Physiological Disorders of Fresh Fruits and Vegetables


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Physiological Disorders

- **Definition**: External or internal blemishes resulting from improper environmental or cultural conditions before and/or after harvest
  - Blemishes without an obvious causal fungal, bacterial, viral or insect agent
  - Blemishes not caused by mechanical injuries (*i.e.*, cuts, punctures, bruises, abrasions, etc.)

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Types of Physiological Disorders

- Disorders caused by adverse **temperature** conditions
- Disorders resulting from some physiological malfunction within the normal temperature range for the product
- Also, damage from environmental toxicants

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Types of Physiological Disorders

- Temperature-related disorders
  - Freezing injury
  - Chilling injury
  - High temperature injury
    - Temperature effect
    - Radiant energy effect (sunburn/sunscald)

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Types of Physiological Disorders

- Nutrition-related disorders
  - Calcium deficiency #1
  - Boron deficiency
  - Excess nitrogen

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Types of Physiological Disorders

- Other disorders
  - Disorders of long-term storage
    - Senescence related
  - Controlled atmosphere disorders
    - Low O_2 or high CO_2
  - Toxic chemicals
    - Ammonia, SO_2, methyl bromide, ozone, $CaCl_2$
  - Ethylene disorders

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Freezing Injury

- Reduction of the ambient temperature below that of the freezing point of the tissue
- Symptoms include water-soaked areas in the tissue, and collapse and even disruption of the epidermis
- Freezing temperatures may occur in the field or in the storage environment

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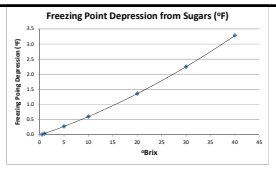
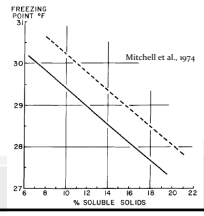
Freezing Injury

- Freezing point depression
  - Dissolved solids in the cell sap reduce the freezing point of plant tissues below that of pure water
  - This **freezing point depression**, which is a function of the osmolality of the cell solution, ranges from less than 1°C to a few °C





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Freezing points for some common fruits and vegetables

Commodity	Freezing point range (°C)
Apple	-2.2 - -1.7
Asparagus	-1.4 - -1.1
Cherry	-4.3 - -3.8
Cucumber	-0.9 - -0.8
Grape	-5.3 - -2.9
Lettuce	-0.6 - -0.3
Onion	-1.3 - -0.9
Orange	-2.3 - -2.0
Potato	-1.8 - -1.7
Tomato	-1.0 - -0.7

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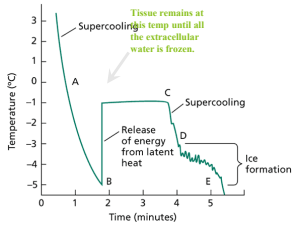
Freezing Injury

- **Supercooling**
  - When the temperature of tissues falls below the freezing point, ice crystals are not immediately formed because there is a substantial capacity for supercooling in plant tissues
    - *i.e.*, the cell solution remains liquid even though it is below its freezing point



Taiz & Zeiger, 2002, Web Topic 25.3

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Freezing Injury

- Supercooling
  - Can be reversible
  - May be devastating because of the rapidity with which freezing occurs when the supercooled solution finally freezes
    - Prolonged exposure to low temperature
    - **Nucleation** due to vibration

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Freezing Injury

- **Ice nucleation**
  - The supercooled solution eventually freezes, either by prolonged exposure to low temperature or when nucleated by vibration
  - Intracellular freezing of the cytoplasm and vacuolar sap is **lethal**

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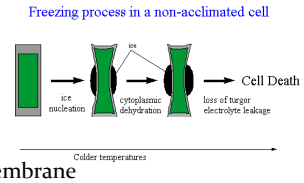
Freezing Injury

