




Ethylene and Fruit Ripening


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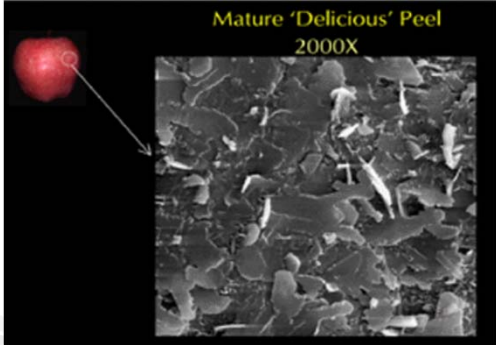
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Indian River Research and Education Center, Fort Pierce




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I. Processes Associated with Fruit Ripening

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



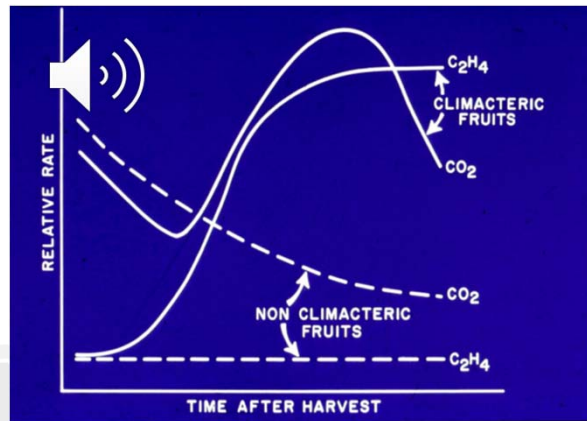
Source: Curry, 2000
<http://postharvest.tfrec.wsu.edu/pgDisplay.php?article=PC2000AA#s2>



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I. 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)




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I. 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

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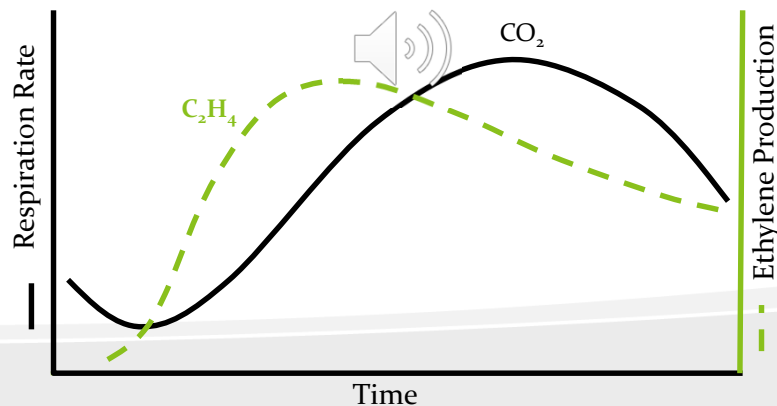
I. Processes Associated with Fruit Ripening

- 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

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II. Factors Influencing Climacteric Fruit Ripening

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



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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

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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

