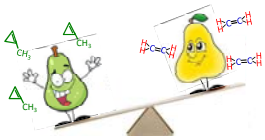
Biology of ethylene production & action



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Ethylene - an important factor

- Useful:
  - Accelerates ripening
  - Causes abscission
- A problem:
  - Accelerates ripening
  - Accelerates senescence
  - Causes abscission

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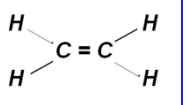
What is ethylene?

- C_2H_4
- Very simple molecule
- A gas (colorless, odorless)
- An important chemical feedstock
- A natural plant hormone

Ethylene
Ripening Hormone



Threshold = 0.1 to 10 ppm

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Where does ethylene come from?

- Ripening fruits
- Smoke
- Vehicle exhausts
- Ripening rooms
- Ripening fruit

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History of ethylene biology

- Prehistoric
  - Fruit ripening, smoky rooms, ripening fruit
- Amos, 1000 B.C.
  - Scarification of figs - wound ethylene
- Neljubow, 1907
  - Ethylene gas - plant growth regulator
- Cousins, 1913
  - Ethylene causes ripening
- Gane, 1932
  - Produced by ripening fruits
- Goeschl and Pratt, 1960
  - Role in plant growth and development
  - Plant hormone
- Veen, 1978
  - Silver thiosulfate
- Yang, 1979
  - Ethylene biosynthesis pathway
- Bleeker, 1988
  - Etr-1
- Sisler and Blankenship, 1996
  - 1-MCP

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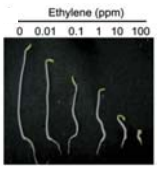
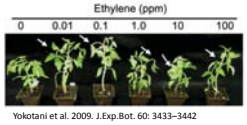
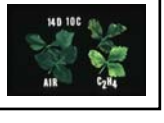
Ethylene Responses

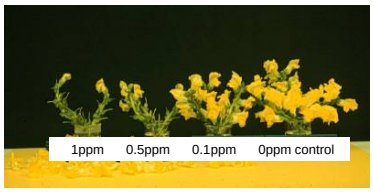
- Reduction in growth (seedlings)
- Loss of leaves and flowers (plants)
- Leaf yellowing or death (plants)
- Epinasty (leaves)
- Senescence (flowers)
- Ripening and softening (fruits)
- Abscission (fruits, leaves, branches)
- Dehiscence (seeds)





Yokotani et al. 2009. J.Exp.Bot. 60: 3433–3442





Abscission of snapdragon flowers in response to ethylene shows a typical threshold and plateau response

Characteristics of ethylene responses

- Threshold concentration (0.1 ppm)
- Plateau concentration (10 ppm)
- Associated respiration rise
- Temperature optimum (15 - 25°C)
- CO_2 (>1%) inhibits

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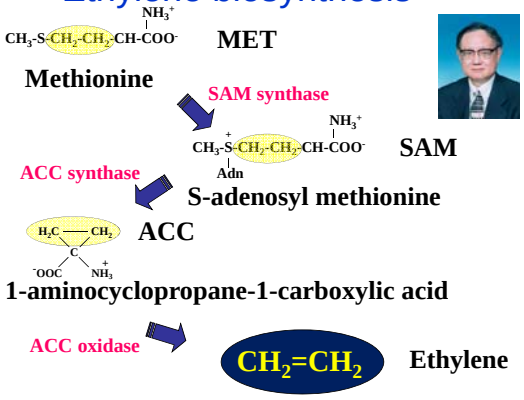
Ethylene Production Rates at 20°C (68°F)

Range (µL/kg-h)	Product
0.01-0.1	Citrus, grape, cherry strawberry **MOST VEGETABLES**
0.1-1.0	Pineapple, blueberry, cucumber
1.0-10.0	Banana, mango, tomato, honeydew melon, fig
10-100	Apple, avocado, cantaloupe, nectarine, papaya, pear
>100	Cherimoya, passion fruit, sapotes

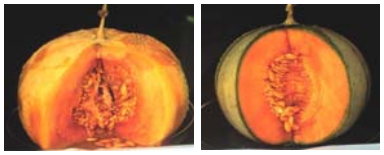
Ethylene production and sensitivity information for specific products:
Produce Facts: http://postharvest.ucdavis.edu/PF/
USDA Handbook 66: http://www.ba.ars.usda.gov/hb66/

