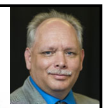
Ethylene and Fruit Ripening

Dr. Mark A. Ritenour

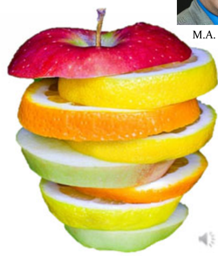
Indian River Research and Education Center, Fort Pierce

Dr. Jeffrey K. Brecht

Horticultural Sciences Department, Gainesville



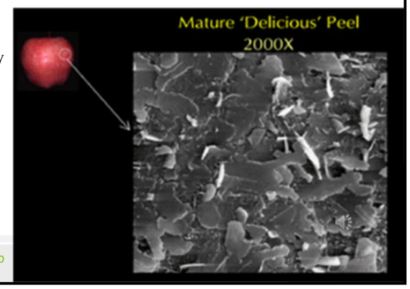
M.A. Ritenour



1

Processes Associated with Fruit Ripening

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

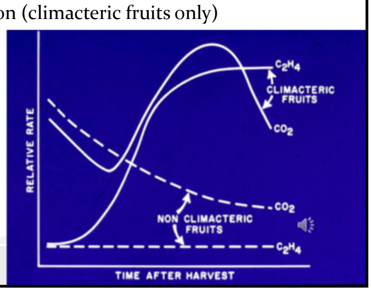


Source: Curry, 2000
http://postharvest.tfrec.wsu.edu/pgDisplay.php?article=PC2000AA#s2

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

4

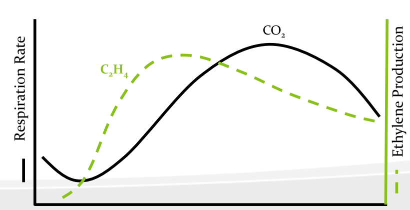
Processes Associated with Fruit Ripening

- 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

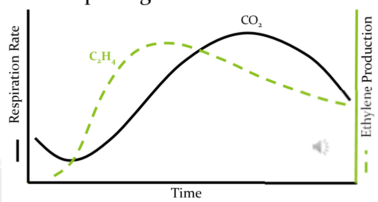
- Factors that affect C_2H_4 production and action can all be manipulated to control ripening



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

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

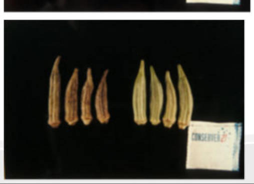
9

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

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

13

Undesirable Ethylene Effects (cont.)

- The ultimate undesirable ethylene effect!!

Explosion, fire destroy banana ripening facility

The Packer July 12, 1999

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 B	0.01—0.61 0.01—0.80	0.05 0.16	47 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 B	0.01—2.78 0.01—1.56	0.33 0.22	144 73	Exhaust from forklifts, other commodities
Inside rail cars at destination	A B	0.01—0.19 0.01—0.02	0.06 0.01	14 3	Decay, other pollution sources
Inside truck units at destination	A B	0.04—0.22 0.08—0.11	0.08 0.09	9 4	Decay, other pollution sources
Distribution centers and warehouses	A B	0.03—2.49 0.01—0.78	0.25 0.08	22 43	Exhaust, other commodities
Retail storage areas	A B	0.02—2.95 0.06—2.88	0.36 0.41	19 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

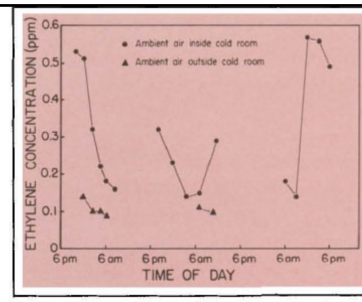
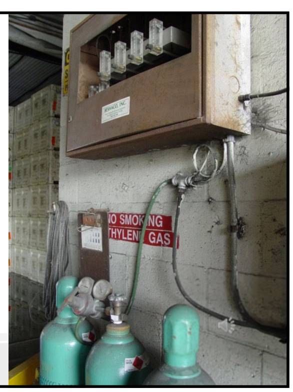


Fig. 2. Fluctuations of ethylene concentration in a cold room used for holding lettuce after cooling, where propane-fueled forklifts were operated during a 3-day period.

16

Commercial Use of Ethylene

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



17

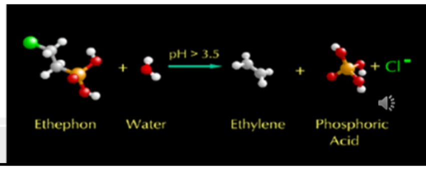
Commercial Use of Ethylene

- 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

20

Commercial Use of Ethylene (cont.)

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

  (Bananas, Tomatoes, Avocados: Very common use)

  - Mangoes
  - Papayas
  - Persimmons
  - Casaba & Honeydew melons

  (Mangoes, Papayas, Persimmons, Casaba & Honeydew melons: Not common)

21

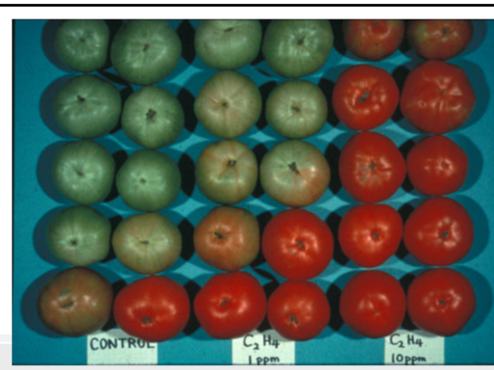
Commercial Use of Ethylene (cont.)

- 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 ft³ 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

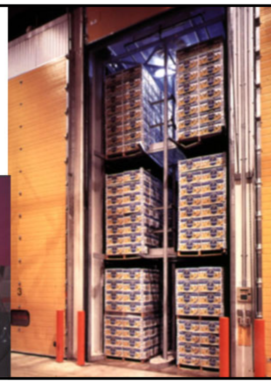
Tomato Ripening Room

23



24

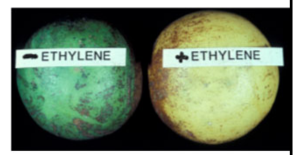
Banana Pressure Ripening Room



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 ft³ 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

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.

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

30

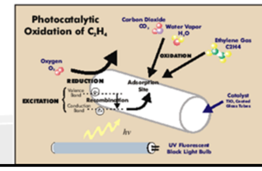
Avoiding Exposure to Ethylene (cont.)

- 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

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)

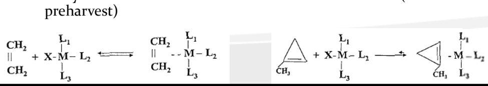


Source: KES Science & Technology, Inc.

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)



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-*cyclo*octene	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

34