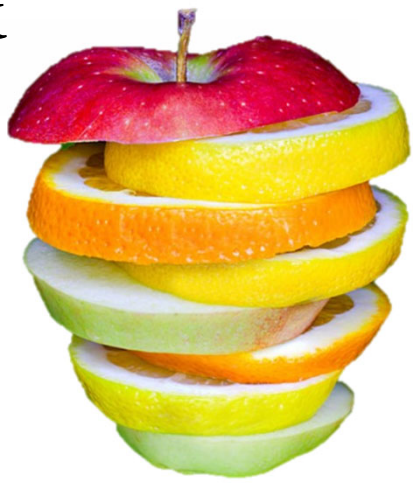
Transpiration & Water Loss



Mark Ritenour
Indian River Research and Education Center, Fort Pierce
Jeff Brecht
Horticultural Science Department, Gainesville

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1

Water Loss

- Typically, 90 to 95% of a commodity is water
- Besides resulting in direct loss of salable weight, it is also an important source of quality loss
  - **Appearance quality** - wilting, shriveling, accelerated development of injuries
  - **Textural quality** – loss of crispness, juiciness, etc.
  - **Nutritional quality** – e.g. vitamins A & C
- Thus, managing water content of commodities is critically important

2

% Water Loss	Potential Effects
0.5	Increased activity of some cell wall enzyme.
1	Increased carbon dioxide & ethylene production. Faster ripening, yellowing & abscission. Reduce wound healing (periderm formation).
2	Reduced turgor. Increased ABA content, reduced susceptibility to chilling injury. Accelerated loss of volatiles.
3	Reduced severity of certain physiological disorders. Loss of membrane integrity.
4	Faster loss of vitamins A & C. Loss of flavor. Discoloration of mechanical injuries.
5	Loss of color intensity & gloss. Accentuation of pitting associated with chilling injury. Wilting & shriveling.
6	Loss of textural quality, e.g., softening, limpness, flaccidity, & loss of crispness & juiciness.

3

Percent water loss that results in unmarketability

Commodity	% Loss
Asparagus	8
Brussels sprouts	8
Cabbage	7
Celery	5
Lettuce	3
Spinach	3

4

Effects of Water Loss

- Physical Effects
- Economic Effects
- Physiological Effects

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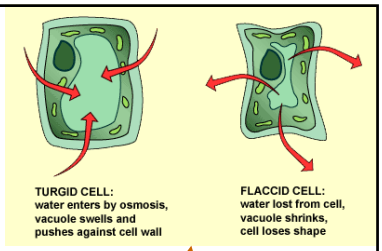
5

Effects of Water Loss



- Physical Effects
  - Reduced turgor pressure from as little as 2% water loss =>
    - Wilting & flaccidity of vegetables
    - Shriveling and wrinkling of fruit
  - Shrinking produce within a package allows it to move/ vibrate during transport = damage

6

Effects of Water Loss

- Economic Effects
  - Commodities are often sold on a weight basis
    - Less weight = lower price
  - Reduced quality/grade of a commodity reduces its value

7

Effects of Water Loss

- Physiological Effects (% water loss)
  - Detrimental
    - Increased respiration & ethylene production (1%)
    - Reduced periderm formation in some roots and tubers (1%)
    - Faster ripening, yellowing & senescence (1%)
    - Accelerated reduction in volatiles (2%)
    - Faster loss of vitamins A & C (4%)
    - Stem end rind breakdown (unknown%)

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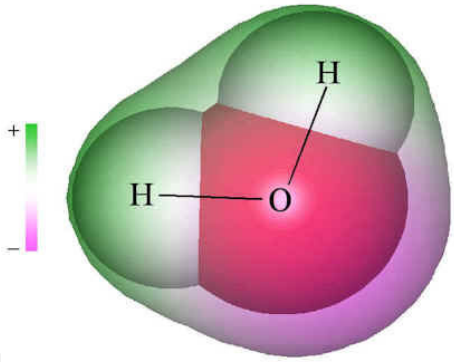
Water - The Molecule

- O atom covalently bonded by 2H
  - 105^{O} bond angle



http://xnet.rrc.mb.ca/rcharney/The%20water%20molecule_files/molecul2.jpg

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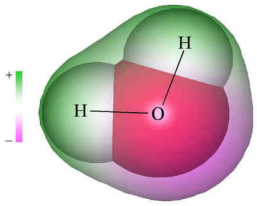
9