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

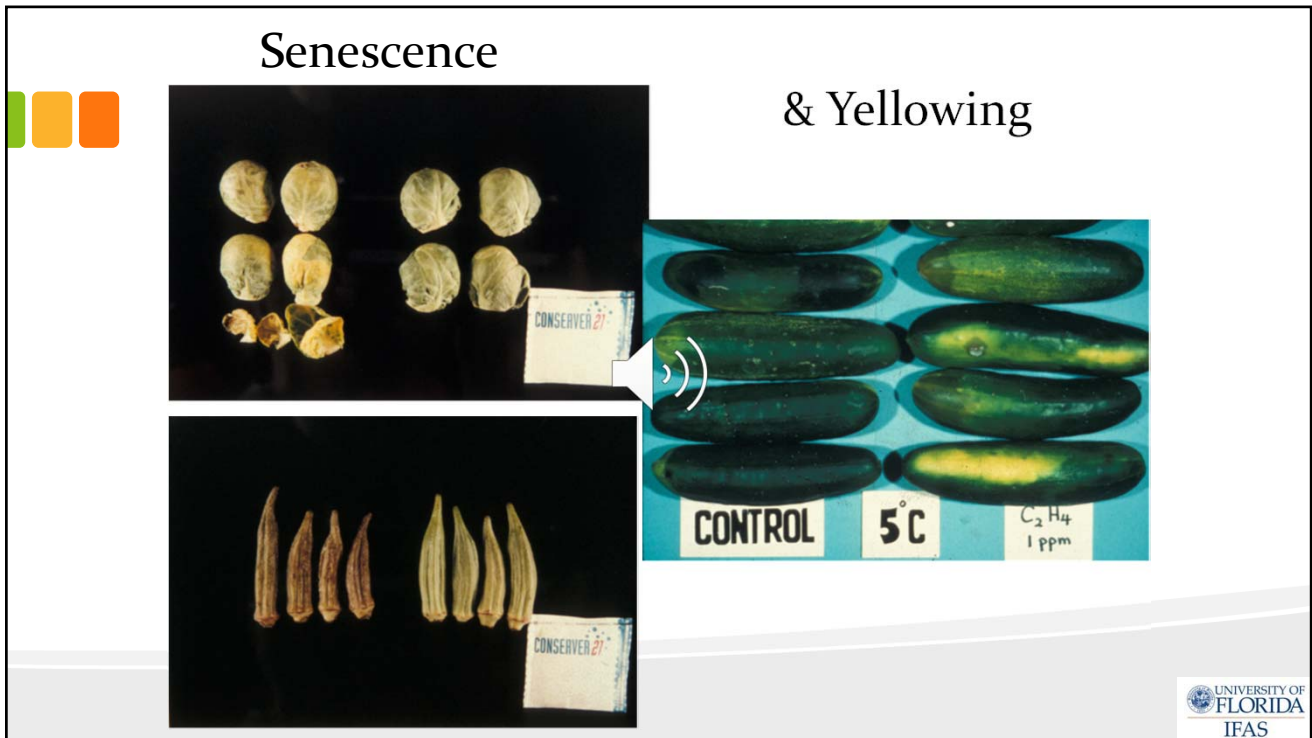
Days at 20°C	Treatment	Flesh Firmness (kg)		
		Nectarine	Peach	Plum
0	At harvest	5.3 ± 1.0	6.9 ± 0.7	2.8 ± 0.9
4	Without added ethylene	1.0 ± 0.5	1.3 ± 0.5	1.7 ± 1.0
4	With 20 ppm ethylene	0.8 ± 0.2	1.0 ± 0.3	0.8 ± 0.5

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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)

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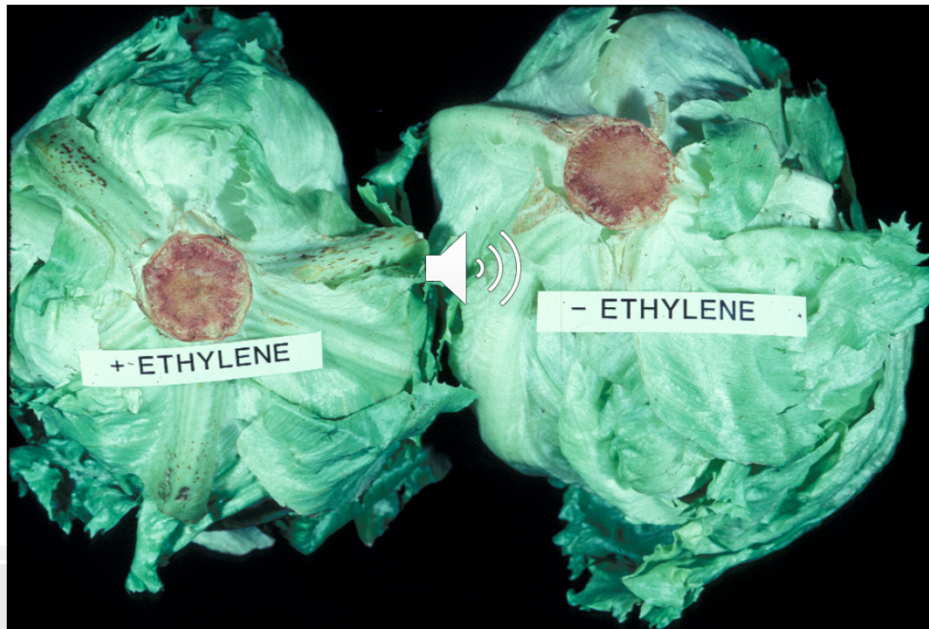
III. Undesirable Ethylene Effects (cont.)