Ethylene biosynthesis



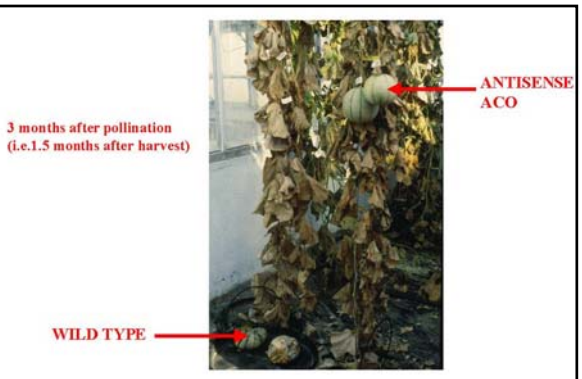
Molecular manipulation of ripening

- Anti-sense ACC synthase; Anti-sense ACC oxidase
- Result - fruits that ripen very slowly, require ethylene treatment to ripen or to produce aroma volatiles
- Naturally occurring ethylene mutants: Never Ripe (NR), a tomato mutant, used to develop long shelf-life tomatoes

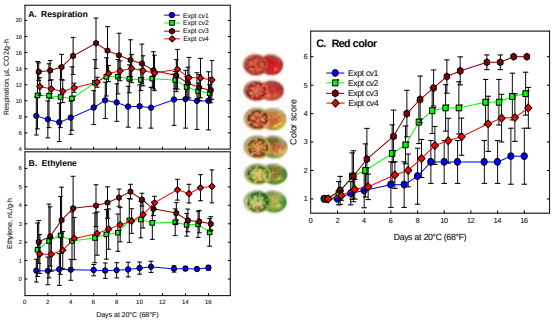


Non-modified wild type Anti-sense ACC Oxidase

Charentais melons harvested 38 days post-pollination
Stored at 25°C for 10 days (J.C. Pech and colleagues)



Tomato cultivars and their ripening physiology and ability to ripen
Hybrids based on mutants can have greatly retarded ripening off the plant



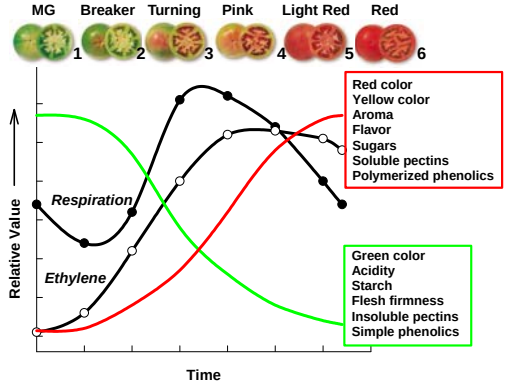
Cantwell, unpublished, 2009

How does ethylene act?

- Ethylene binds to receptors in cell membranes
- After binding there is an "ethylene response cascade" leading to known consequences.
- Can modify ethylene response by molecular modification of binding site proteins.

Ethylene-induced senescence of petunia flower at pollination is retarded with transgenic *etr* mutant gene

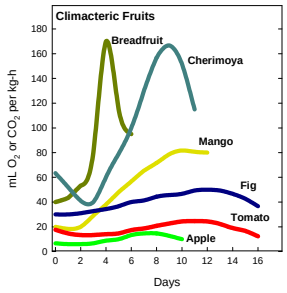
M.L.Jones.2008. Ethylene signaling is required for pollination-accelerated corolla senescence in petunias. Plant Science 175: 190.