Water - The Molecule

- Polar molecule
  - O atom - partially negative
  - 2H atoms - partially positive
  - Overall - neutral molecule
  - Water's polarity is responsible for many of its unique properties
- Water has one of the highest Dielectric Constants (a measure of a molecule's polarity)



http://xnet.rrc.mb.ca/rcharney/The%20water%20molecule_files/molecul2.jpg

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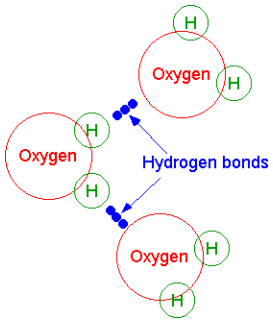
10

http://www.mse.cornell.edu/courses/engri111/images/hydrogn.gif

Hydrogen Bonding



- Polarity gives rise to Hydrogen Bonds
- H-bonding = the weak electrostatic attraction between partially (+) charged "H" and partially (-) charged "O"
  - Besides water, H-bonds can also form between other molecules with other electronegative atoms (O or N)

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Properties of Water

- High Specific Heat (S.H.) (1 kcal/kg/°C).
  - Lots of energy required to raise the temperature of water 1 °C
- High Thermal Conductivity (T.C.) (5.2 kcal/kg/h/°C)
  - Water rapidly conducts heat away from the point of application
  - Disperses heat quickly (reason for effectiveness for hydrocooling)

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12

Properties of Water

- High heat of vaporization (540 kcal/kg)
  - Water that evaporates (transpiration) absorbs a great deal of heat => cools the plant tissue
- High heat of fusion (80 kcal/kg)
  - When water goes from a liquid to a solid, it releases heat energy. Principal behind freeze protection
  - From solid to liquid, water absorbs energy. Added benefit for top-icing

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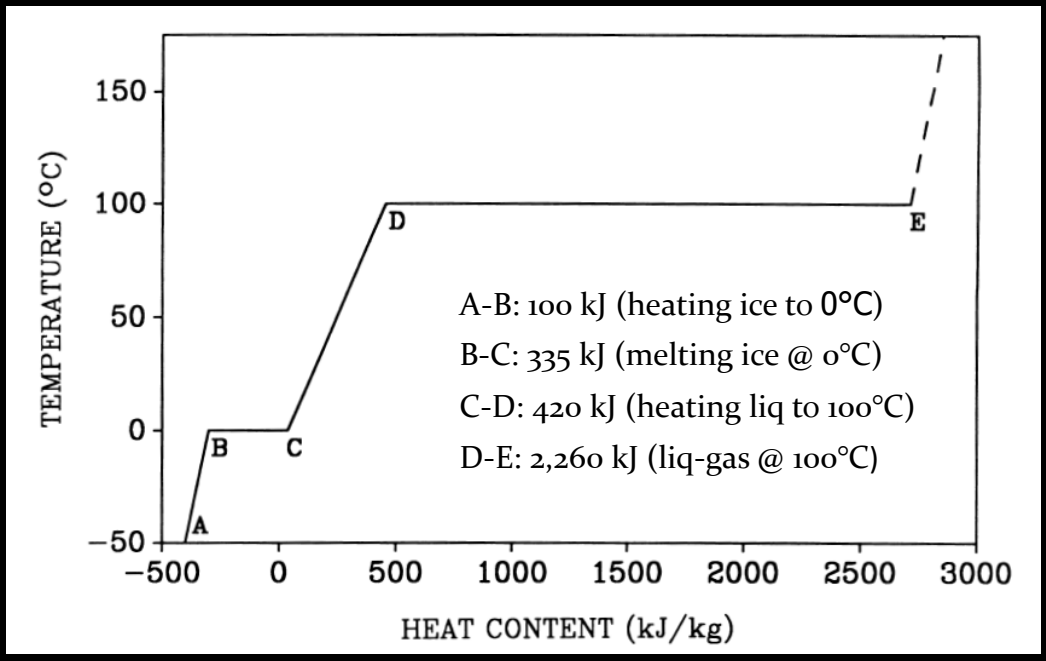
13



