Fruit Respiration

Perishable Commodities are still alive!

They consume oxygen and produce carbon dioxide

Sugar+ O_2

↓

Energy + CO_2 + Water + Heat

Respiration → Heat → Faster respiration → More heat →

The rate of respiration is affected by levels of oxygen and carbon dioxide

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

glucose + oxygen → carbon dioxide + water

reactants *products*

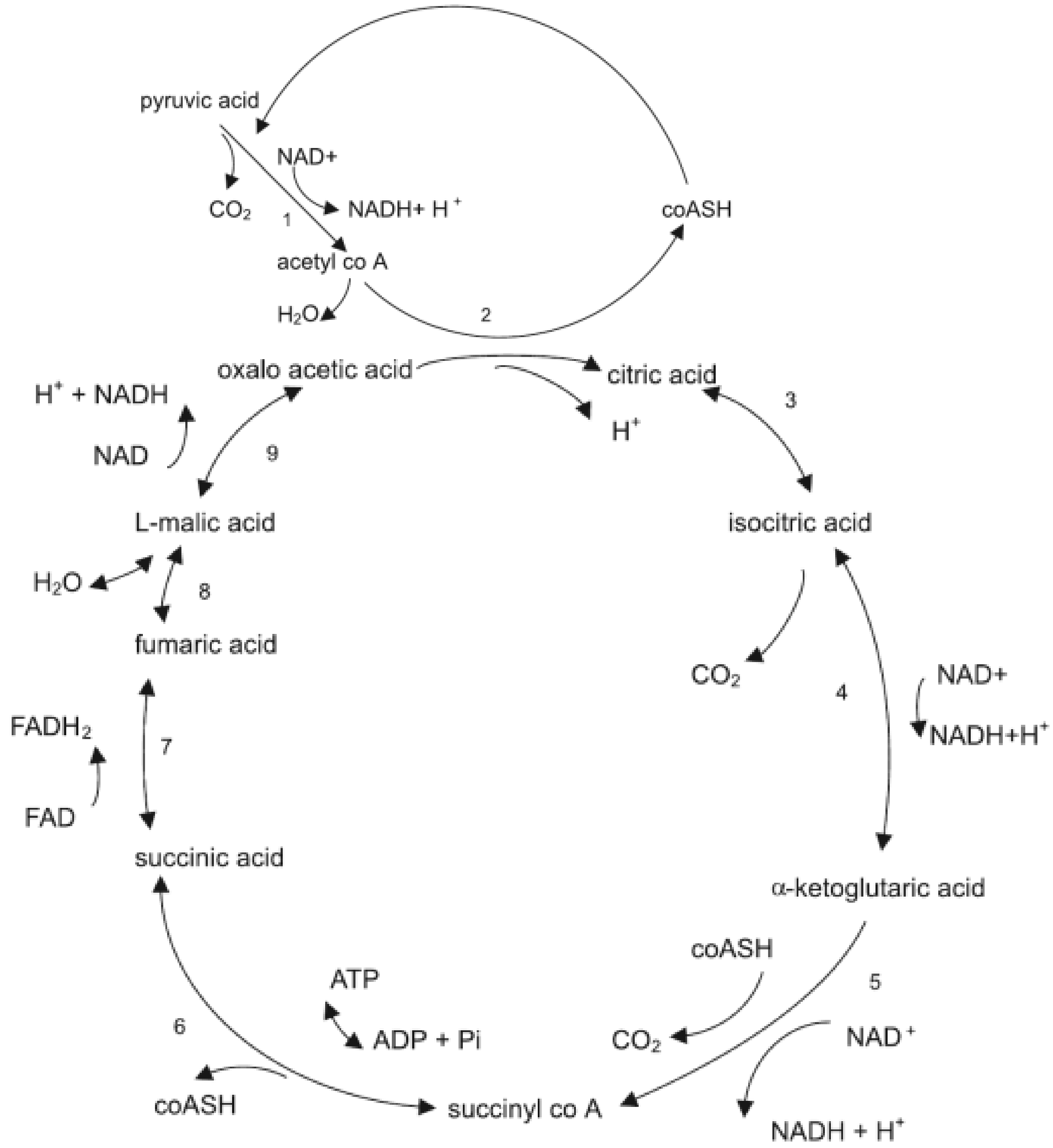


Fig. 2.26 The reactions of the TCA cycle. The numbers refer to the enzymes which catalyse the reactions. 1, pyruvic acid dehydrogenase; 2, citrate synthase; 3, aconitase; 4,isocitrate dehydrogenase; 5, α-ketoglutarate dehydrogenase; 6, succinate thiokinase; 7, succinate dehydrogenase; 8, fumarase; 9, malate dehydrogenase.

Figure 3.7
A simplified scheme for aerobic respiration of carbohydrate reserves in plants via glycolysis and the TCA cycle. Malate from the vacuole or mitochondria can be directly metabolised to pyruvate by NAD- or NADP-specific malic enzyme (ME). Pyruvate produced by ME or from fructose 6-phosphate can be oxidised via the TCA cycle or by anaerobic respiration. The conversion of intermediates in these pathways to CO_2 and the reduction of NAD and FAD to NADH and $FADH_2$, respectively, are also indicated. NADH and $FADH_2$ are oxidised via the electron transport chain (see Figure 3.8).

