Respiration

Internal & Environmental Factors

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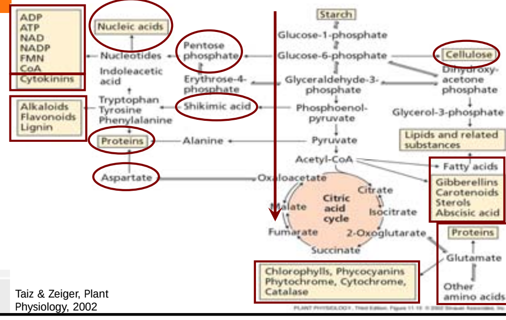
Respiration is tied to many metabolic process within a cell



Taiz & Zeiger, Plant Physiology, 2002

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Respiration is tied to many metabolic process within a cell

- Thus:
  - It is an accurate indicator of the general metabolic state of a cell
  - The rate of respiration is influenced by many internal and external factors that affect general metabolism

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Internal Factors

- Genotype of a commodity
- Type of plant part
- Stage of development at harvest
- Respiratory substrate
- Preharvest factors

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Internal Factors

- Genotype of a commodity
  - Between different commodities and within different cultivars of a single species
- Type of plant part
  - E.g. storage organs (potato) have low rates while developing meristems (broccoli) have high rates

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Class	($mg\ CO_2/kg\text{-}hr$) at 5 ºC (41 ºF)	Commodities
Very Low	< 5	Dates, dried fruits and vegetables, nuts
Low	5 - 10	Apple, beet, celery, citrus fruits, cranberry, garlic, grape, honeydew melon, kiwifruit, onion, papaya, persimmon, pineapple, potato (mature), sweet potato, watermelon
Moderate	10 - 20	Apricot, banana, blueberry, cabbage, cantaloupe, carrot (topped), celeriac, cherry, cucumber, fig, gooseberry, lettuce (head), mango, nectarine, olive, peach, pear, plum, potato (immature), radish (topped), summer squash, tomato
High	20 - 40	Avocado, blackberry, carrot (with tops), cauliflower, leeks, lettuce (leaf), lima bean, radish (with tops), raspberry
Very High	40 - 60	Artichoke, bean sprouts, broccoli, Brussels sprouts, cut flowers, endive, green onions, kale, okra, snap bean, watercress
Extremely High	> 60	Asparagus, mushroom, parsley, peas, spinach, sweet corn

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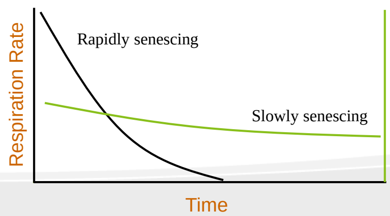
Internal Factors

- Stage of development at harvest
  - Maturing plant organs usually have declining rates of respiration



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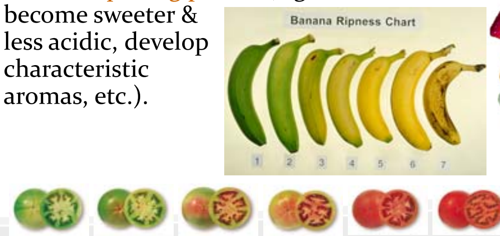
Climacteric Commodities

- Have a "ripening phase" (e.g. soften, become sweeter & less acidic, develop characteristic aromas, etc.).



Pictures courtesy Adel Kader and Marita Cantwell, UC Davis

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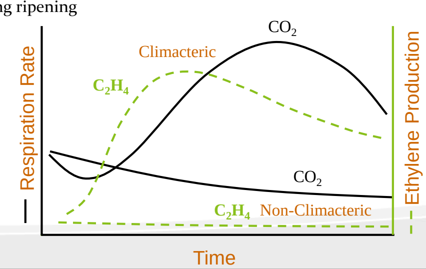
Climacteric Commodities