Kays, 1997

14

The Psychrometric Chart

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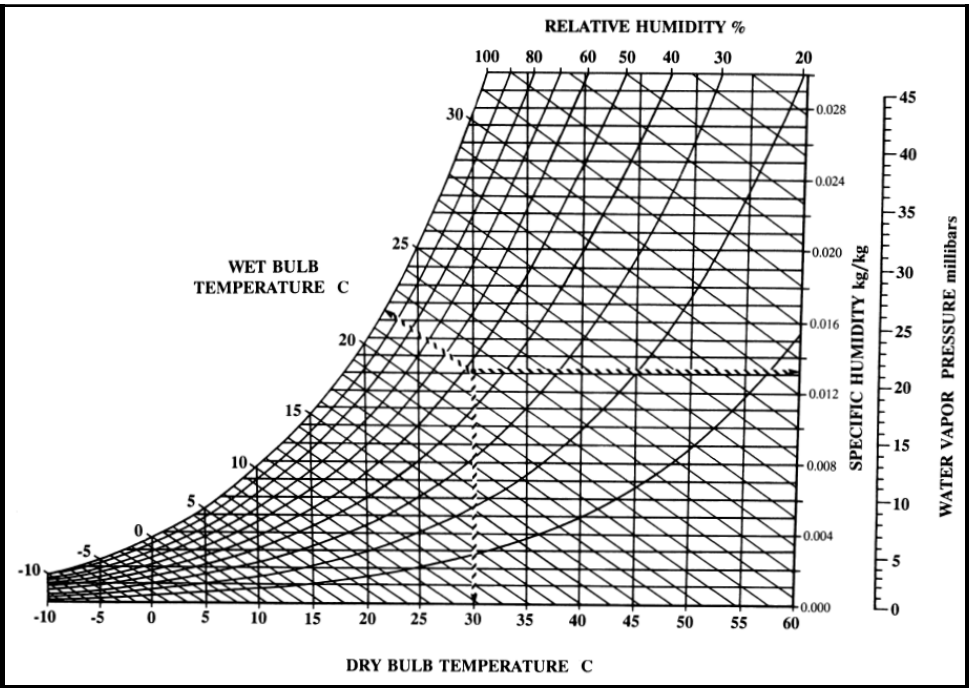
15



16

Liquid – Gas Equilibrium

- Humidity Ratio (HR):
  - Also called the mixing ratio, specific humidity, or absolute humidity
  - Shows the moisture content of the air (= water content mass of water per mass of air)
  - Water vapor is often only = 0.4 to 1.5% of the weight of air
- Vapor pressure:
  - Directly proportional to humidity ratio
  - Shows the partial pressure of water vapor in the air

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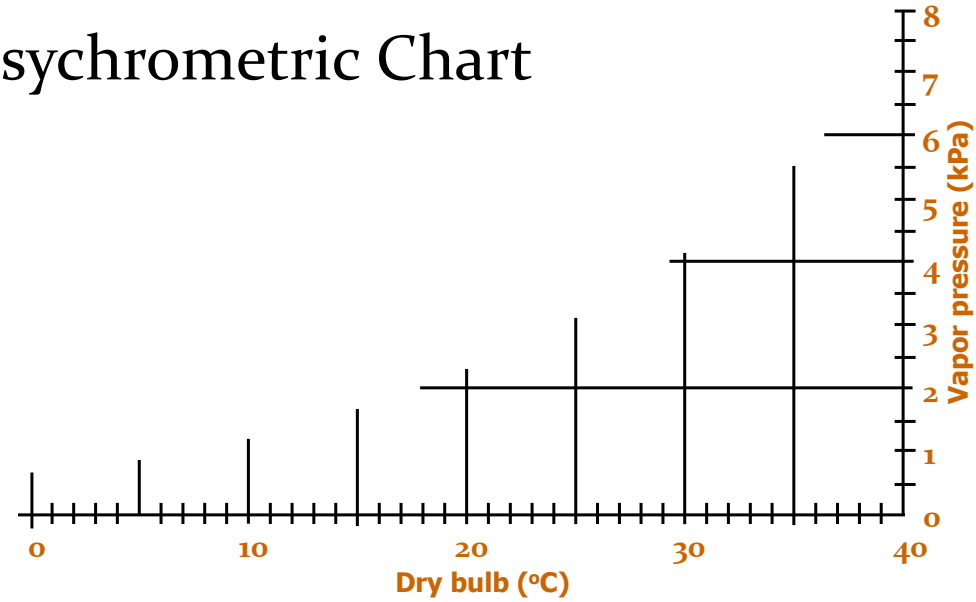
17

