asparagus


12

## 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

https://postharvest.ucdavis.edu/produce-facts-sheets/carnation-miniature-carnation

UNIVERSITY OF FLORIDA IFAS

13

## Undesirable Ethylene Effects (cont.)

- The ultimate undesirable ethylene effect!!

***Explosion, fire destroy banana ripening facility***


'ACKER July 12, 1999

Tom Burfield/The Packer

One worker was killed and several others injured in an explosion and fire at Pan-American Banana Co., Los Angeles, on July 6. The cause of the explosion is unknown, but firefighters suspect ethylene gas or propane could be responsible.

*The Packer*
*July 12, 1999*

UNIVERSITY OF FLORIDA IFAS

14


# Postharvest Sources and Levels of Ethylene in Lettuce Handling

**Levels of Ethylene Found in the External Atmosphere and in Packed Cartons at Various Locations between Field and Consumption**

| Sample locations | | Ethylene concentration (ppm) Range | Mean | No. of samples analyzed | Potential sources |
|---|---|---|---|---|---|
| Field | A* | trace†—0.12 | — | 21 | Air pollution. |
| Field to cooler | B* | 0.03—0.11 | 0.07 | 3 | Mechanically injured lettuce. Exhaust from truck, other pollution |
| Holding areas prior to vacuum cooling | A<br>B | 0.01—0.61<br>0.01—0.80 | 0.05<br>0.16 | 47<br>12 | Exhaust from trucks and forklifts |
| Immediately following cooling | B | 0.01—0.29 | 0.12 | 11 | (Vacuum cooling removes much of the $C_2H_4$ inside cartons) |
| Cold storage rooms at vacuum coolers | A<br>B | 0.01—2.78<br>0.01—1.56 | 0.33<br>0.22 | 144<br>73 | Exhaust from forklifts, other commodities |
| Inside rail cars at destination | A<br>B | 0.01—0.19<br>0.01—0.02 | 0.06<br>0.01 | 14<br>3 | Decay, other pollution sources |
| Inside truck units at destination | A<br>B | 0.04—0.22<br>0.08—0.11 | 0.08<br>0.09 | 9<br>4 | Decay, other pollution sources |
| Distribution centers and warehouses | A<br>B | 0.03—2.49<br>0.01—0.78 | 0.25<br>0.08 | 22<br>43 | Exhaust, other commodities |
| Retail storage areas | A<br>B | 0.02—2.95<br>0.06—2.88 | 0.36<br>0.41 | 19<br>18 | Other commodities |
| Home refrigerator | A | 0.02—1.58 | 0.25 | 33 | Other commodities |

*A = atmosphere external to carton; B = inside carton
†Trace = less than 0.10 ppm

15

# Fluctuation of Ethylene Levels Corresponding to Forklift Activity

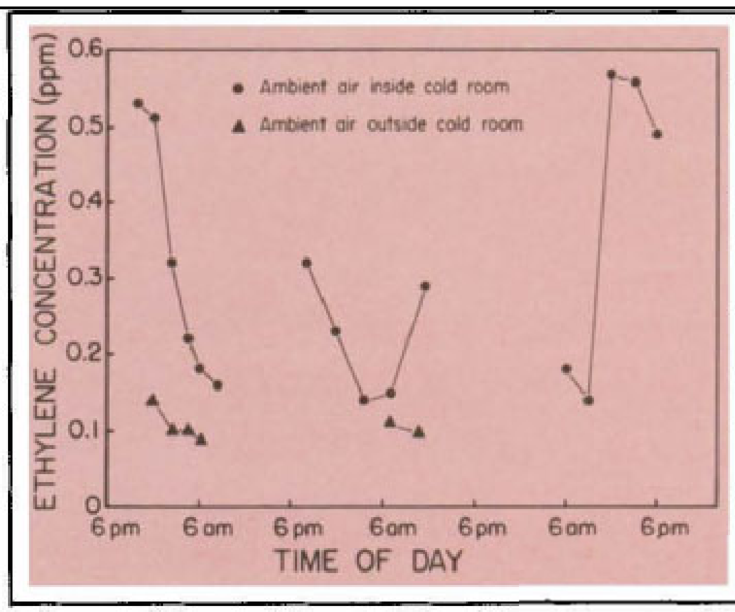



**Fig. 2. Fluctuations of ethylene concentration in a cold room used for holding lettuce after cooling, where propane-fueled forklifts were operated during a 3-day period.**