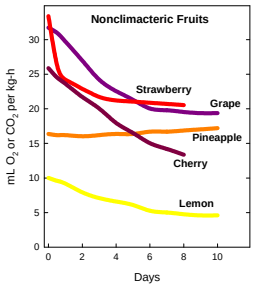
Changes during the ripening of a Climacteric Fruit

Respiration rates of Ripening Fruits

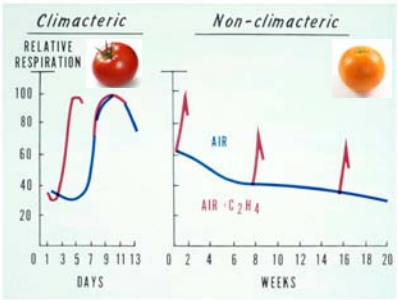
Ethylene Triggers Ripening



Ethylene Not involved in Ripening



Responses of Climacteric & Nonclimacteric Fruits to Ethylene Treatment



Modified from M. Saltveit, UC Davis
PLS172 Fall 2012

Differences between **Climacteric** and **Non-climacteric** fruits in their synthesis of ethylene and response to applied ethylene application

Parameter	Climacteric	Non-climacteric
Endogenous ethylene production	Highly variable, from low to very high	Low
Response to exogenous application of ethylene	Stimulates respiration only prior to respiratory rise	Stimulates respiration while exposed
Magnitude of respiratory response	Independent of ethylene concentration	Dependent on ethylene concentration
Reversibility of ethylene induced respiratory rise	Irreversible	Reversible, dependent on continued exposure
Autocatalytic production of ethylene	Present	Absent

Modified from M. Saltveit, UC Davis
PLS172 Fall 2012

Fruit Ripening

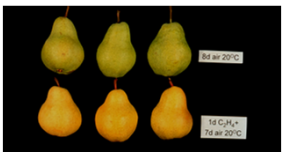
- Provide ethylene before natural production to control when ripening occurs
- Ethylene serves as "trigger" of ripening
- Temperature control is critical
  - forced-air ripening rooms
  - Control ripening rate

Fruit	Exposure to 100 ppm ethylene hours	Ripening temperatures °C
Avocado	8-48	15-20
Banana	24-48	14-18
Kiwifruit	12-24	12-25
Mango	24-48	20-25
Pear	24-48	20-25
Tomato	24-72	18-20

Fewer hours for more mature fruit
Faster ripening at higher temperatures

Ethylene as a ripening 'trigger'

- Once ripening is initiated, climacteric fruits produce ethylene
- Ripening is then self-controlled



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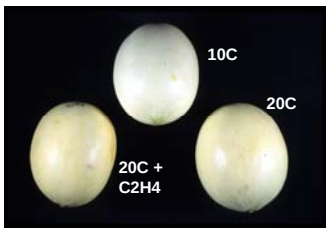
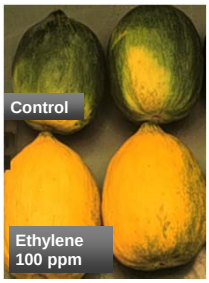
Ethylene effects on melons

- ❑ **Improve external color**
- ❑ **Improve aroma**
- ❑ **Increase pulp softening**
- ❑ **No effect on sweetness**





Tools for working with ethylene: **Measurement**

- Bioassay - cheap, difficult
- Kitagawa tubes - $6 / measurement
- Proprietary analyzers - $500 - $1000
- Gas chromatograph - $10,000 - 30,000
- Photo-acoustic detector - $75,000

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Uses of Ethylene in Horticulture

- Induction of flowering
  - Bulbs, Pineapple & other Bromeliads
- Harvest aid
  - Walnuts, Sour cherries
- Induction of ripening or coloring
  - Bananas, Citrus, Pears, Melons

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Tools for working with ethylene: **Application**

- Ripening fruits
  - Ethylene gas
    - Enclosed space
  - Acetylene, CO
  - Ethephon
    - Liquid, spray, drench
    - Breaks down to release ethylene gas

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Unsprayed **Gravenstein** ***Sprayed***

Deleterious effects of ethylene

- Plants
  - Growth distortion
- Leaves
  - Yellowing, abscission, necrosis
- Flowers
  - Senescence, abscission
- Fruits
  - Ripening, softening

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Detrimental Effects of Ethylene on Vegetables

Commodity	Symptoms
Beans, snap	Yellowing
Broccoli	Yellowing, floret abscission, off-flavors
Cabbage	Yellowing, leaf abscission
Carrots	Bitterness
Cauliflower	Yellowing, leaf abscission, browning of remaining leaves