Psychrometric Chart



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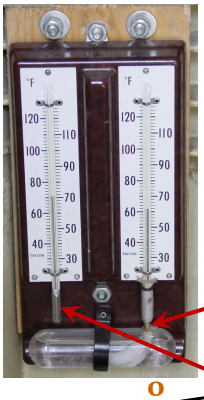
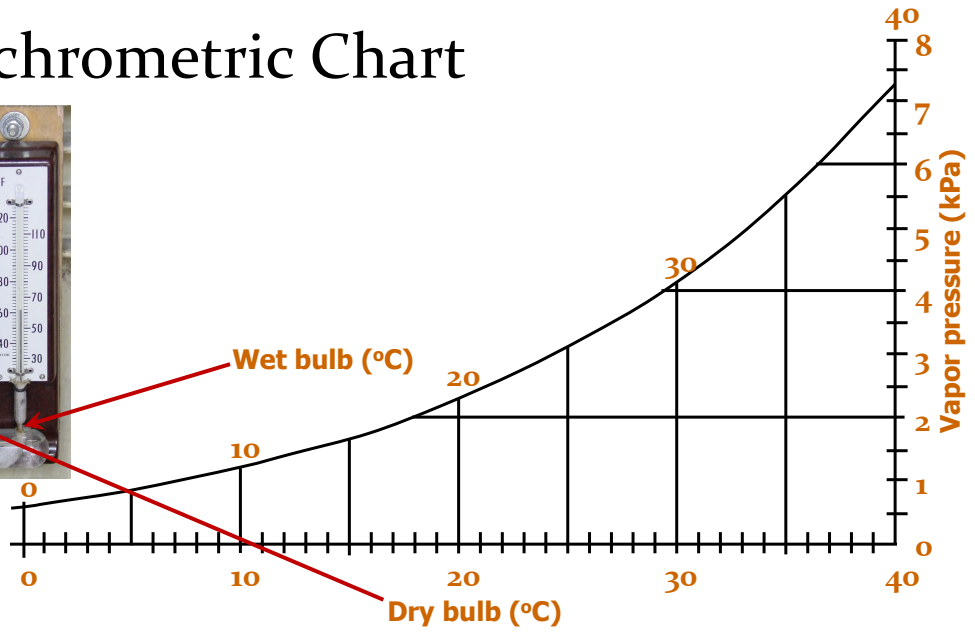
Psychrometric Chart





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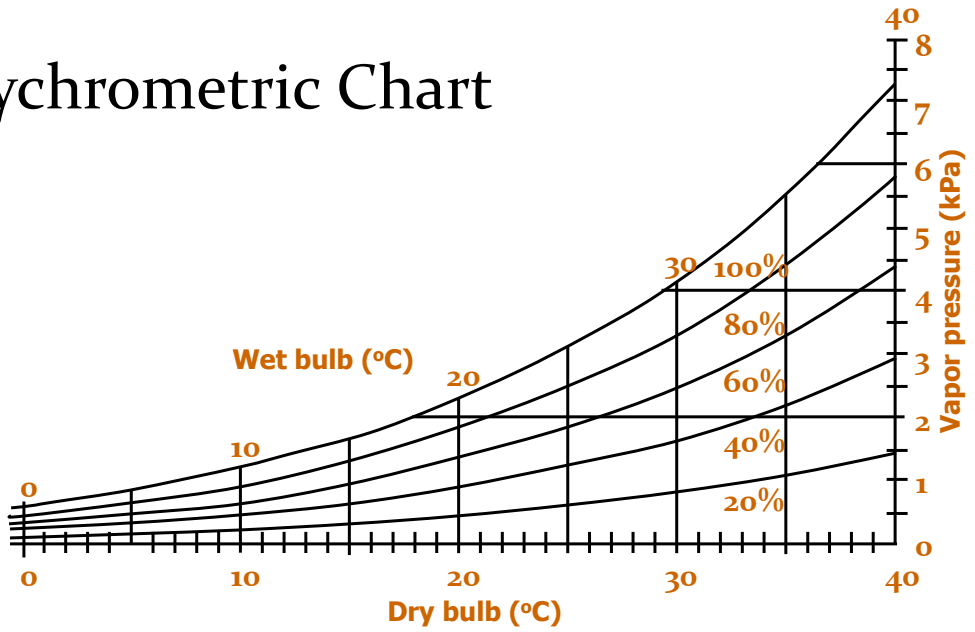
Psychrometric Chart