16

## Commercial Use of Ethylene

- Methods of application
  - Cylinders of ethylene or banana gas ($C_2H_4$ in $CO_2$) with flowmeters

17

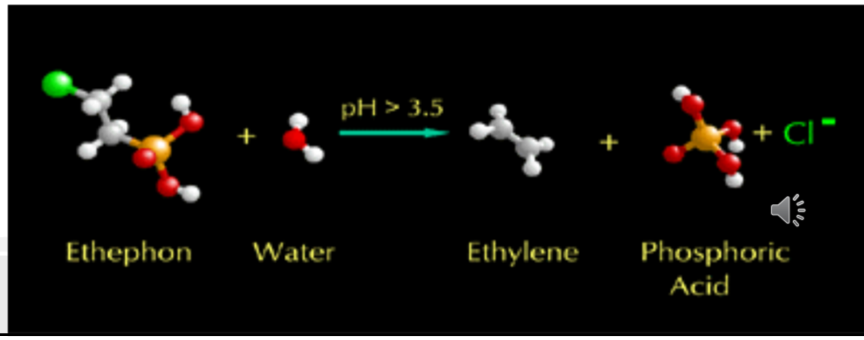
## Commercial Use of Ethylene

- Methods of application
  - Ethylene generators (liquid ethanol plus catalyst => $C_2H_4$)


18

# Commercial Use of Ethylene

- Methods of application
  - Ethylene-releasing chemicals
    - *e.g.*, Ethephon = 2-chloroethane-phosphonic acid
  - Intended for field application, but sometimes used postharvest




19

# Commercial Use of Ethylene (cont.)

- Ethylene concentration and duration of treatment
  - physiological responses are saturated at 100 ppm
  - mature climacteric fruit 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

UNIVERSITY OF FLORIDA IFAS

20

## Commercial Use of Ethylene (cont.)

- Used for ripening of climacteric fruits
  - Bananas
  - Tomatoes
  - Avocados

  Very common use

  - Mangoes
  - Papayas
  - Persimmons
  - Casaba & Honeydew melons

  Not common

21

## 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)

22

## *Tomato Ripening Room*

23


24

## *Banana Pressure Ripening Room*


25

## Commercial Use of Ethylene (cont.)

- Degreening of citrus fruits
- Recommended conditions (Florida)
  - 28 to 29°C
  - 90 to 96% RH
  - 5 ppm $C_2H_4$
  - Air circulation = 10 $ft^3$ per min. per box
  - Ventilation = 1 air change per hour or sufficient to maintain <0.2% $CO_2$


26

## *Grapefruit Degreening Room*

27

## Avoiding Exposure to Ethylene

- Exclusion of ethylene from storage rooms
  - use of electric forklifts
  - $C_2H_4$ absorber on forklift exhaust
  - avoiding other pollution sources
  - avoiding mixing ethylene-producing and ethylene-sensitive crops

UNIVERSITY OF FLORIDA IFAS

28

# Avoiding Exposure to Ethylene (cont.)

- Removal of ethylene from storage rooms
  - use of adequate ventilation (air exchange)
  - use of ethylene absorbers
    - Potassium permanganate (alkaline $KMnO_4$ on inert pellets = "Ethylene Control," etc.)
    - Activated and brominated charcoal +/- $KMnO_4$ = "Stayfresh" absorbers
    - Palladium-impregnated zeolite (It's Fresh! – the most effective)



Source: Ethylene Control, Inc.