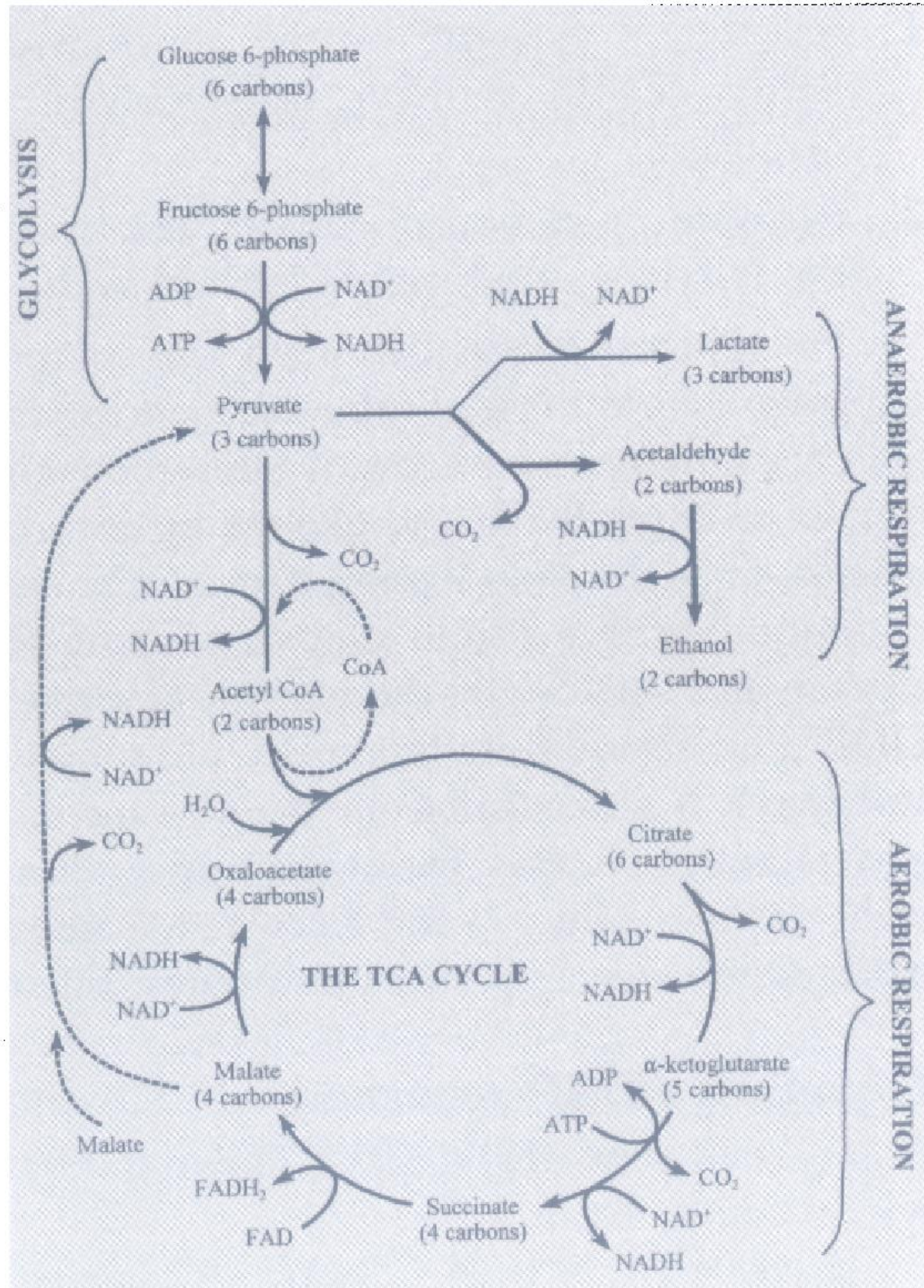


Figure 3.8
NADH and $FADH_2$ are oxidised via the electron transport chain to produce water and ATP from ADP. Three ATP molecules are produced from NADH and two from $FADH_2$.

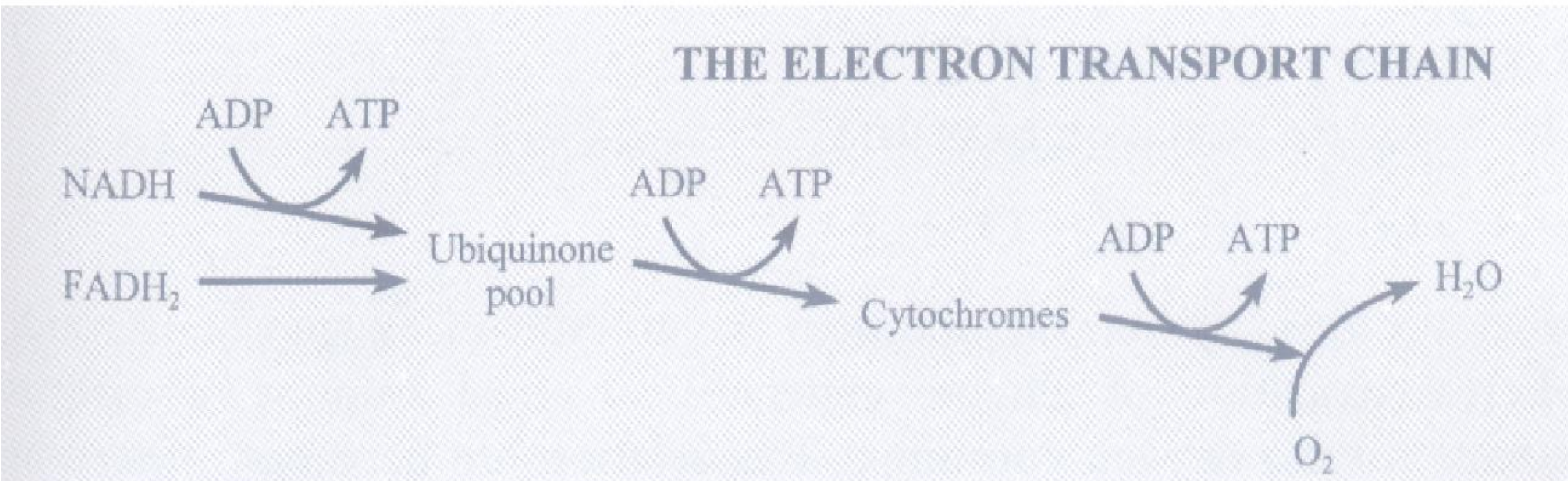


Table 1.2 Classification of fruits according to their respiration rate and pattern

Class	Range of respiration rates (ml CO_2/kg·h) at 5°C	Fruits: Climacteric	Fruits: Non-climacteric
Very low	<5	—	Date, grape, nuts, pepino, pineapple
Low	5–10	Apple, Asian pear (some cultivars), kiwifruit, papaya, pear, persimmon, plum, quince	Cactus pear, cherry, cranberry, grapefruit, jujube, lemon, lime, mandarin, olive, orange, pomegranate, pummelo (pomelo)
Moderate	11–20	Apricot, banana, blueberry, feijoa, fig, guava, mango, nectarine, peach, plantain, rambutan, sapotes	Gooseberry, lanson, longan, loquat, lychee, tamarillo, star fruit (carambola)
High	21–30	Avocado, breadfruit, passion fruit	Blackberry, boysenberry, raspberry, strawberry
Very high	>30	Cherimoya, durian, jackfruit, soursop	—

Sources: Hardenburg *et al.*, 1996; Kader, 1992; Ryall & Pentzer, 1982.

Adel A. Kader, 2001

TABLE 3.19 Some Horticultural Commodities Classified According to Their Respiration Rates

Class	Range at 20°C ($mg\,CO_2/kg\,h$)	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, pomegranate, potato, pumpkin, sweet potato, water melon, winter squash
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, leek, lettuce (leaf), lima bean, radish (with tops), raspberry, strawberry
Very high	40–60	Artichoke, bean sprouts, broccoli, Brussels sprout, cherimoya, cut flowers, endive green onions, kale, okra, passion fruit, snap bean, watercress
Extremely high	>60	Asparagus, mushroom, parsley, peas, spinach, sweet corn

Classification of Fruits and Vegetables Based on Respiration Rate

	Respiration Rate (mg carbon dioxide/kg h)		
Class	**10°C**	**20°C**	**Examples**
I. Very low	<10	<40	Nuts, dates, dried fruits
II. Low	10	40	Potatoes, onions, cucumbers, apple, pear, kiwi fruit, pomegranate, Chinese date
III. Moderate	10–20	40–80	Peppers, carrots, tomatoes, eggplant, citrus fruits, banana
IV. High	20–40	80–120	Peas, radish, apricot, fig, ripe avocado, cherimoya, papaya
V. Very high	>40	>120	Mushrooms, green onions, cauliflower, dill, parsley, melons, okra, strawberry, blackberry, raspberry

TABLE 3.27 Classification of Fresh Horticultural Commodities According to Relative Perishability and Potential Postharvest Life at Optimal Temperature and Relative Humidity

Relative Perishability	Potential Storage Life (Weeks)	Commodities
Very high	<2	Apricot, blackberry, blueberry, cherry, fig, raspberry, asparagus, bean sprouts, broccoli, cauliflower, cantaloupe, green onion, leaf lettuce, mushroom, pea, spinach, sweet corn, tomato (ripe), most cut flowers and foliage, fresh-cut (minimally processed) fruits and vegetables
High	2–4	Avocado, banana, grape (without SO_2 treatment), guava, loquat, mandarin, mango, melons (honeydew, crenshaw, pershian), nectarine, papaya, peach, pepino, plum, artichoke, green beans, Brussels sprouts, cabbage, celery, eggplant, head lettuce, okra, pepper, summer squash, tomato (partially ripe)
Moderate	4–8	Apple and pear (some cultivars), grapes (SO_2 treated), orange, grapefruit, lime, kiwifruit, persimmon, pomegranate, pummel, table beet, carrot, radish, potato (immature)
Low	8–16	Apple and pear (some cultivars), lemon, potato (mature), dry onion, garlic, pumpkin, winter squash, sweet potato, taro, yam, bulbs and other propagules of ornamental plants
Very low	>16	Tree nuts, dry fruits, and vegetables