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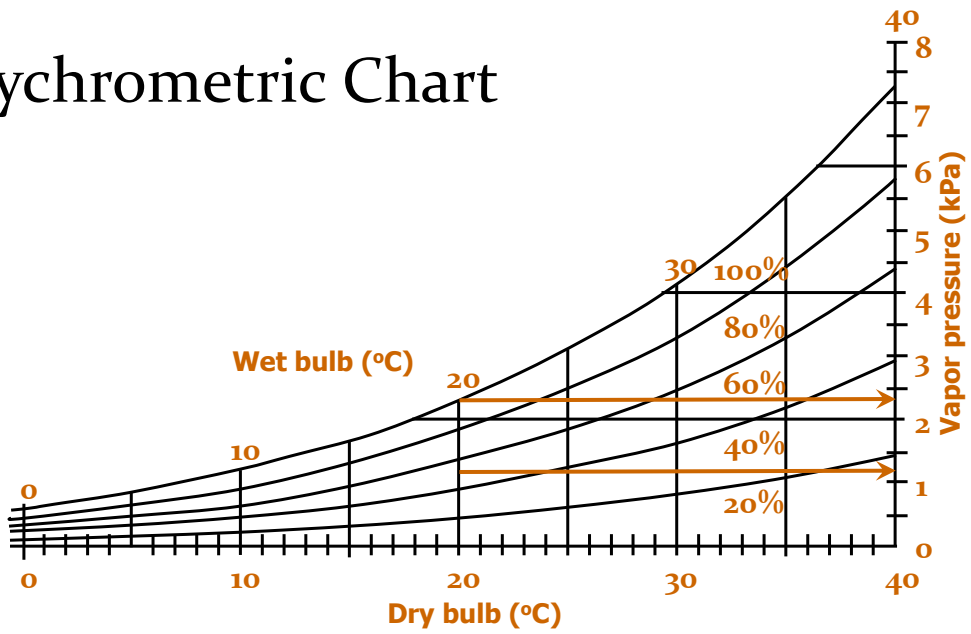
Psychrometric Chart



21

Relative Humidity

- Relative humidity (RH):
  - Corresponds to the ratio of actual water content of the air to the maximum water content at a given temperature

$$RH = \frac{VP}{SVP} \times 100$$

  - RH = Relative humidity
  - VP = Vapor pressure
  - SVP = Saturated vapor pressure (100% relative humidity)

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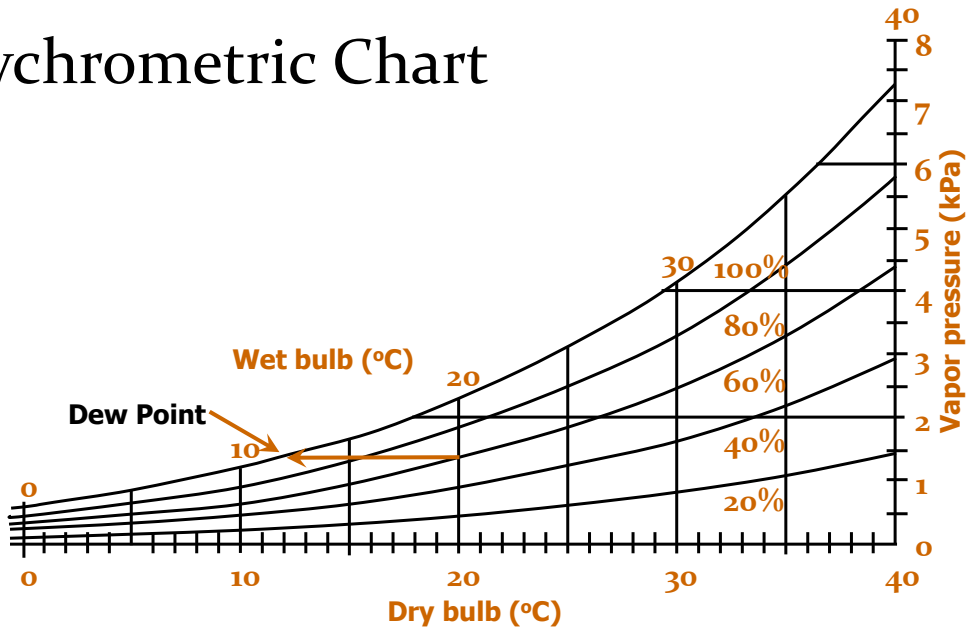
22

Psychrometric Chart



23

Dew-Point

- Dew-point temperature:
  - Where the horizontal lines intersect the wet-bulb temperature line
  - Represents the point where condensation begins to form as the air is cooled
    - As the air cools, its water-holding capacity decreases until it is no long able to hold even the water vapor it initially held