- Extracellular freezing
  - Ice crystals in the dilute wall liquid increase the VPD across the cell membrane
  - Ice crystals continue to grow at the expense of the liquid in the cell, which may become plasmolysed (collapsed)
    - **plasmolyze** => solutes move out (K^+, Ca^{2+}), get dehydration injury, get dehydration injury



http://www.agronomy.psu.edu/Courses/AGRO518/FREEZING.htm#contents

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Freezing Injury

- Extracellular freezing
  - Natural "freeze-drying"
  - Usually reversible
  - Reduces the freezing point of the cell sap by increasing its osmolality, thereby making the tissue more resistant to intercellular freezing

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Freezing Injury

- Extracellular freezing
  - Can also be lethal due to:
    - Dehydration of the plasma membrane.
    - Puncturing of membranes when ice crystals grow into the space left inside the wall by the plasmolysing cytoplasm.

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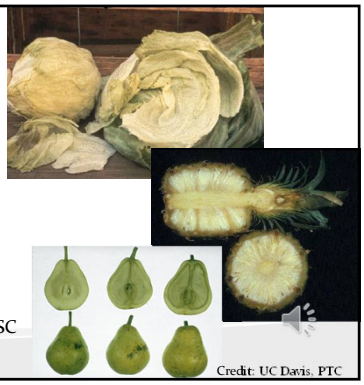
Freezing Injury

- Symptoms of freezing injury
  - Watersoaked appearance
  - Limp, flaccid tissues
  - Secondary symptoms include discoloration (browning) and decay
  - Freezing from outside to inside, or wherever the SSC is lowest



Credit: UC Davis, PTC

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Freezing Injury

- What if the commodity is exposed to freezing temperatures?
  - Don't move frozen tissue or tissue with temperature below 0°C
    - Vibration can cause nucleation of supercooled tissues and rapid freezing
  - If freezing was slight:
    - Slowly warm commodity to ~5°C to allow any ice crystals to melt and tissues to recover from the stress as best as possible
  - Market quickly because quality will likely deteriorate quickly (*i.e.*, internal desiccation, accelerated decay, etc.). Depends on the freeze severity

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Freezing Injury

- Work to avoid freezing temperatures in the first place
  - Choose cultivars and planting dates so that the produce is harvested before freezing temperatures are likely to occur.
  - Maintain refrigeration equipment and sensors and install alarms if temperatures fall below 0°C.

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Chilling Injury

- Exposure to temperatures below a critical **threshold temperature** but still above the freezing point
- Characterized by increased susceptibility to fungal attack, collapse and necrosis of tissues, water soaking, and tissue death

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Chilling Injury

- **Threshold temperature**
  - Characteristic of a commodity
  - Lowest temperature at which no injury is seen, regardless of the length of storage
  - Below the threshold temperature, CI occurs
- Commonly in the 10-15°C range
  - Can vary from quite low (*e.g.*, 3°C for some apple varieties) to quite high (as high as 20°C for some pineapples)

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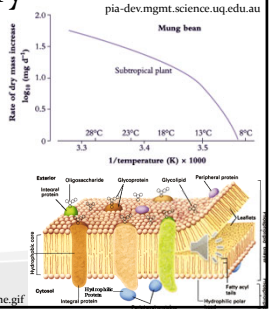
Causes of Chilling Injury

- **Phase transition** hypothesis
  - Sharp break in the rate of mitochondrial respiration plotted on an Arrhenius plot, suggests a sudden change in the activation energy of some key enzyme in respiratory metabolism at that point
  - Threshold temperatures are close to temperatures at which membranes of chilling sensitive plants change from a liquid to a crystalline state

pia-dev.mgmt.science.uq.edu.au



http://tiger.towson.edu/~cfaneli/istc301/cell-membrane.gif

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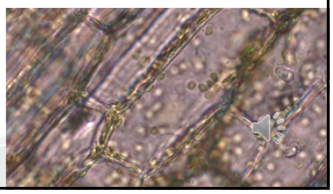
Causes of Chilling Injury

- **Inhibition of cytoplasmic streaming (cyclosis)**
  - Occurs within minutes of cold exposure
  - Inability of the cell to transport substrates, metabolites, and control molecules could result in metabolic imbalance and accumulation of toxic respiratory intermediates