TABLE 3.12 Characteristics for Some Subtropical Fruits

Produce	Precooling	Temperature (°C)	% RH	Postharvest Life	Sensitivity
Avocado	FC	4–13	85–90	2–4 weeks	CI
Orange	RC, FC	3–8	90	3–12 weeks	CI
Grapefruit	RC	10–15	85–90	6–8 weeks	CI
Lemon	RC	10–13	85–90	1–6 months	CI
Lime	RC	9–10	85–90	6–8 weeks	CI
Pomegranate	HC, FC	5°C	90	2–3 months	CI
Persimmon	FC	–1°C	90	3–4 weeks	
Lychee	FC	1.5	90–95	3–5 weeks	Desiccation
Fig	FC	0	85–90	7–10 days	
Date	RC	–15 to 0	≤75	6–12 months	
Olive	RC	5–10	85–90	4–6 weeks	CI
Kiwifruit	FC	0	85	4–7 weeks	

HC, *hydrocooling;* FC, *forced-air cooling;* RC, *room cooling;* CI, *chilling injury.*

TABLE 3.13 Characteristics of Some Tropical Fruits

Produce	Precooling	Temperature (°C)	% RH	Postharvest Life (Weeks)	Sensitivity
Banana	FC, RC	13–15	90–95	1–4	CI
Plantain	FC, RC	13–15	90–95	1–5	CI
Mango	FC	10–13	85–90	2–4	CI
Papaya	FC	7–13	85–90	1–3	CI
Guava	FC	5–10	85–90	2–3	CI

FC, *forced-air cooling;* RC, *room cooling.*

TABLE 3.14 Characteristics of Some Small Fruits

Produce	Precooling	Temperature (°C)	% RH	Postharvest Life
Grape	FC	−1 to 0	90–95	1–6 months
Strawberry	FC	−1 to 0	90–95	5–7 days
Blackberry	FC	−1 to 0	90–95	2–3 days
Blueberry	FC	−1 to 0	90–95	2 weeks
Cranberry	FC	−1 to 0	90–95	2–4 months
Gooseberry	FC	−1 to 0	90–95	2–4 weeks
Raspberry	FC	−1 to 0	90–95	2–3 days

FC, *forced-air cooling*.

TABLE 3.15 Characteristics of Some Pome Fruits

Produce	Precooling	Temperature (°C)	% RH	Postharvest Life	Sensitivity
Apple	FC, HC	0–4	85–90	2–9 months	Brown core in McIntosh
Pear	FC, HC	−0.5 to 0.5	90–95	2–6 months	
Quince	VC	0.1	95	2–3 months	

VC, *vacuum cooling*; HC, *hydrocooling*; FC, *forced-air cooling*; RC, *room cooling*.

TABLE 3.16 Characteristics of Some Stone Fruits

Produce	Precooling	Temperature (°C)	% RH	Postharvest Life (Weeks)
Peach	HC, FC	0	90–95	2–4
Nectarine	HC, FC	0	90–95	2–4
Plum	FC, RC	0	90–95	4–5
Apricot	FC, RC	0	90–95	1–2

HC, *hydro-cooling;* FC, *forced-air cooling;* RC, *room cooling.*

TABLE 3.17 Characteristics of Some Nuts

Produce	Postharvest Life (Months)
Pecan	12–18
Walnut	10–20
Almond	15–20
Macadamia	12–24
Pistachio	12

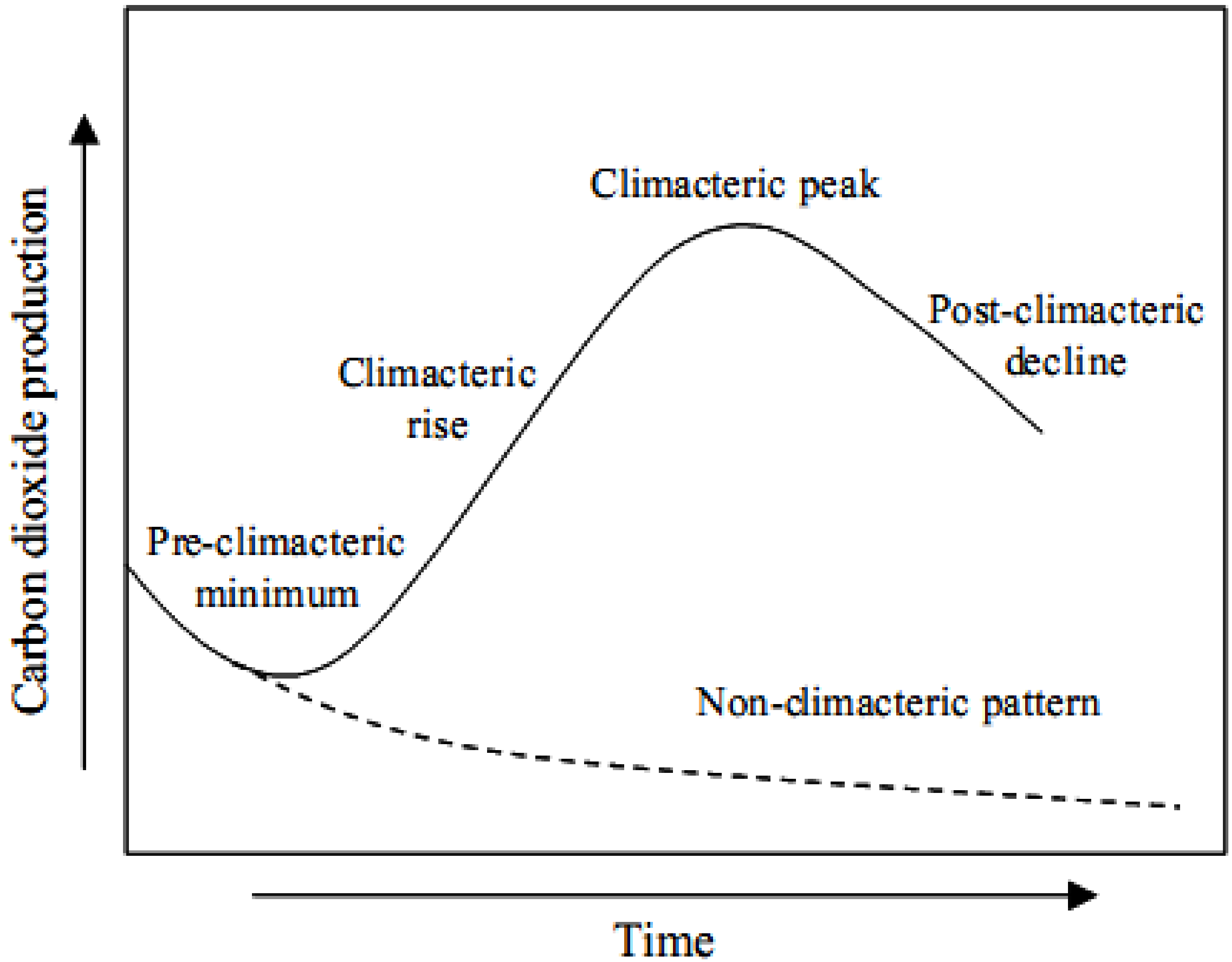
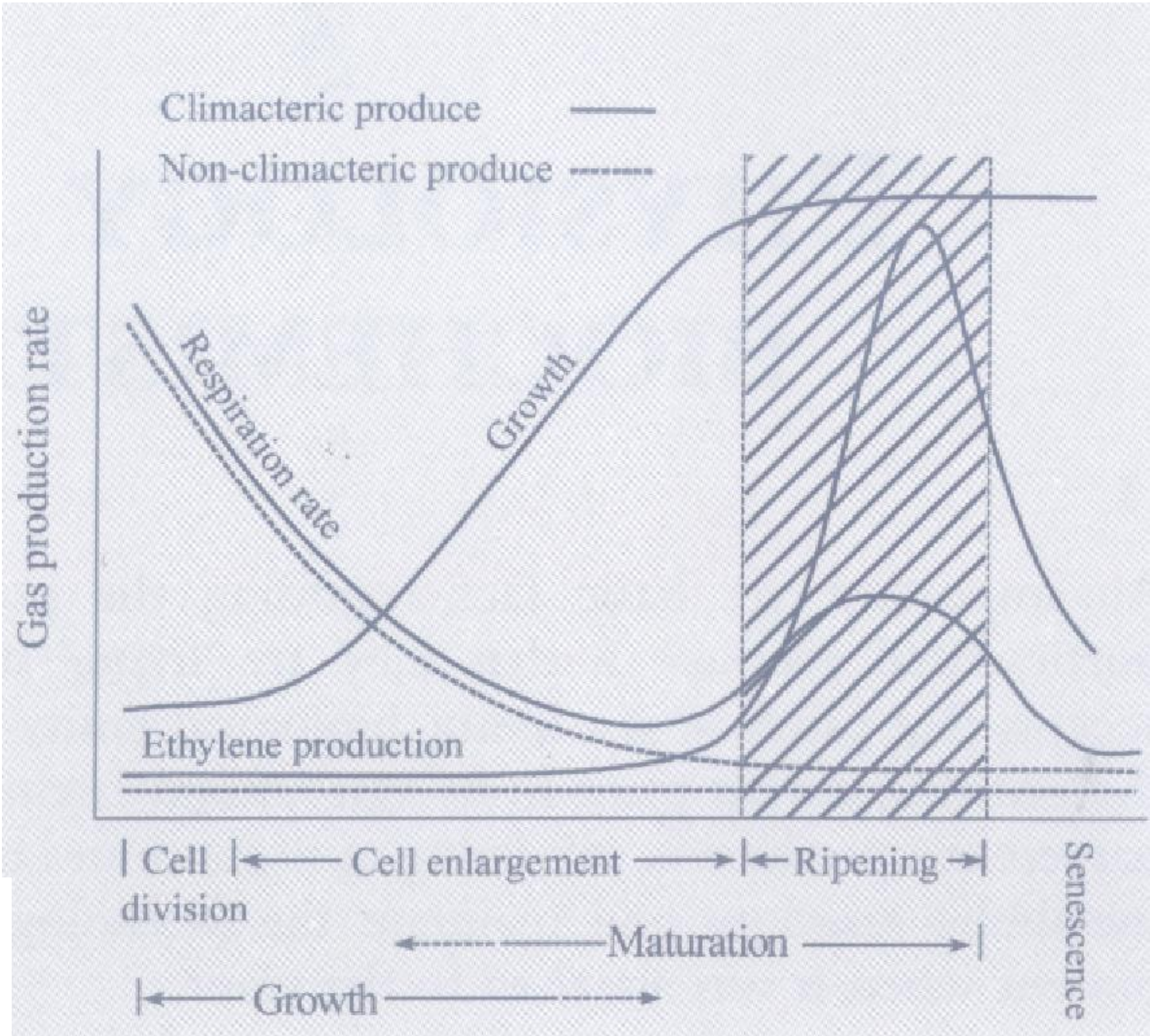