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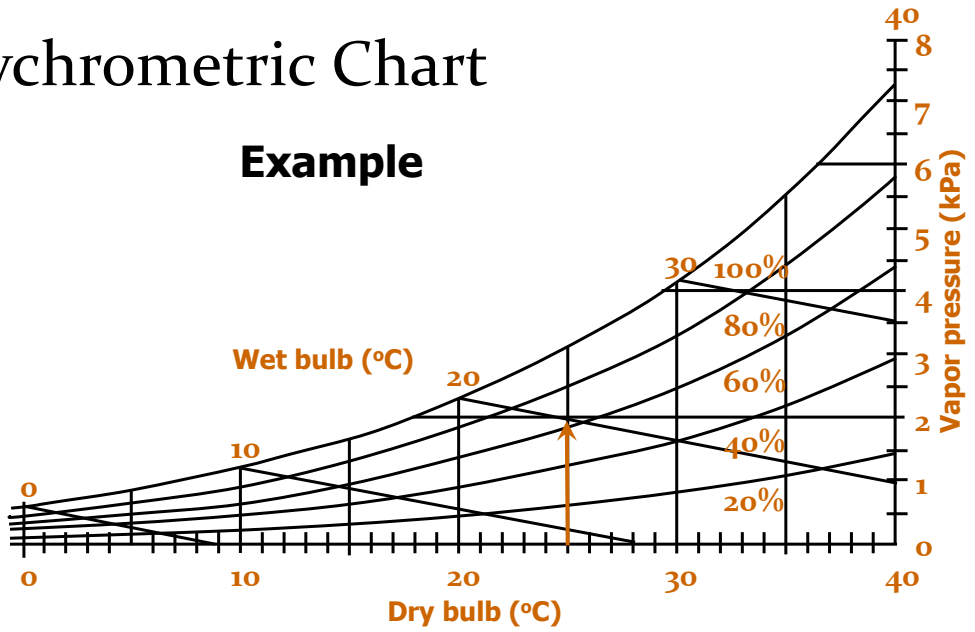
24

Psychrometric Chart

Example



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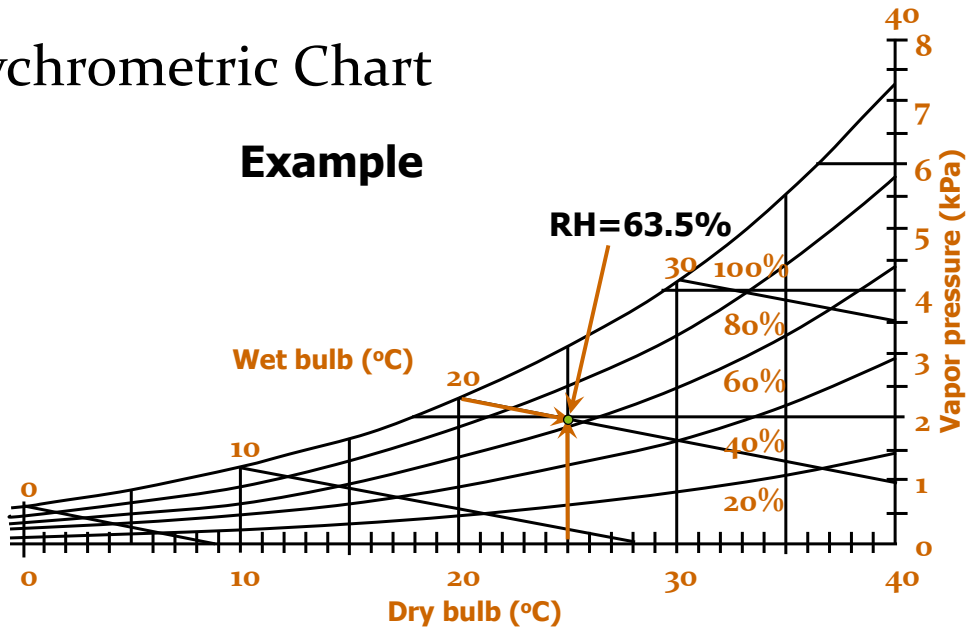
Psychrometric Chart

Example



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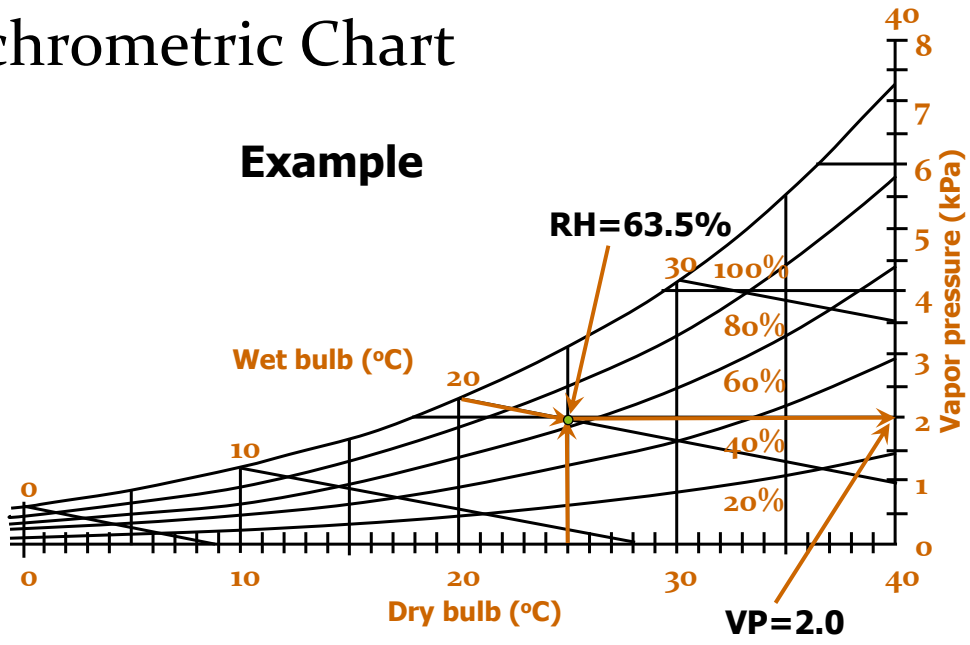
Psychrometric Chart