Berkshire Community College Bioscience Image Library



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Causes of Chilling Injury

- **Enzyme temperature sensitivity**
  - Differences in the temperature sensitivity of important regulatory enzymes such as phosphofructokinase (in glycolysis)
  - Because of the critical role that regulation of these enzymes plays in the regulation of metabolism overall, it may be that their malfunction could also be a cause of the symptoms of chilling injury

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Causes of Chilling Injury

- **Peroxidation of membrane lipids**
  - Commonly observed in plants exposed to chilling stress
  - Sensitive plants may be unable to mobilize antioxidant defenses (against ROS) or enzyme repair systems at low temperatures

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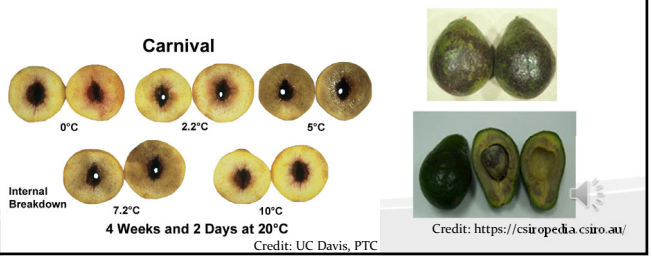
Chilling Injury Symptoms

- **Flesh discoloration**, as in apples, avocados, and peaches



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Chilling Injury Symptoms

- **Pitting**, as in citrus fruits, cucumbers, peppers and tomatoes
- **Necrosis**, as in seeds of eggplants, peppers and tomatoes
- **Accelerated decay**, as in cucumber, melons, papaya and mango

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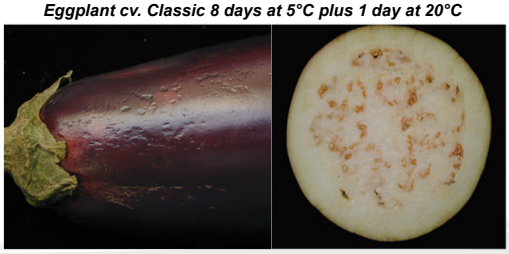
Pitting & Seed Necrosis

Eggplant cv. Classic 8 days at 5°C plus 1 day at 20°C



Chilling injury resulting in pitting of the skin and darkening of the seeds and flesh

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Pitting & Seed Necrosis

10 days at 5°C

After transfer to 20°C for 1 day

Bell pepper cv. Bell Boy

Chilling injury resulted in pitting of the skin and darkening of the seeds

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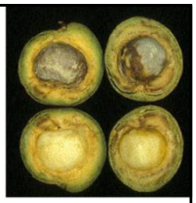
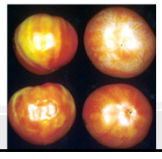
Chilling Injury Symptoms

- **Vascular discoloration**, as in avocado and banana
- **Ripening inhibition** and irregular/uneven ripening, as in most climacteric fruit





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Factors Affecting Chilling Injury Symptom Development

- **Temperature**: the lower the temperature, the more severe the symptoms
- **Time**: the longer the exposure, the more severe the symptoms
  - But, crops can recover from short exposures
- **Chilling injury is cumulative**
  - Preharvest + postharvest exposure
- **Symptoms may not develop until after removal to higher temperature**
  - Low temperature inhibits the reactions leading to symptom development

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Factors Affecting Chilling Injury

- These factors alleviate chilling injury:
  - **Advanced maturity**: chilling sensitivity decreases with maturation and ripening
  - **Acclimation**: short periods of exposure to low, non-chilling temperatures
  - Previous **high temperature exposure** (*e.g.*, 2 days in air @ 38°C or 10 min in 53°C water)
  - **Intermittent warming**: may allow metabolism or detoxification of toxic compounds (**recall**: peroxidation of membrane lipids hypothesis)

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Factors Affecting Chilling Injury