UNIVERSITY OF FLORIDA IFAS

29

# Avoiding Exposure to Ethylene (cont.)

- Removal of ethylene from storage rooms
  - use of ozone or UV radiation to oxidize ethylene:

1. $O_2$ + UV → $O_3$
2. $C_2H_4$ + [O] → → $CO_2$ + $H_2O$

  - ozone may also be produced by corona discharge
  - must remove excess $O_3$ to avoid injury to fruits & vegetables

Source: Applied Ozone Systems

UNIVERSITY OF FLORIDA IFAS

30

## Avoiding Exposure to Ethylene (cont.)

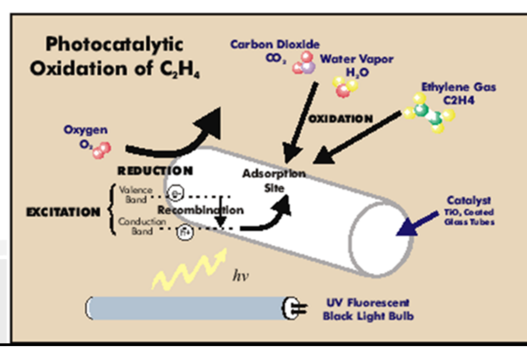
- Removal of ethylene from storage rooms
  - use of low pressure system (*i.e.*, hypobaric CA storage)
    - 1/10 atm = 1/10 gas concentrations in storage atmosphere (*e.g.*, 21% $O_2$ becomes 2.1% $O_2$)
    - low pressure also facilitates gas (*i.e.*, $C_2H_4$) diffusion from fruit tissue

UNIVERSITY OF FLORIDA IFAS

31

## Avoiding Exposure to Ethylene (cont.)

- Removal of ethylene from storage rooms
  - oxidation of ethylene with platinum or oxide catalysts + heat (200-300°C)
  - low temperature catalysis (*e.g.*, $TiO_2$ + UV radiation at ~100°C)



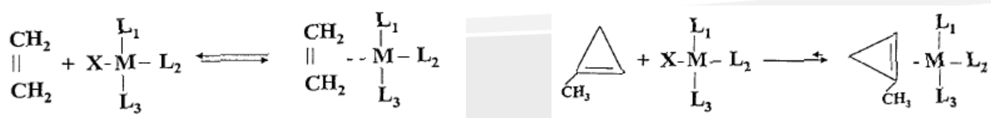

Source: KES Science & Technology. Inc.

UNIVERSITY OF FLORIDA IFAS

32

# Inhibiting Ethylene Biosynthesis & Action

- Biosynthesis inhibition
  - AVG (aminoethoxyvinylglycine)
    - inhibits ACS (i.e., SAM → ACC)
    - the commercial product is "ReTain"
- Action inhibition
  - 1-MCP (1-methylcyclopropene)
    - Irreversibly binds to ethylene receptors
    - "EthylBloc" for ornamentals and "SmartFresh" for fruits ("Harvista" for preharvest)



UNIVERSITY OF FLORIDA IFAS

33

**Table 1.** Concentration of compound needed to protect plants against ethylene.

| Compound | Plant | Concentration ($nl.l^{-1}$) |
|---|---|---|
| 2-5-NBD | Banana | 55,000 |
| *trans*-Cyclooctene | Banana | 780 |
| *cis*-Cyclooctene | Banana | 512,000 |
| DACP (dark) | Carnation | 700,000 |
| DACP (light) | Carnation | 140 |
| 1-MCP | Banana | 0.7 |
| 1-MCP | Carnation | 0.5 |
| 1-MCP | Pea growth | 40 |
| 3,3-DMCP | Banana | 700 |

**Table 2.** Time required for the receptor to become free. Time is for 1/2 of the receptor to become free after being exposed to the compound. In the case of 3,3-DMCP and 1-MCP, time refers to time for bananas become sensitive after a single exposure to ethylene.

| Compound | Plant | Time (Minutes) |
|---|---|---|
| Ethylene | Mung bean sprout | 10 |
| Ethylene | Tobacco leaf | 10 |
| Ethylene | Tomato leaf | 2 |
| 2,5-NBD | Mung bean sprout | 180 |
| Trans-*cycloo*ctene | Mung bean sprout | 360 |
| 3,3-DMCP | Banana | 25,200 |
| 1-MCP | Banana | 43,200 |

Source: Sisler & Serek, 1999, Bot. Bull. Acad. Sin. 40:1-7

UNIVERSITY OF FLORIDA IFAS

34