Figure 1. The climacteric pattern of respiration in ripening fruit.



Growth, respiration and ethylene production patterns of climacteric and non-climacteric plant organs.

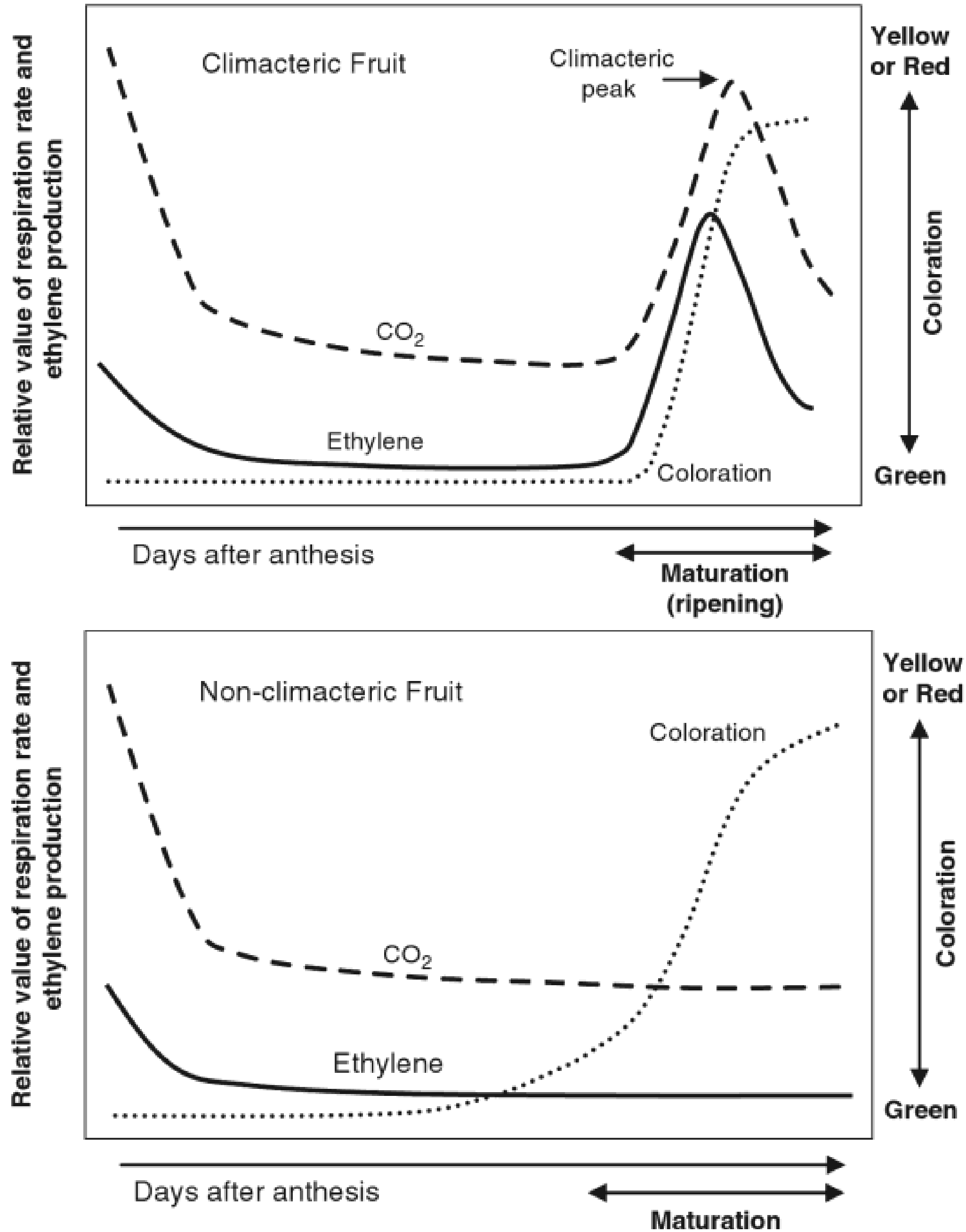
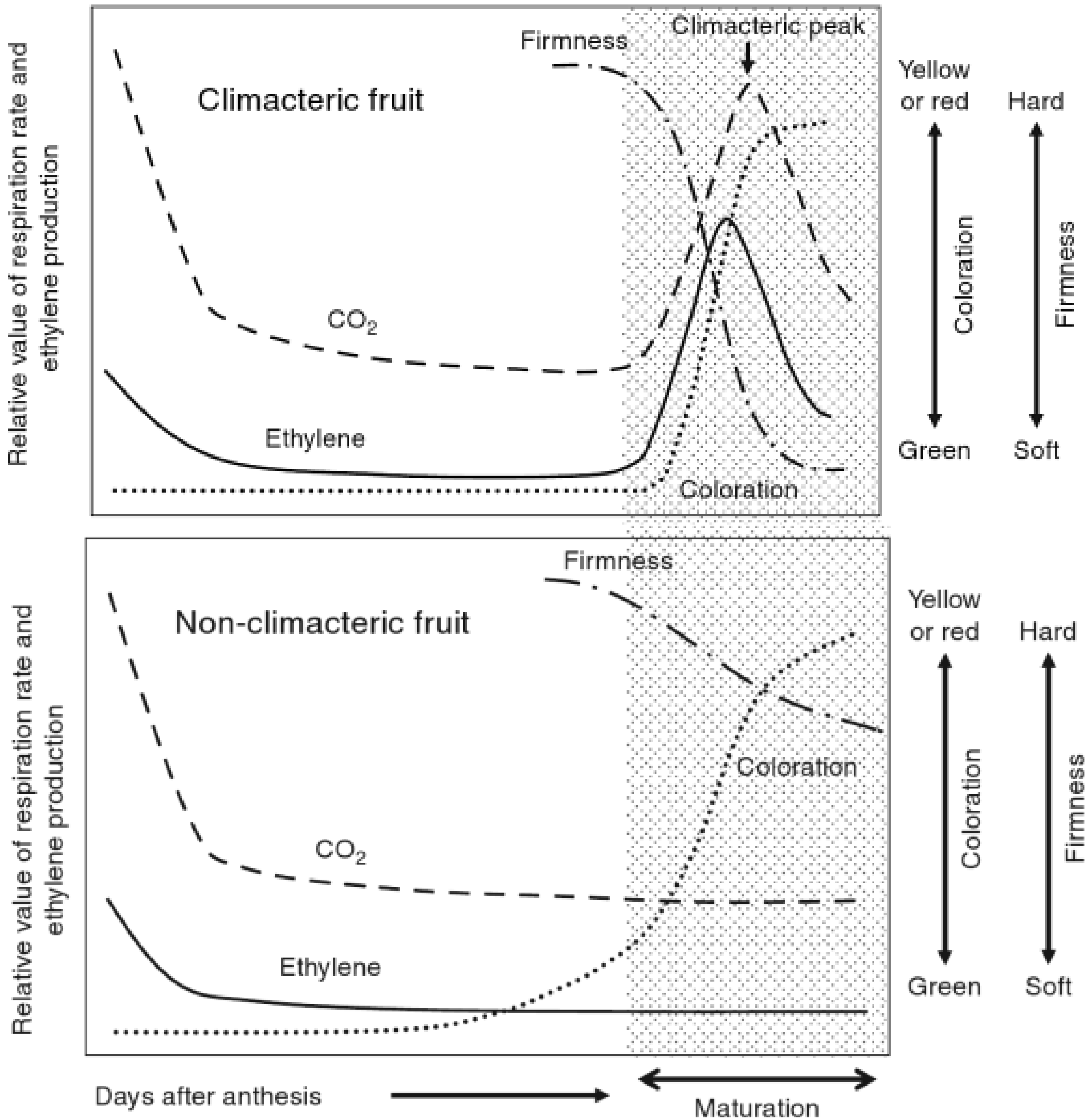