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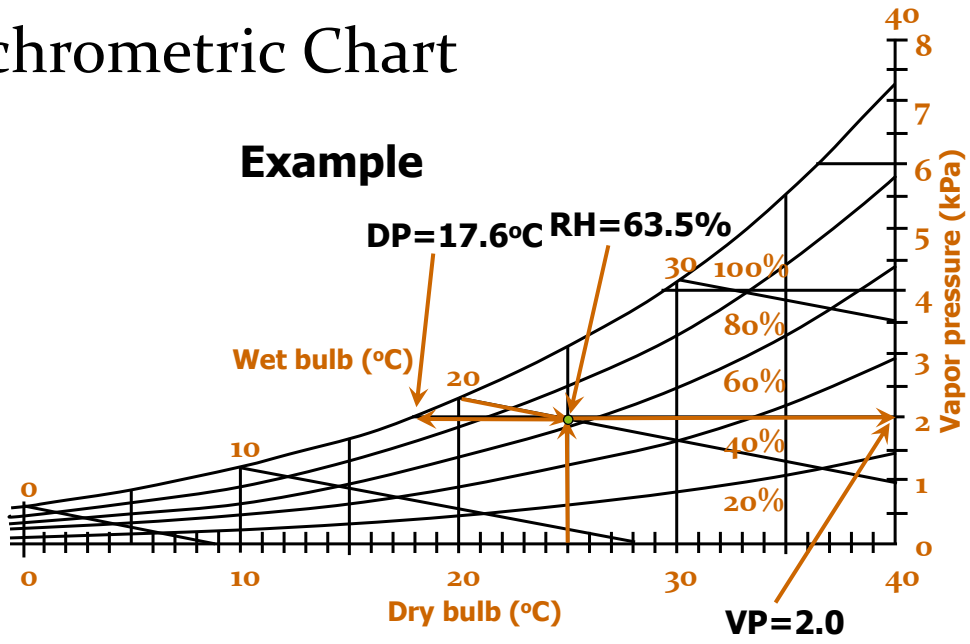
Psychrometric Chart

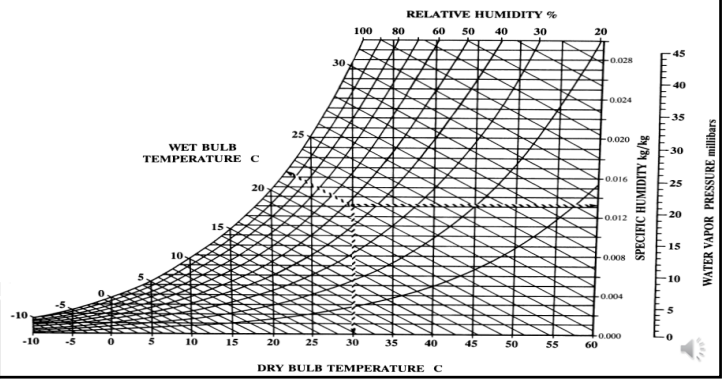


28

Liquid – Gas Equilibrium

Key concepts

- Maximum air water content (vapor pressure or humidity ratio) increases rapidly with increasing temperature
  - Warm air can hold more water than cold air



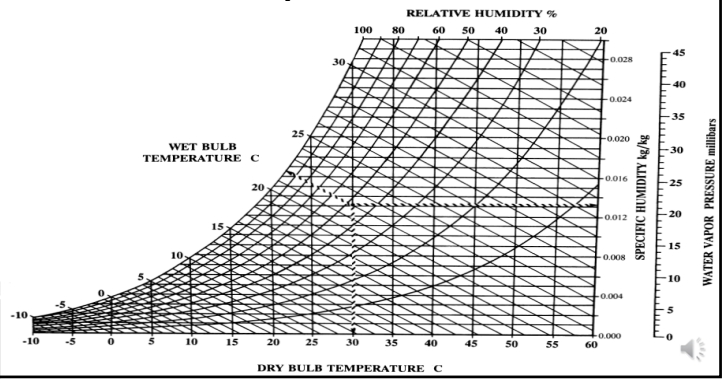
Kays, 1997

29

Liquid – Gas Equilibrium

Key concepts

- When warm, moist air is cooled, RH increases until it reaches its dew-point
- Air cooled below its dew-point begins to loose water as condensation