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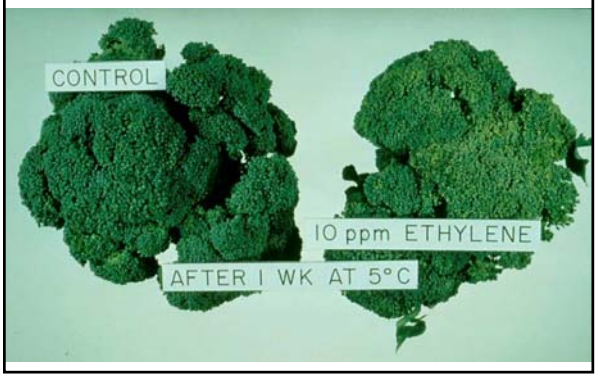
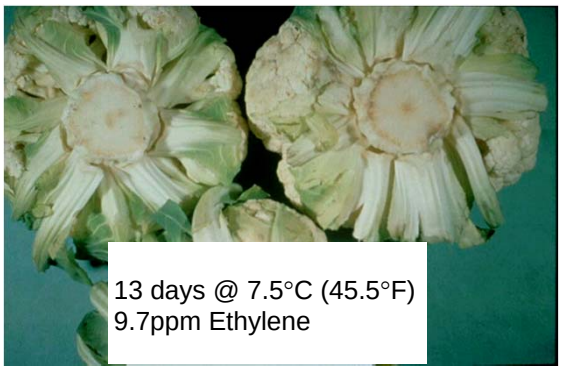
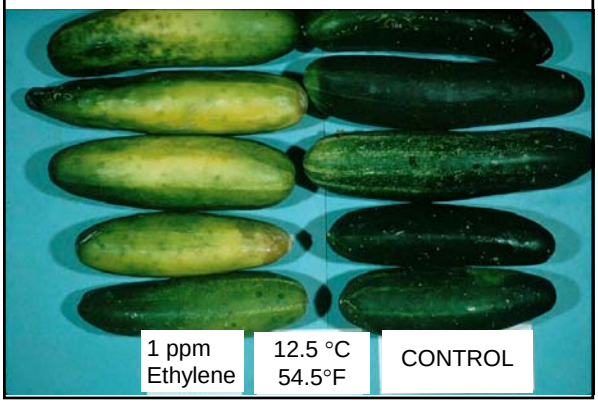
Ethylene induces yellowing and floret opening of broccoli



Ethylene induces leaf abscission of cauliflower



Ethylene induces yellowing of cucumbers



Detrimental Effects of Ethylene on Fruits

Commodity	Symptoms
Kiwifruit	As little as 50ppb induces softening
Avocado & Fuyu Persimmon	Exposure to 1ppm at 5°C increases chilling injury symptoms
Citrus	Use of ethylene for degreening increases senescence
Stone Fruits	Increase in decay development by accelerated softening and increased growth of fungus

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Effect of Ethylene on Watermelon Quality after 7 Days at 18ºC (64°F)

C_2H_4 (ppm)	Firmness (N)	Rind Thickness (mm)	SSC (%) Heart Area	SSC (%) Seed Area	Acceptability (%)
0	12.7 a	16 a	10.3	9.7	87
5	9.8 b	12 b	10.3	9.9	20
30	9.8 b	13 b	10.6	10.0	13

Risse & Hatton (1982)

Detrimental Effects of Ethylene on Ornamentals

Commodity	Symptoms
Cut flowers	Failure-to-open of flowers cut at the bud stage, closure of open flowers
Flowering plants	Flower abscission, flower closure
Foliage plants	Leaf abscission, leaf chlorosis, epinastic responses (downward leaf curvature)

Detrimental Effects of Ethylene on Ornamentals

Commodity	*Symptoms*
Flowering bulbs	*Inhibition of shoot/root elongation, abnormal flowers, gummosis in tulips, flowerbud abscission (lily)*
Geranium seedlings	*Leaf chlorosis, poor growth after planting*
Dormant nursery stock	*Reduced budbreak, greater mortality after planting*

Points to Remember

- Ethylene has both positive and negative effects in postharvest handling
- Learn which products are sensitive to ethylene
- Ethylene can be beneficial for many fruit, but stimulates ripening and senescence processes

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