



Physiological Disorders of Fresh Fruits and Vegetables

Dr. Jeffrey K. Brecht
Horticultural Sciences Department, Gainesville


Dr. Mark A. Ritenour
Indian River Research and Education Center, Fort Pierce

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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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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


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



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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


- Other disorders
 - Disorders of long-term storage
 - Senescence related
 - Controlled atmosphere disorders
 - Low O₂ or high CO₂
 - Toxic chemicals
 - Ammonia, SO₂, methyl bromide, ozone, CaCl₂
 - Ethylene disorders



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I. Freezing Injury

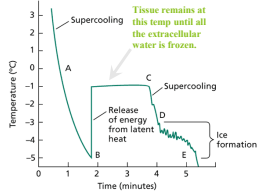
- Reduction of the ambient temperature below that of the freezing point of the tissue
- Symptoms include water-soaked areas in the tissue, and collapse and even disruption of the epidermis
- Freezing temperatures may occur in the field or in the storage environment




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Freezing Injury

- **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



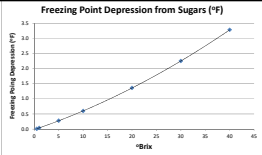
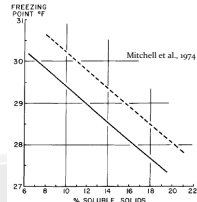

Tairz & Zeiger, 2002, Web Topic 25.3



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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 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 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

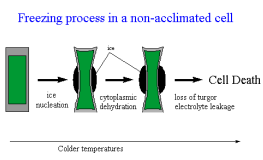
- **Ice nucleation**
 - The supercooled solution eventually freezes, either by prolonged exposure to low temperature or when nucleated by vibration.
 - Intracellular freezing of the cytoplasm and vacuolar sap is **lethal**.



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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 pH changes, get dehydration injury




<http://www.agronomy.psu.edu/Courses/AGRO518/FREEZING.html#contents>

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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

- 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

- 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

- 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

- 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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II. Chilling Injury

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



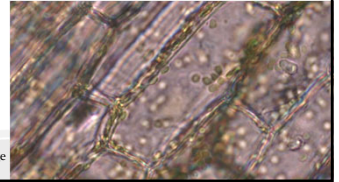
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Causes of Chilling Injury

- **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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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

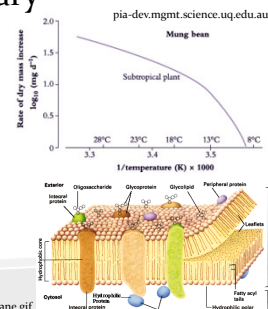
- **Enzyme temperature sensitivity**
 - Differences in the temperature sensitivity of important regulatory enzymes such as phosphofructokinase (in glycolysis)
 - Because of the critical role that regulation of these enzymes plays in the regulation of metabolism overall, it may be that their malfunction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



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Causes of Chilling Injury

- **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



<http://tiger.towson.edu/~cfanelh/istc301/cell-membrane.gif>

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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

Carnival

Internal Breakdown

4 Weeks and 2 Days at 20°C

Credit: UC Davis, PTC

Credit: <https://csiropedia.csiro.au/>

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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

- 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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Chilling Injury Symptoms

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

Control Chilling Injury

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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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Factors Affecting Chilling Injury Symptom Development