- Have increased respiration & ethylene production during ripening



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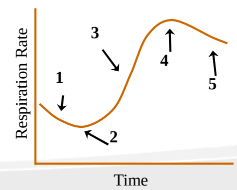
Phases of the Climacteric

1) The preclimacteric
2) The preclimacteric minimum
3) The climacteric rise
4) The climacteric peak
5) The postclimacteric phase



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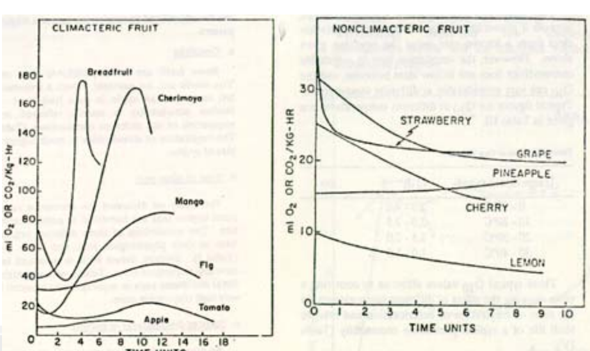

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Climacteric / Non-Climacteric

Climacteric

- Apple
- Apricot
- Avocado
- Banana
- Blueberry
- Breadfruit
- Broccoli
- Carnation
- Cherimoya
- Feijoa
- Fig
- Guava
- Jackfruit
- Kiwifruit
- Mango
- Muskmelon
- Nectarine
- Papaya
- Passion Fruit
- Peach
- Pear
- Persimmon
- Plum
- Quince
- Ranbutan
- Sapodilla
- Sapote
- Soursop
- Tomato

Non-Climacteric

- Cacao
- Carambola
- Cherry
- Cucumber
- Grape
- Grapefruit
- Lemon
- Lime
- Longan
- Loquat
- Lychee
- Olive
- Orange
- Pepper
- Pineapple
- Pomegranate
- Strawberry
- Tamarillo
- Watermelon

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Internal Factors

- Respiratory Substrate – carbohydrates, lipids, and organic acids

Respiratory quotient (RQ) = $\frac{[CO_2] \text{ evolved}}{[O_2] \text{ consumed}}$

- [ ] indicates moles of each
- RQ range from 0.7 to 1.3 for aerobic (with O_2) respiration
- RQ is much greater if tissue goes into anaerobic (without O_2) respiration

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Internal Factors

- Respiratory quotient (RQ) indicates when the cell utilizes different types of substrates for respiration
  - Carbohydrates: RQ = 1
  - Lipids: RQ < 1
  - Organic Acids: RQ > 1

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Internal Factors

- Preharvest factors such as:
  - Plant nutrition
    - e.g. nitrogen & calcium
  - Water supply
  - Pruning, training and thinning
  - Insect & Pathogen pressures
  - Climate and weather patterns
    - Temperature
    - Humidity
    - Wind
    - Light intensity, etc.

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Environmental Factors

- Temperature
- Atmospheric composition
  - Oxygen concentration
  - Carbon dioxide concentration
  - Ethylene
- Physical stresses
- Pathogen attack
- Other plant growth regulators
- Radiation
- Light
- Chemical stress
- Water stress

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Respiration and Shelf Life

- Respiration rate is inversely related to shelf life

Higher respiration =>

=> Shorter Shelf Life

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Environmental Factors
Temperature

- Temperature is the most important factor influencing postharvest life of a given commodity
  - Dictates the speed of chemical reactions (including respiration)
- Typically, for every 10 °C (18 °F) increase, respiration increases between 2 and 4 fold (Q_{10} or Van't Hoff Rule)

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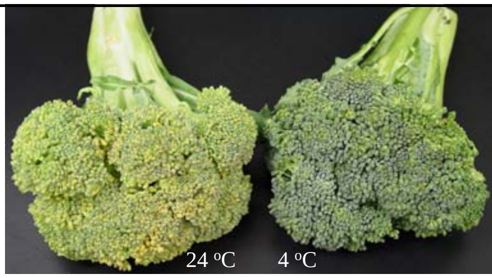