Fig. 15.3 Patterns of respiration rate, ethylene production, and coloration in climacteric and non-climacteric fruit



Typical ripening pattern in climacteric and non-climacteric fruits.

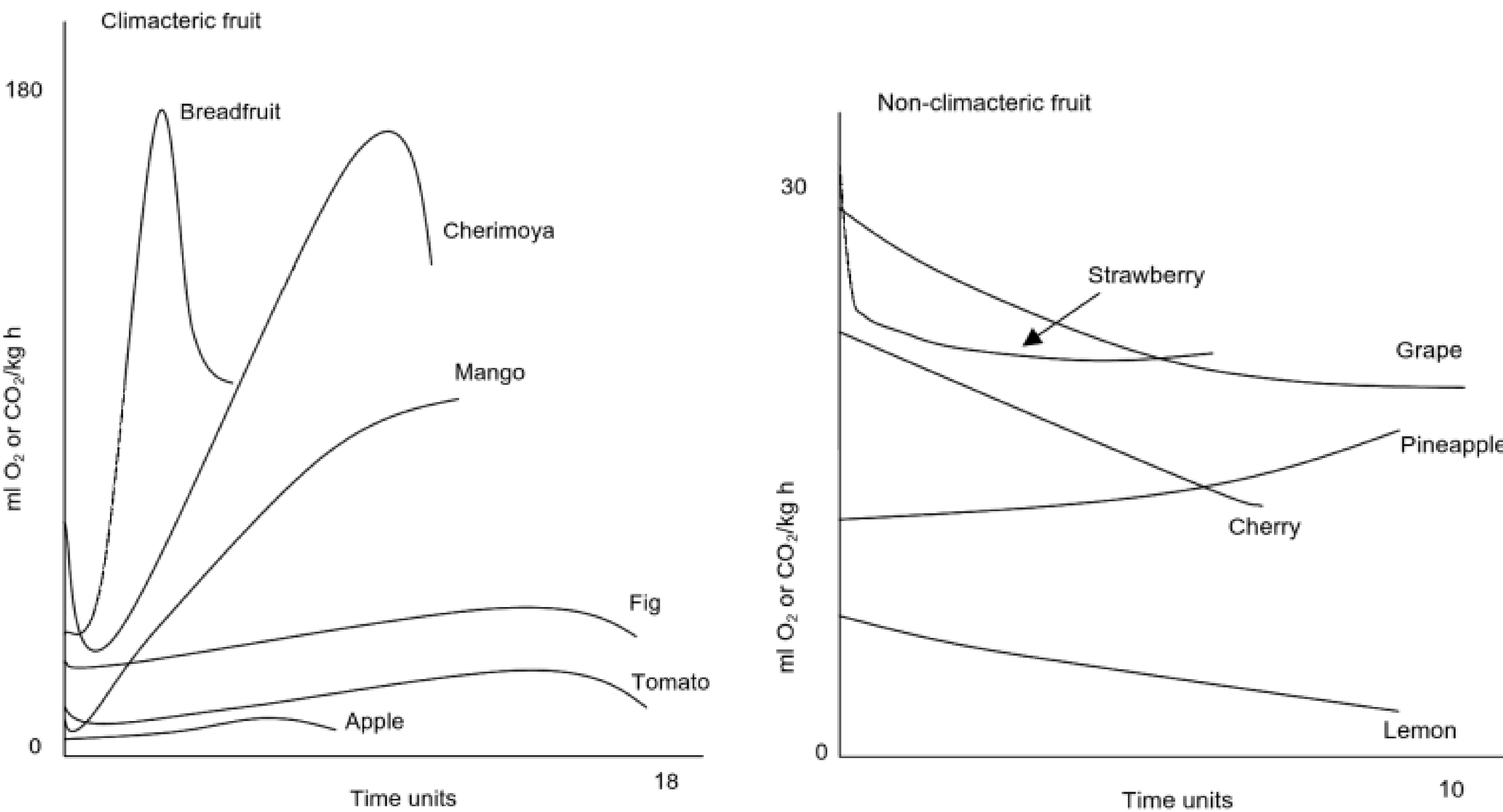
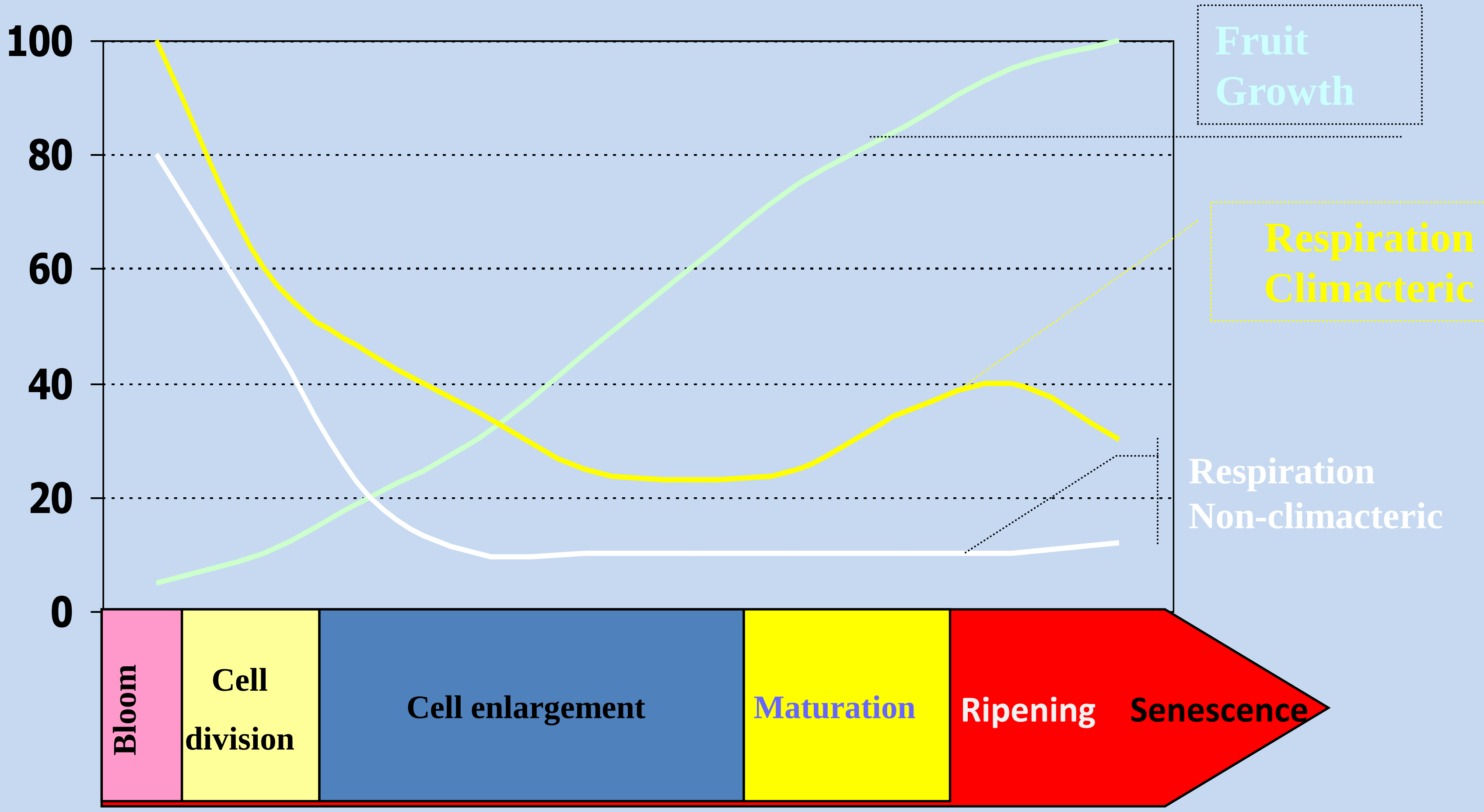