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

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Russet Spotting



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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

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III. Undesirable Ethylene Effects (cont.)

- The ultimate undesirable ethylene effect!!

Explosion, fire destroy banana ripening facility



*The Packer
July 12, 1999*

One worker was killed and several others injured in an explosion and fire at Pan-American Banana Co., Los Angeles, on July 12, 1999. The cause of the explosion is unknown, but firefighters suspect ethylene gas or propane could be responsible.



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IV. Postharvest Sources and Levels of Ethylene in Lettuce Handling

Sample locations	Ethylene concentration (ppm)		No. of samples analyzed	Potential sources
	Range	Mean		
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 0.01—0.61	0.05	47	Exhaust from trucks and forklifts
	B 0.01—0.80	0.16	12	
Immediately following cooling	B 0.01—0.29	0.12	11	(Vacuum cooling removes much of the C ₂ H ₄ inside cartons)
Cold storage rooms at vacuum coolers	A 0.01—2.78	0.33	144	Exhaust from forklifts, other commodities
	B 0.01—1.56	0.22	73	
Inside rail cars at destination	A 0.01—0.19	0.06	14	Decay, other pollution sources
	B 0.01—0.02	0.01	3	
Inside truck units at destination	A 0.04—0.22	0.08	9	Decay, other pollution sources
	B 0.08—0.11	0.09	4	
Distribution centers and warehouses	A 0.03—2.49	0.25	22	Exhaust, other commodities
	B 0.01—0.78	0.08	43	
Retail storage areas	A 0.02—2.95	0.36	19	Other commodities
	B 0.06—2.88	0.41	18	
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

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Fluctuation of Ethylene Levels Corresponding to Forklift Activity

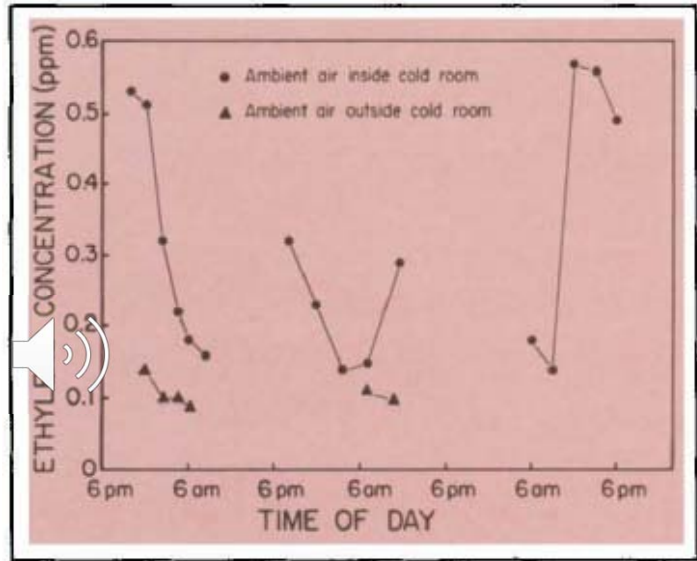


Fig. 2. Fluctuations of ethylene concentration in a cold room used for holding lettuce after cooling, where propane-fueled forklifts were operated during a 3-day period.