Affect of temperature on the quality of broccoli after just 48 h of storage at either room temperature (24°C; 75°F) or in the refrigerator (4°C; 40°F)

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Temperature Coefficient (Q_{10})

$$Q_{10} = \left(\frac{R_2}{R_1}\right)^{\left(\frac{10}{T_2 - T_1}\right)}$$

R_1 = rate of reaction at temperature 1 (T_1)
R_2 = rate of reaction at temperature 2 (T_2)
Temperatures are in °C
With a 10 °C Change in temperature => $Q_{10} = \frac{R_2}{R_1}$

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Typical Q_{10} Values

Temperature Range (°C)	Q_{10}
0 – 10	2.5 – 4.0
10 – 20	2.0 – 2.5
20 – 30	1.5 – 2.0
30 – 40	1.0 – 1.5

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Temperature effects on shelf-life

Temperature °C (°F)	Q_{10}	Deterioration	Shelf-Life
0 (32)		1	100
10 (50)	3	3	33
20 (68)	2.5	7.5	13
30 (86)	2	15	7
40 (104)	1.5	22.5	4

E.g. grapes at
32C (90F) for 1 h = 1 day at 4C (39F) = 1 week at 0C (32F)

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Example of Calculating The Q_{10}

- Say there is a new variety of Grapefruit
- Researchers have determined the following respiration rates at different temperatures:
  - 5 mg CO_2/kg-hr at 0C (32F)
  - 10 mg CO_2/kg-hr at 5C (41F)
  - 15 mg CO_2/kg-hr at 10C (50F)
  - 30 mg CO_2/kg-hr at 20C (68F)
  - 45 mg CO_2/kg-hr at 30C (86F)
  - 55 mg CO_2/kg-hr at 35C (95F)

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Example of Calculating The Q_{10}

- How much additional shelf life would a packinghouse manager expect if they held fruit at 10°C (50°F) compared to 30°C (86°F)?
- First, determine Q_{10} between 10 & 20°C, and between 20 & 30°C

$$Q_{10} = \left(\frac{R_2}{R_1}\right)^{\left(\frac{10}{T_2 - T_1}\right)}$$

If $T_2 - T_1 = 10$ Then

$$Q_{10} = \frac{R_2}{R_1}$$

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Example of Calculating The Q_{10}

- First, determine Q_{10} between 10 & 20C
  - 15 mg CO_2/kg-hr = R_1
    - 10C = T_1
  - 30 mg CO_2/kg-hr = R_2
    - 20C = T_2

$$Q_{10} = \left(\frac{30}{15}\right)^{\left(\frac{10}{20-10}\right)}$$

$$Q_{10} = \left(2\right)^{\left(\frac{10}{10}\right)} = 2^1 = 2$$

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Example of Calculating The Q_{10}

- Determine Q_{10} between 20 & 30C
  - 30 mg CO_2/kg-hr = R_1
  - 20C = T_1
  - 45 mg CO_2/kg-hr = R_2
  - 30C = T_2

$$Q_{10} = \left(\frac{45}{30}\right)^{\left(\frac{10}{30-20}\right)}$$

$$Q_{10} = \left(1.5\right)^{\left(\frac{10}{10}\right)} = 1.5^1 = 1.5$$

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Calculated Q_{10} Values for the new grapefruit variety

Temperature Range (ºC)	Q_{10}
0 – 10	(you calculate)
10 – 20	2
20 – 30	1.5

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Temperature effects on shelf-life

Temperature (ºC)	Q_{10}	Shelf-Life
0		
10	3	30
20	2	15
30	1.5	10

Thus, 10 day at 30C = 15 days at 20C = 30 days at 10C

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Low Temperature Injury

- Freezing will kill the tissue
- Chilling sensitive commodities
  - Q_{10} is usually much higher at chilling temperatures. In some commodities, respiration may increase at the lowest chilling temperatures
  - Upon return to non-chilling temperatures, respiration becomes abnormally high and may remain high