Fig. 2.27 Respiration patterns during the ripening of climacteric and non-climacteric fruit. Source: Seymour *et al.* 1993.

Types of Fruit

Climacteric vs. Non-climacteric

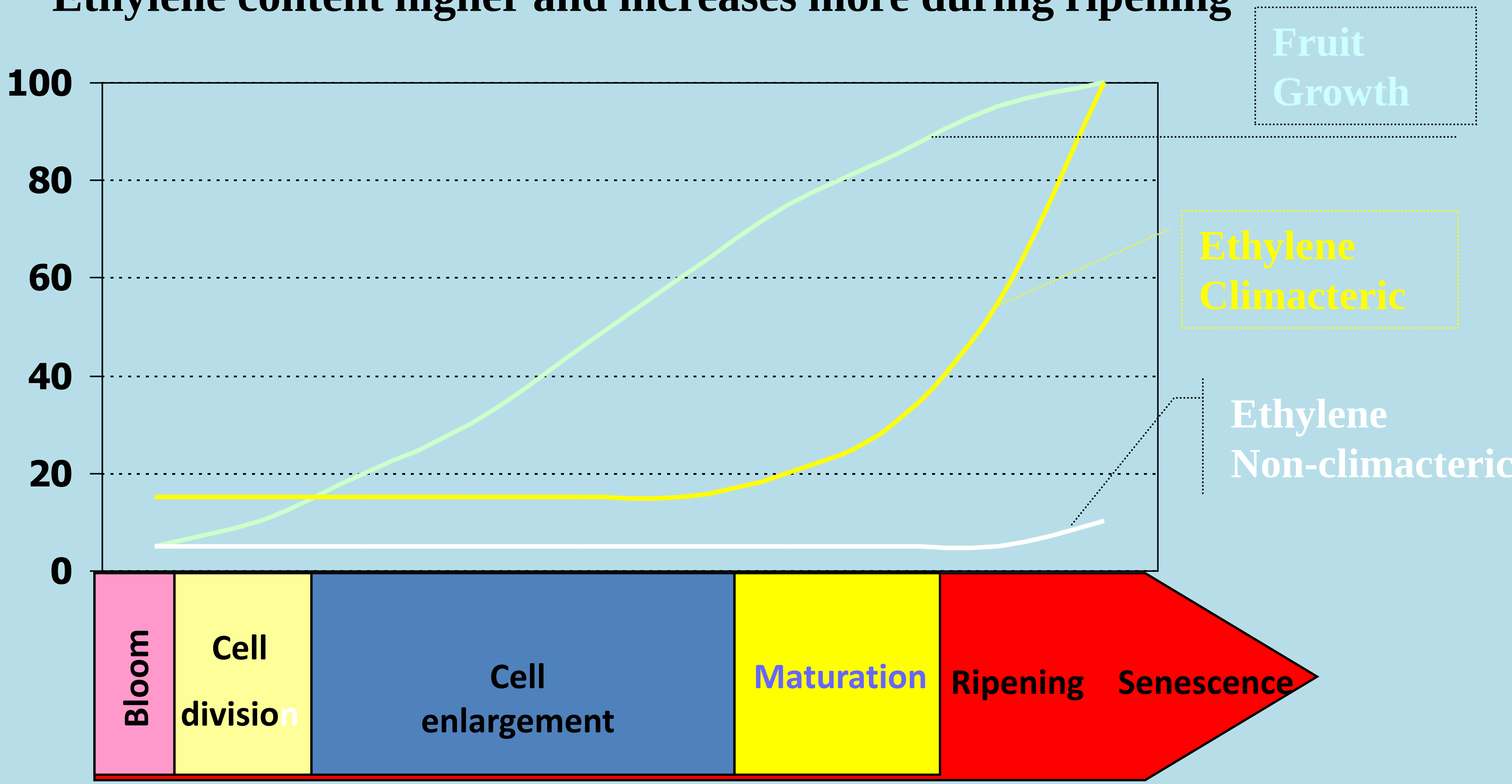
Respiration increases during ripening



Types of Fruit

Climacteric vs. Non-climacteric

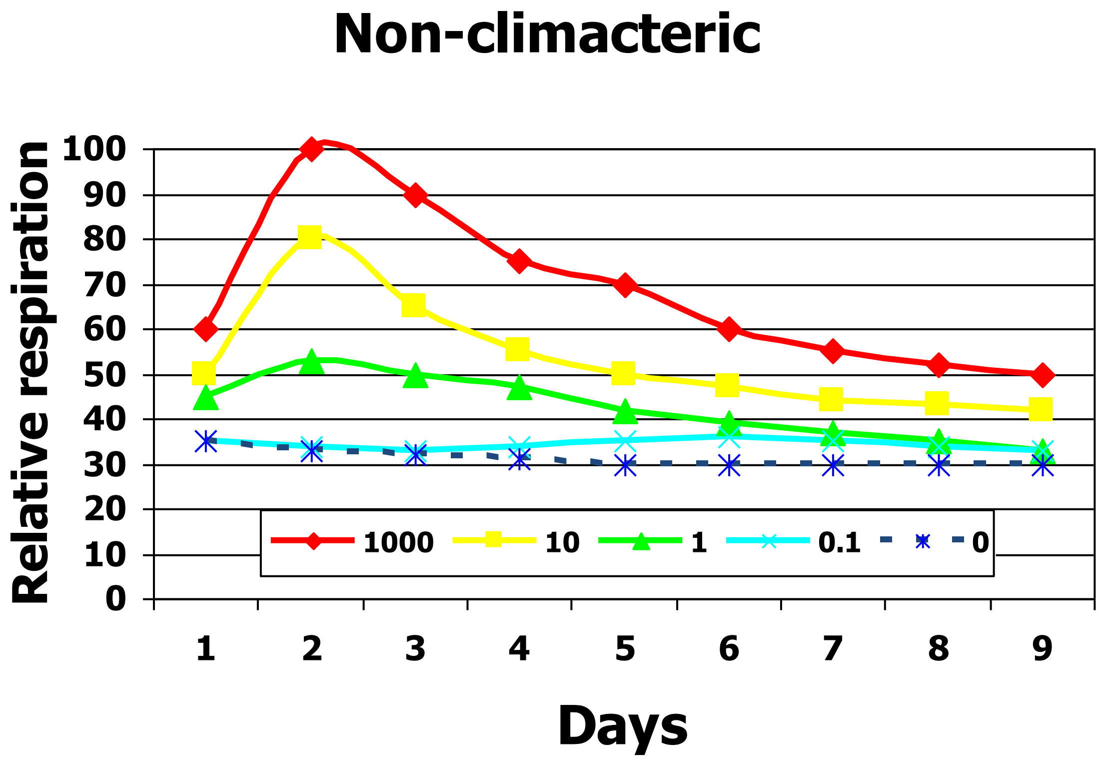
Ethylene content higher and increases more during ripening



- **Climacteric fruit**
  - **Increased respiration at ripening**
  - **Ripen faster**
  - **Ethylene**
    - **Produce more**
    - **Higher internal level**
    - **Level increases at ripening**
  - **Applied Ethylene**
    - **Respond to applied ethylene in non-rate dependent fashion**