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V. Commercial Use of Ethylene

- Methods of application

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



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V. Commercial Use of Ethylene

- Methods of application

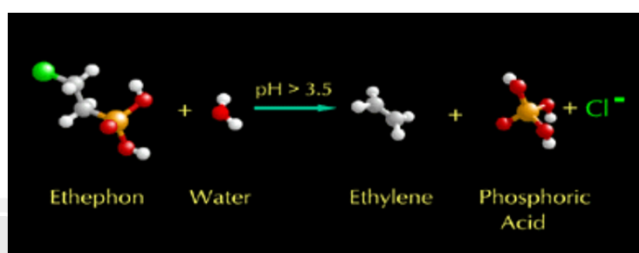
- Ethylene generators (liquid ethanol plus catalyst \Rightarrow C_2H_4)



V. 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



V. 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

V. 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

V. Commercial Use of Ethylene (cont.)

- Ripening climacteric fruits
- Recommended conditions (tomatoes)
 - 20 to 21°C
 - 90 to 95% RH
 - 100 to 150 ppm C₂H₄
 - 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 CO₂ build-up)

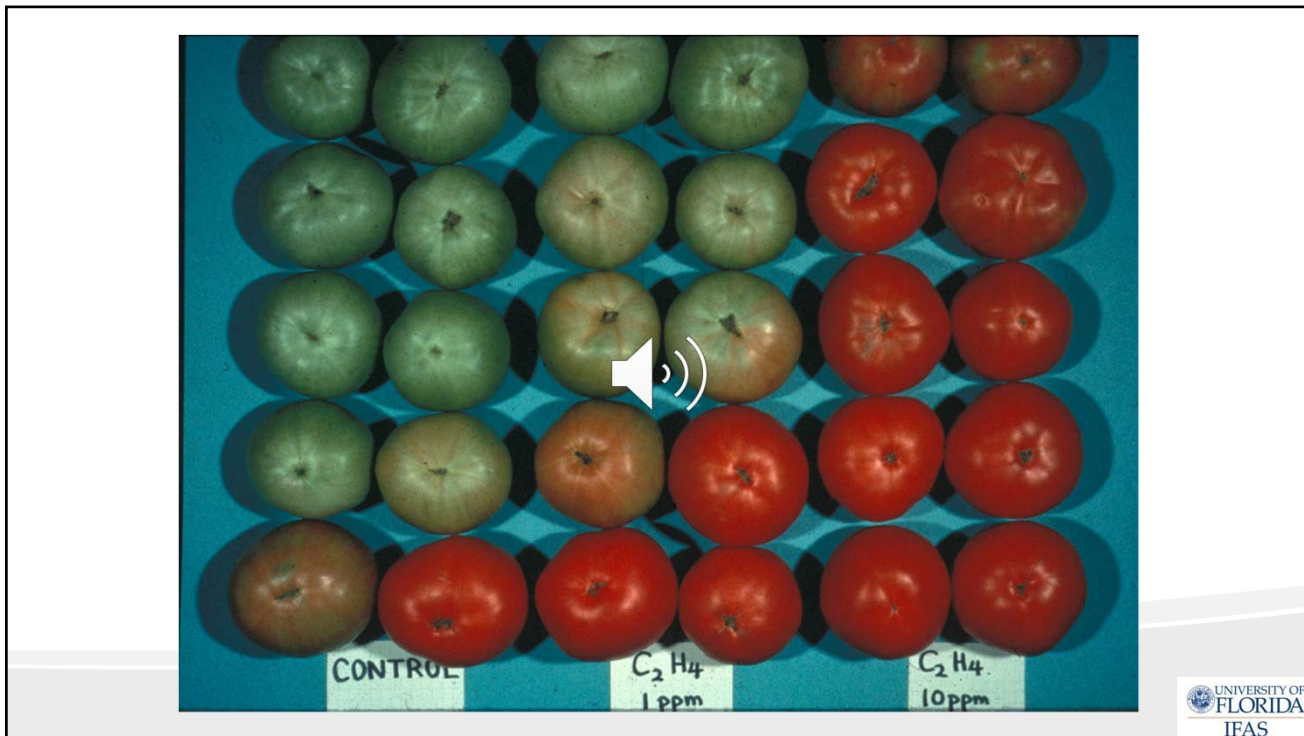


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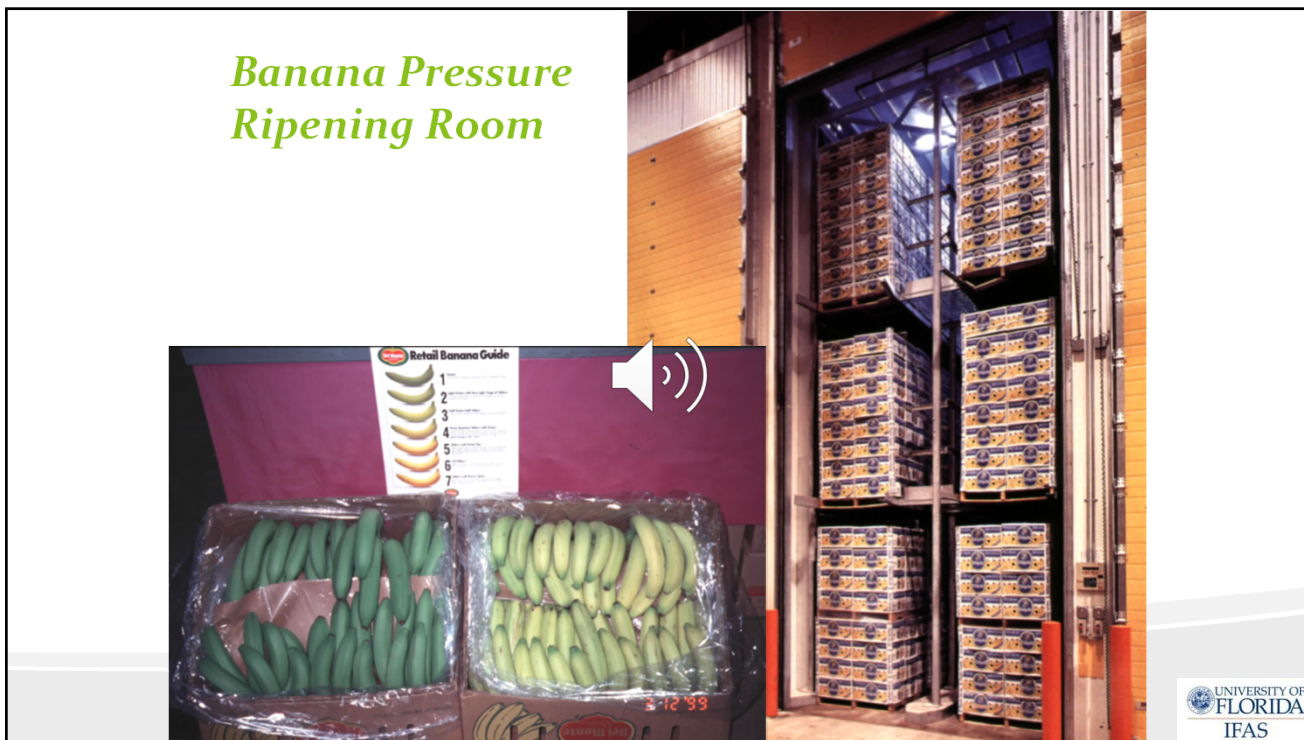
Tomato Ripening Room



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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