- These factors alleviate chilling injury (cont.):
  - **Genetics**: different varieties of chilling susceptible species can differ in the chilling tolerance
  - **High relative humidity conditions**: slows water loss to slow development of pitting
  - **Modified or Controlled Atmospheres (esp. high CO_2)**: shown to inhibit chilling injury of avocado, mango, and grapefruit
  - **Some fungicides**: *e.g.*, thiabendazole used on grapefruit

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High Temperature Injury

- High temperatures can inhibit key enzymes and, thus, disrupt normal metabolism, *e.g.*, ripening
- Radiant energy from sun exposure causes **sunburn** or **sunscald**.
  - Ripening inhibition
  - Actual death of cells, resulting in collapsed and bleached areas on the commodity

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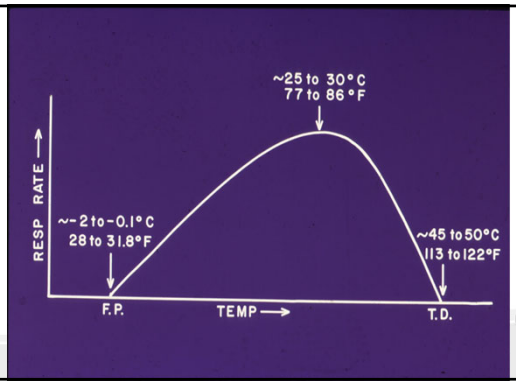

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"Checkerboarding" (high temperature injury) of tomatoes

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"Scald" (hot water injury) on mangoes

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"Sunscald" on tomatoes

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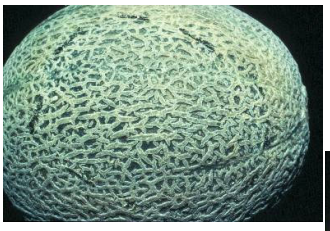

Sunscald on cantaloupe melons

← At harvest

After ripening →

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Nutritional Disorders

- **Low calcium** levels in tissue
  - Bitter pit of apples
  - Cork spot of pears
  - Blossom end rot (BER) of tomatoes, peppers, melons
  - Blackheart of cabbage, celery
  - Tipburn of lettuce
  - etc., etc., etc.

Kader & Cantwell, 2006

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"Tipburn" of Iceberg head lettuce

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Nutritional Disorders

- **Low calcium** levels in tissue
  - Calcium moves through the transpiration stream
  - Deficiency symptoms appear in locations with minimal transpiration
    - Blossom end of fruit
    - Interior leaves of heading crops
  - Symptoms may not appear until during postharvest period

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Nutritional Disorders

- Control of low calcium disorders
  - Resistant varieties
  - Harvest maturity: low maturity = low calcium
  - Fertilizer management
    - Excess N promotes vegetative growth, which is where most of the calcium goes due to transpiration
    - Calcium applications:
      - Preharvest sprays
      - Postharvest dips/infiltration

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Nutritional Disorders

- **Low boron** levels in tissue
  - Cork flesh in tree fruits
  - Internal necrosis and blackspeck of cole crops
- **Excess nitrogen.**
  - Brown center-hollowheart of potato
  - Exacerbates calcium disorders
  - Increases susceptibility to disease and physical damage

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Blackspeck (boron deficiency + low temperature)

Kader & Cantwell, 2006

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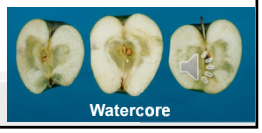
Storage Disorders

Credit: UC Davis PTC

- Disorders of long-term storage
  - Senescence related disorders
    - **Superficial scald** (apples) related to oxidation of alpha-farnesene, a phenolic compound
    - **Water core** (apples) a result of infiltration of intercellular spaces with translocation fluid containing sorbitol
    - **Pink rib** (lettuce)



Kader & Cantwell, 2006 Credit: UC Davis, PTC

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Storage Disorders

- Controlled atmosphere disorders
  - Low O_2 or high CO_2
- Toxic chemicals
  - Ammonia, SO_2, methyl bromide, ozone, $CaCl_2$
- Ethylene disorders

Brown stain (CO_2 injury)

Kader & Cantwell, 2006

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