- **Non-climacteric fruit**
  - **No increase in respiration**
  - **Ripen slower**
  - **Ethylene**
    - **Produce less**
    - **Lower internal levels**
    - **No increase at ripening**
  - **Applied Ethylene**
    - **Rate dependent response**

Fruit Respiration in Response to Ethylene

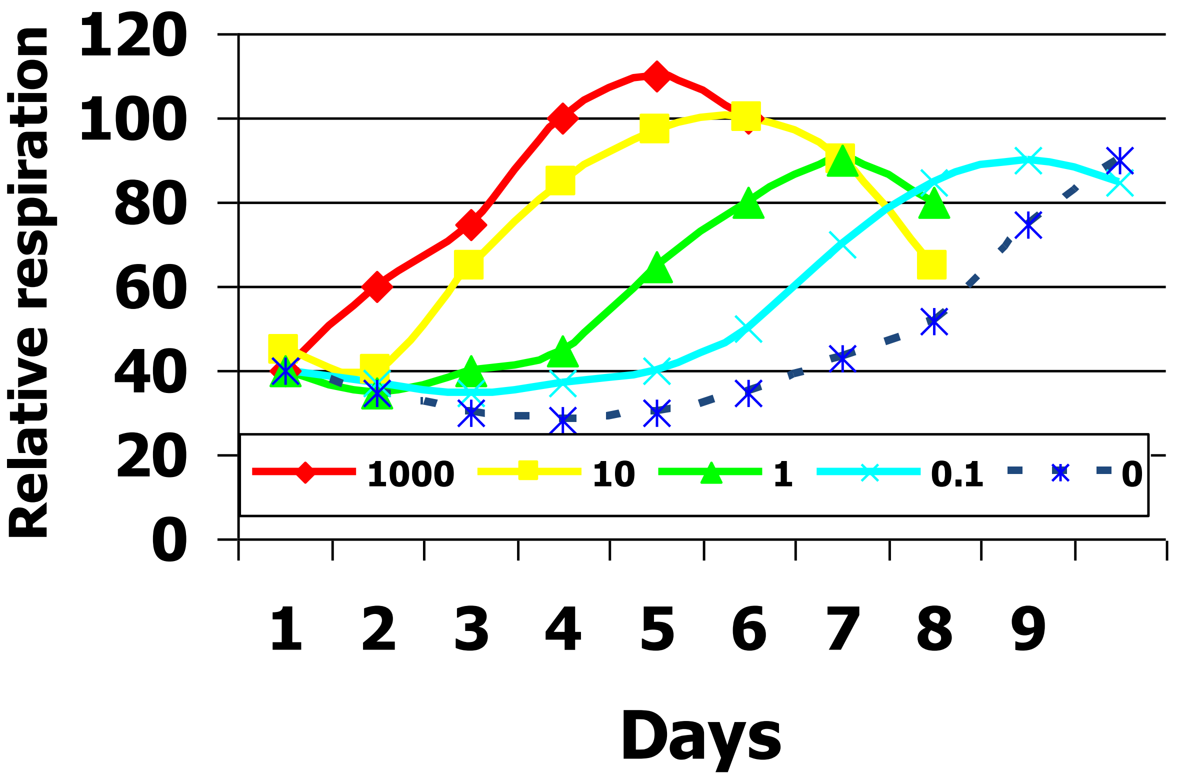


Rate dependent response to ethylene

Amount of ethylene dictates the ultimate level of response

Fruit Respiration in Response to Ethylene

Climacteric



Non-rate dependent

React to a threshold level to give about same response

Respiration and Shelf Life

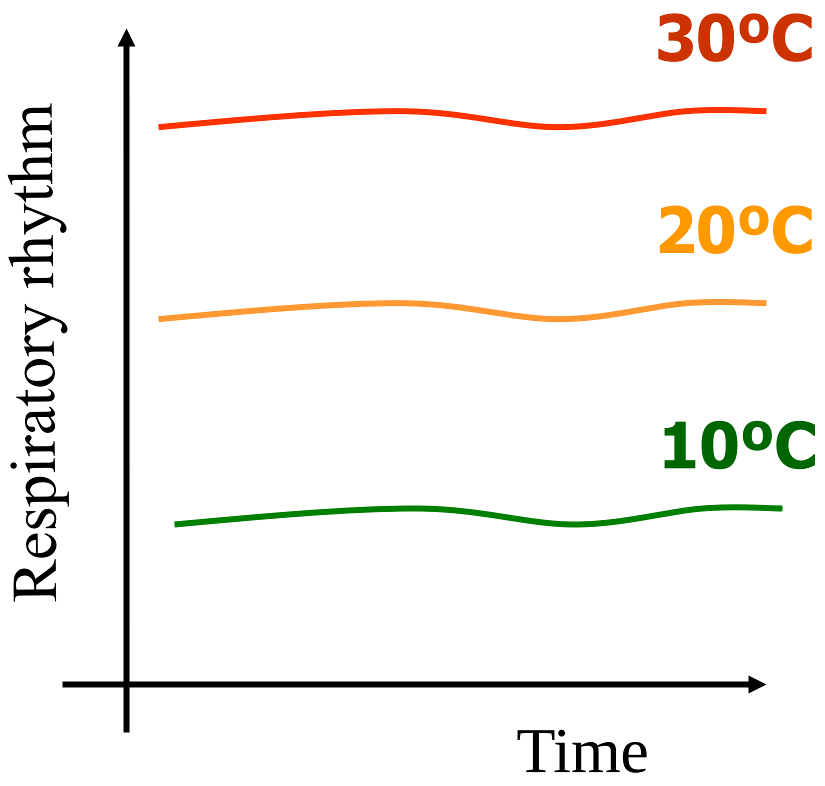
Respiration rate and shelf life are inversely related.