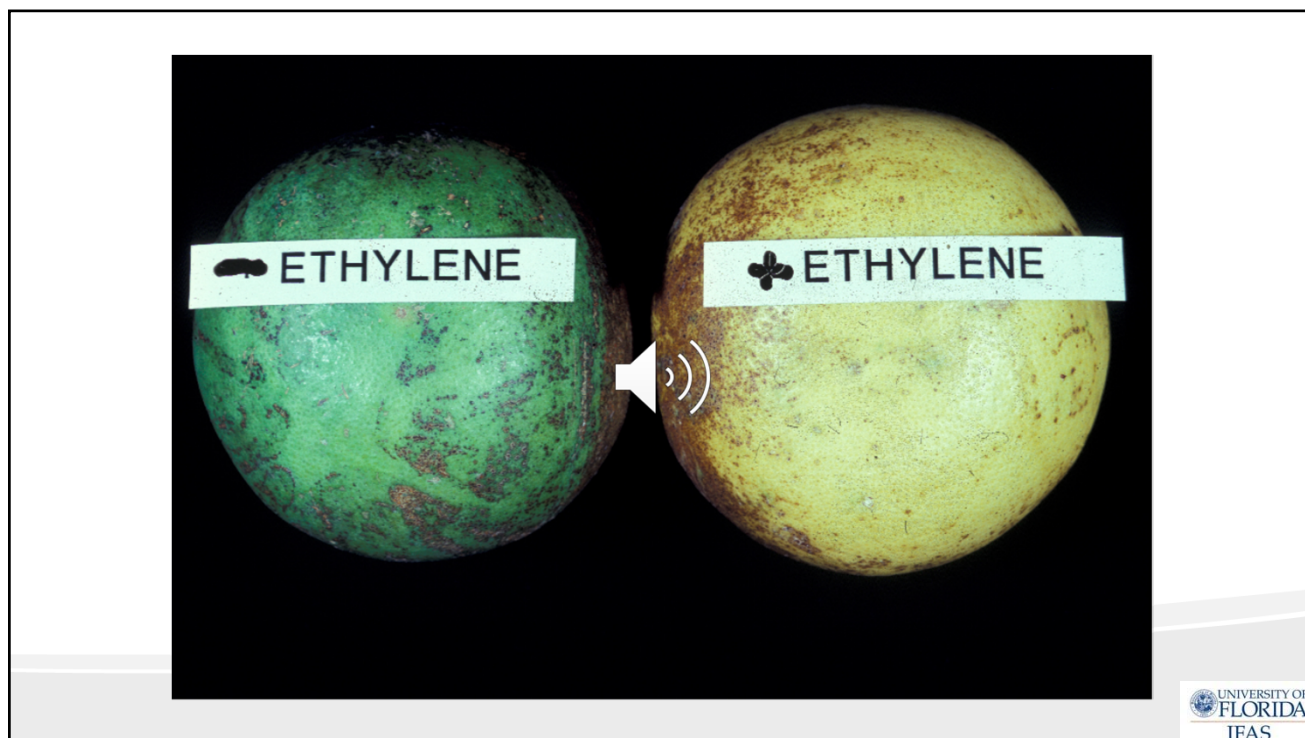


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Grapefruit Degreening Room



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VI. 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

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VI. 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.



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VI. Avoiding Exposure to Ethylene (cont.)

- Removal of ethylene from storage rooms
 - use of ozone or UV radiation to oxidize ethylene:
 1. $\text{O}_2 + \text{UV} \rightarrow \text{O}_3$
 2. $\text{C}_2\text{H}_4 + [\text{O}] \rightarrow \text{CO}_2 + \text{H}_2\text{O}$
 - ozone may also be produced by corona discharge
 - must remove excess O_3 to avoid injury to fruits & vegetables



Source:
Applied
Ozone
Systems



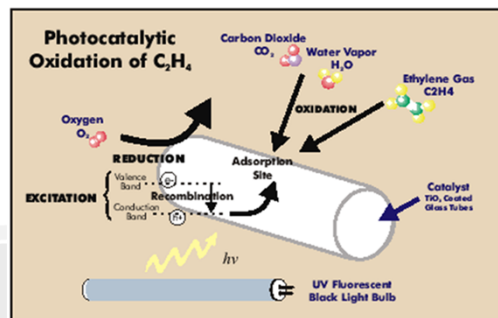
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VI. Avoiding Exposure to Ethylene (cont.)

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

VI. Avoiding Exposure to Ethylene (cont.)

- Removal of ethylene from storage rooms
 - oxidation of ethylene with platinum or oxide catalysts + heat ($200\text{-}200^\circ\text{C}$)
 - low temperature catalysis (e.g., TiO_2 + UV radiation at $\sim 100^\circ\text{C}$)



Source: KES Science & Technology, Inc.

VII. Inhibiting Ethylene Biosynthesis & Action

- Biosynthesis inhibition
 - AVG (aminoethoxyvinylglycine)
 - inhibits ACS (i.e., $\text{SAM} \rightarrow \text{ACC}$)
 - 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)



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

Compound	Plant	Concentration (nl.l ⁻¹)
2-5-NBD	Banana	55,000
<i>trans</i> -Cyclooctene	Banana	780
<i>cis</i> -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
<i>Trans-cyclooctene</i>	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

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