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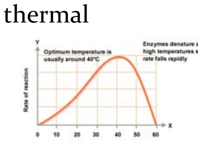
High Temperature Injury

- Respiration increase as temperature increases to a point
  - Above that point (tissue & commodity specific) protein denatures and respiration declines rapidly
- Time x Temperature component to thermal cell death
  - Cells can survive short periods at high temperatures (used for some quarantine treatments)



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High Temperature Injury

- Heat shock (brief exposure to high, non-lethal temperatures) can protect cells from subsequent high or low temperature stress
  - Induce the production of heat-shock proteins
  - Turns on the antioxidant defense system that counters reactive oxygen species (ROS) that can damage cellular components

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Atmospheric Concentration
Oxygen

- Low O_2 concentrations reduce respiration.
  - Below ~2-3% O_2, ETS starts to be inhibited
- If metabolic (ATP) demand is higher than inhibited Krebs cycle and ETS can supply, anaerobic respiration will attempt to satisfy ATP demand
  - Anaerobic respiration only produces 2 ATP per glucose vs. 30 ATP under aerobic respiration = 15 fold greater ATP production under aerobic conditions
  - CO_2 production is faster under anaerobic respiration (at least 15-fold higher!)

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Atmospheric Concentration
Carbon Dioxide

- High CO_2 also reduced respiration
  - Probably by inhibiting decarboxylation during aerobic respiration
- Different commodities vary widely to their ability to tolerate high CO_2 (e.g. lettuce very sensitive vs. strawberries very tolerant)
- As with low O_2 inhibition, if metabolic (ATP) demand is higher than inhibited Krebs cycle and ETS can supply, anaerobic respiration will attempt to satisfy ATP demand

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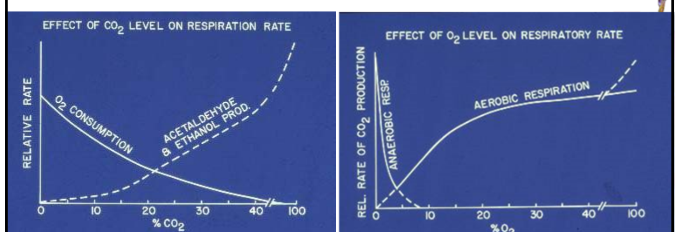
Relationship Between O2 and CO2 Concentrations and Respiratory Metabolism



Source: A.A. Kader, UC Davis

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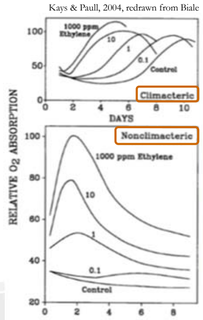
Atmospheric Concentration
Ethylene

- Climacteric & Non-Climacteric plant organs differ in their response to ethylene in the environment
- Climacteric fruit:
  - Ethylene reduces the time to onset of the climacteric rise (including autocatalytic ethylene production)
  - Concentration of added ethylene has little effect on respiration rate before or during the climacteric

Kays & Paull, 2004, redrawn from Biale



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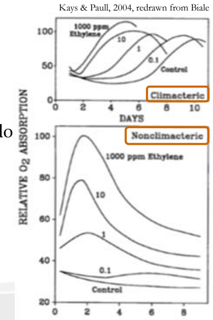
Atmospheric Concentration
Ethylene

- Non-Climacteric fruit:
  - Added ethylene induces a rise in respiration
  - Exposure to greater ethylene concentrations do not change how fast maximum respiration rates are obtained
  - Exposure to greater ethylene concentrations elicit greater rates of respiration
  - Does not induce autocatalytic ethylene production
  - Respiration rates return to normal after ethylene is removed

Kays & Paull, 2004, redrawn from Biale



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Physical Stress

- Any type of physical stress can cause respiration and ethylene production to rise quickly in both climacteric and non-climacteric commodities

Courtesy of Steve Sargent

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Environmental Factors

- Temperature
- Atmospheric composition
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- Physical stresses
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