Higher respiration

↓

Shorter Shelf Life

Temperature effects on respiration rate.



- At temperatures above the optimum, the rate of deterioration increases 2 to 3 fold for every 10ºC rise in temperature.
- High temperature- increases the transpiration rate.

Temperature & Respiration

- Temperature is the most important factor influencing the postharvest life of the given commodity.
- Temperature dictates the speed of chemical reactions including respiration.
- Typically, for every increase of 10^{o}C, the respiration increases between 2 and 4 fold.

R1=Respiration at Temperature 1 (T1)

R2=Respiration at Temperature 2 (T2)

$$Q_{10} = \left(\frac{R2}{R1}\right)^{\left(\frac{10}{T2-T1}\right)}$$

Table 2 Effect of Temperature on Respiration Rate of Vegetables

Temperature (°C)	Assumed Q_{10}	Relative velocity of respiration	Relative shelf life
0		1.0	100
	3.0		
10		3.0	33
	2.5		
20		7.5	13
	2.0		
30		15.0	7
	1.5		
40		22.5	4

Table 3 Respiration Rates (mg $CO_2 \cdot kg^{-1} \cdot h^{-1}$) and Q_{10} Values for Selected Vegetables

Temperature (°C)	Asparagus		Cauliflower		Kale		Lettuce		Onions		Tomatoes	
	Resp.	Q_{10}	Resp.	Q_{10}	Resp.	Q_{10}	Resp.	Q_{10}	Resp.	Q_{10}	Resp.	Q_{10}
0	54		19		—		23		3		—	
		3.2		1.3		—		1.7		1.7		—
5	96		22		22		30		4		8	
		3.0		2.7		3.5		1.7		4.0		5.1
10	167		36		41		39		8		18	
		2.1		2.3		3.6		2.6		1.7		2.4
15	244		54		78		63		11		28	
		2.5		2.5		3.1		2.5		3.0		2.1
20	387		86		138		100		19		41	
		2.0		2.6		2.7		2.2		2.3		1.6
25	550		140		226		147		29		51	

Table 4 Temperature Quotient (Q_{10}) for Rate of Vegetable Deterioration

	Temperature range (°C)		
Commodity	0 to 10	10 to 20	20 to 30
Asparagus			
Appearance quality	2.7	2.4	1.8
Sugar loss	5.8	2.7	1.4
Fiber increase	10.0	2.0	2.0
Brussels sprouts (visual)	3.8	2.7	1.9
Celery (visual)	4.1	2.3	1.9
Head lettuce (visual)	2.5	2.2	1.9
Peas			
Appearance quality	3.3	2.8	2.0
Sugar loss	2.7	2.6	1.5
Spinach (visual)	3.3	2.5	1.8
Sweetcorn (sugar loss)	3.9	3.6	1.5

The affect of temperature

The affect of temperature on broccoli after 48 hr of storage at either room temperature or in cold storage

24^{o}C **4^{o}C**

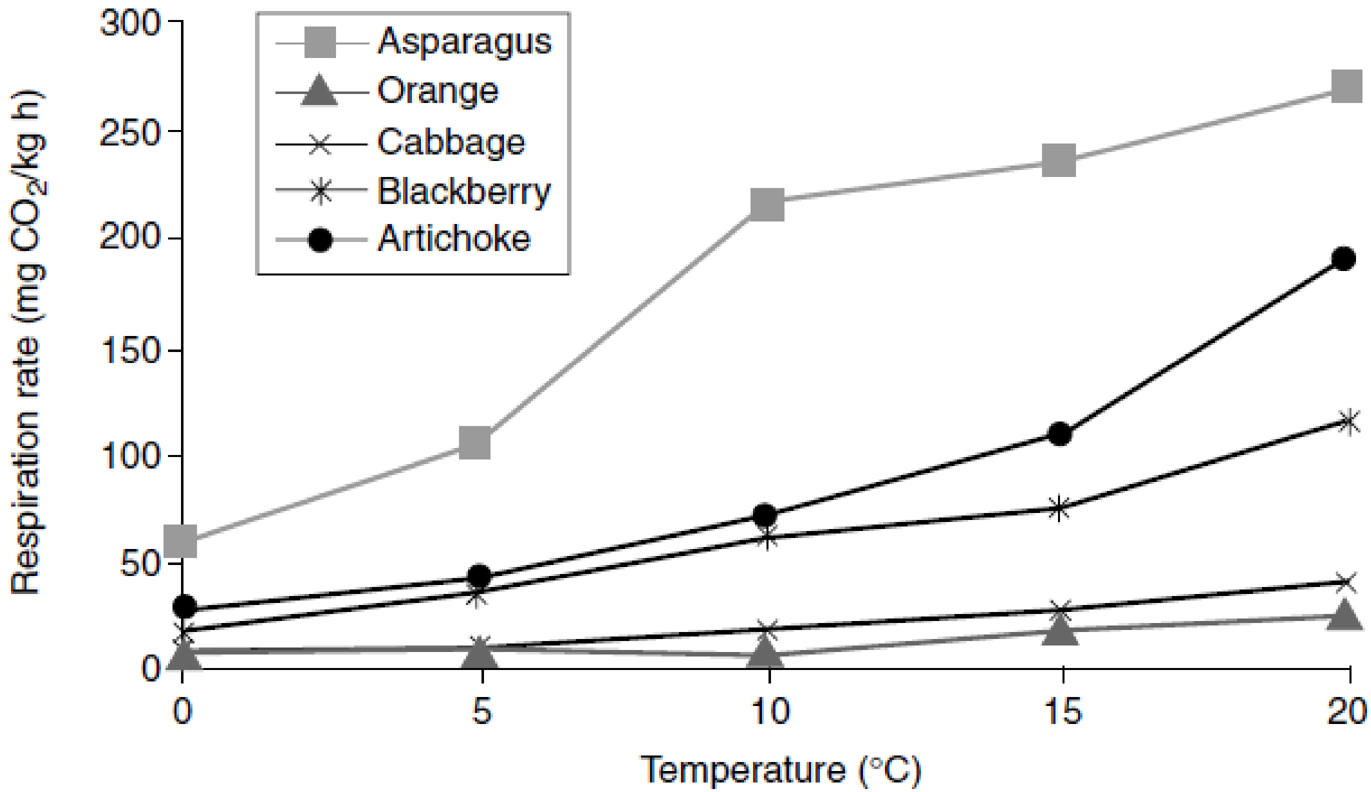


FIGURE 2.3 Effect of temperature on the respiration rates of some fruits and vegetables. (Data taken from K. C. Gross et al. *The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks—A Draft Version of the Revision to USDA Agricultural Handbook Number 66* (2002) (revised in 2004) (www.ba.ars.usda.gov/hb66/index.html.)