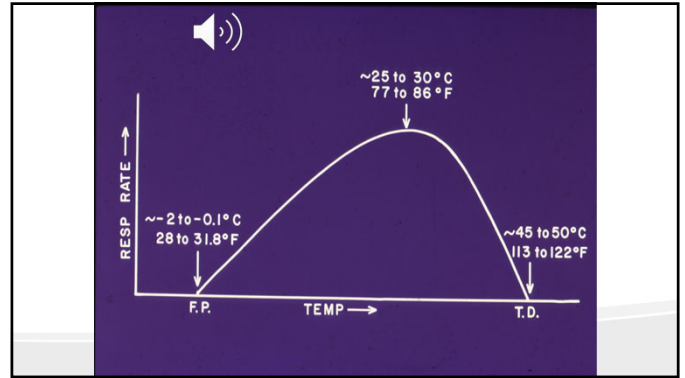
- Temperature**: the lower the temperature, the more severe the symptoms
- Time**: the longer the exposure, the more severe the symptoms
 - But, crops can recover from short exposures
- Chilling injury is cumulative**
 - Preharvest + postharvest exposure
- Symptoms may not develop until after removal 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:
 1. **Advanced maturity:** chilling sensitivity decreases with maturation and ripening
 2. **Acclimation:** short periods of exposure to low, non-chilling temperatures
 3. Previous **high temperature exposure** (e.g., 2 days in air @ 38°C or 10 min in 53°C water)
 4. **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.):
 5. **Genetics:** different varieties of chilling susceptible species can differ in the chilling tolerance
 6. **High relative humidity conditions:** slows water loss to slow development of pitting
 7. **Modified or Controlled Atmospheres (esp. high CO₂):** shown to inhibit chilling injury of avocado, mango, and grapefruit
 8. **Some fungicides:** e.g., thiabendazole used on grapefruit

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“Checkerboarding” (high temperature injury) of tomatoes

The photograph shows a box of tomatoes with a mix of red and yellowish-green fruits, illustrating the effect of high temperature injury known as checkerboarding.

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III. 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

The images illustrate high temperature injury: a yellowish mango (top right), a green mango with sunburn spots (middle right), and three red tomatoes (bottom center).



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“Scald” (hot water injury) on mangoes

The photograph shows mangoes with dark, sunken areas characteristic of scald. Labels indicate '30°C for 7 days' and 'Hot Water Treated'.



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“Sunscald” on tomatoes

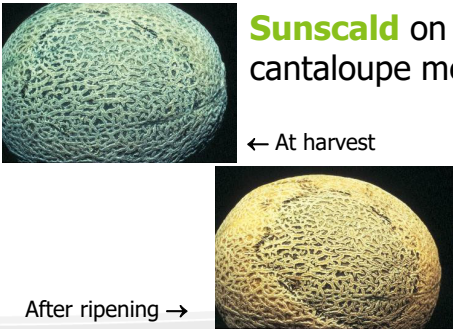

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“Tipburn” of Iceberg head lettuce

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Sunscald on cantaloupe melons

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Nutritional Disorders

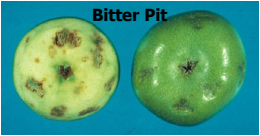

- **Low calcium** levels in tissue
 - Calcium moves through the transpiration stream
 - Deficiency symptoms appear in locations with minimal transpiration
 - Blossom end of fruit
 - Interior leaves of heading crops
 - Symptoms may not appear until during postharvest period




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IV. 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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Nutritional Disorders

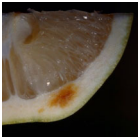

- Control of low calcium disorders
 - Resistant varieties
 - Harvest maturity: low maturity = low calcium
 - Fertilizer management
 - Excess N promotes vegetative growth, which is where most of the calcium goes due to transpiration
 - Calcium applications:
 - Preharvest sprays
 - Postharvest dips/infiltration



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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







Kader & Cantwell, 2006

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V. Storage Disorders

- 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).

Credit: UC Davis, PTC

Kader & Cantwell, 2006

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Blackspeck (boron deficiency + low temperature)






Kader & Cantwell, 2006

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Storage Disorders

- Controlled atmosphere disorders
 - Low O₂ or high CO₂
- Toxic chemicals
 - Ammonia, SO₂, methyl bromide, ozone, CaCl₂
- Ethylene disorders

Brown stain (CO₂ injury)

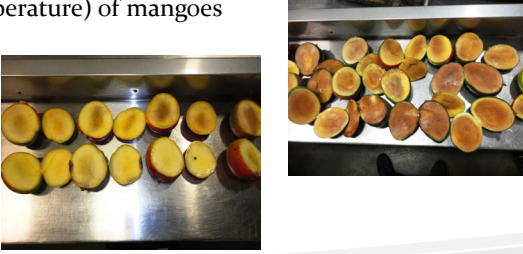

Russet spotting



Kader & Cantwell, 2006

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Cutting black (corte negro; low calcium? + low temperature) of mangoes

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