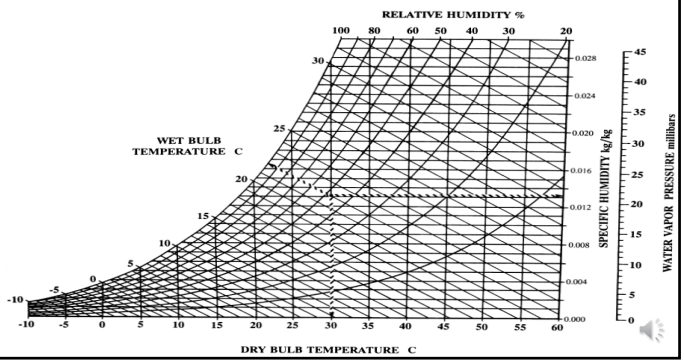
Kays, 1997

30

Liquid – Gas Equilibrium

Key concepts

- Placing a cold commodity in a warm room with moist air, cools the air that contacts the commodity to below the dew-point
  - Condensation will form on the commodity surface (AKA "sweating")



Kays, 1997

31

Liquid – Gas Equilibrium

Key concepts

- Placing a warm commodity in room with cold, moist air will warm the air contacting the commodity
  - The RH will drop as the air warms because warmer air can hold more water
  - Increased water loss until the commodity is cooled
- Delayed cooling results in greater water loss

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32

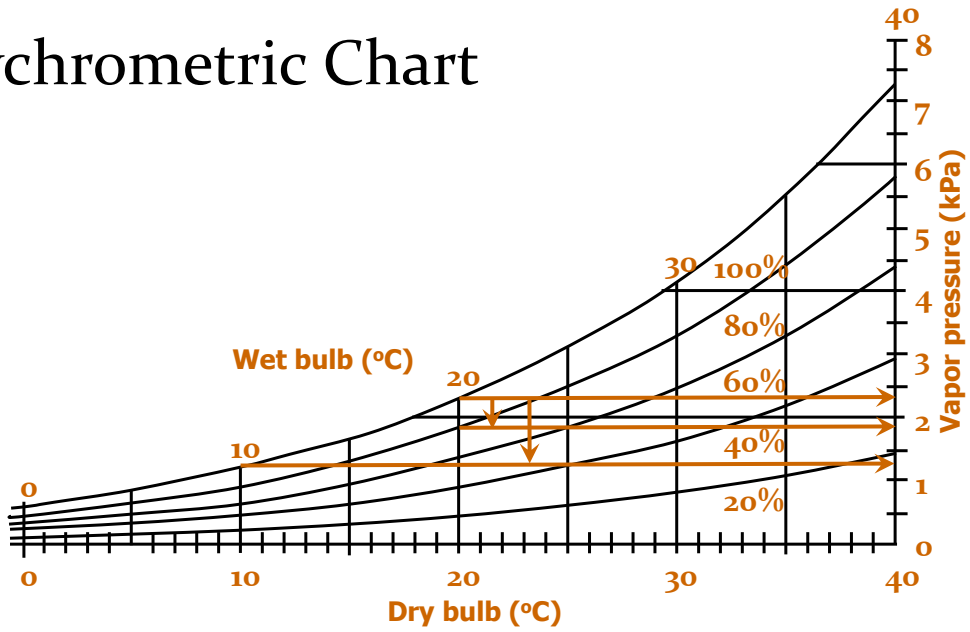
Water Loss

- The rate of water diffusion between two points is related to the concentration gradient
  - Greater concentration (or vapor pressure) difference = faster diffusion rate (stronger driving force)
  - VPD (vapor pressure difference) is the driving force of water movement
  - The vertical bars represent VPD between 80% and 100% RH at 0°C & 40°C

Water Loss

- VPD = SVP_{tissue} – VP_{air}
- SVP_{tissue} = Saturation vapor pressure of the air at a given temperature
  - Air within a commodity is nearly saturated (no less than 95%, usually estimated at 100%)
- VP_{air} = Vapor pressure of the air at a given temperature, pressure & RH

Psychrometric Chart



35

Water Loss

- For each commodity:

$$J = VPD * k$$

- J = rate of water loss
  - e.g., %/day, gm/h, lb/week, etc.
- k = proportionality constant
  - Depends on different features of the commodity

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36

Sample Questions

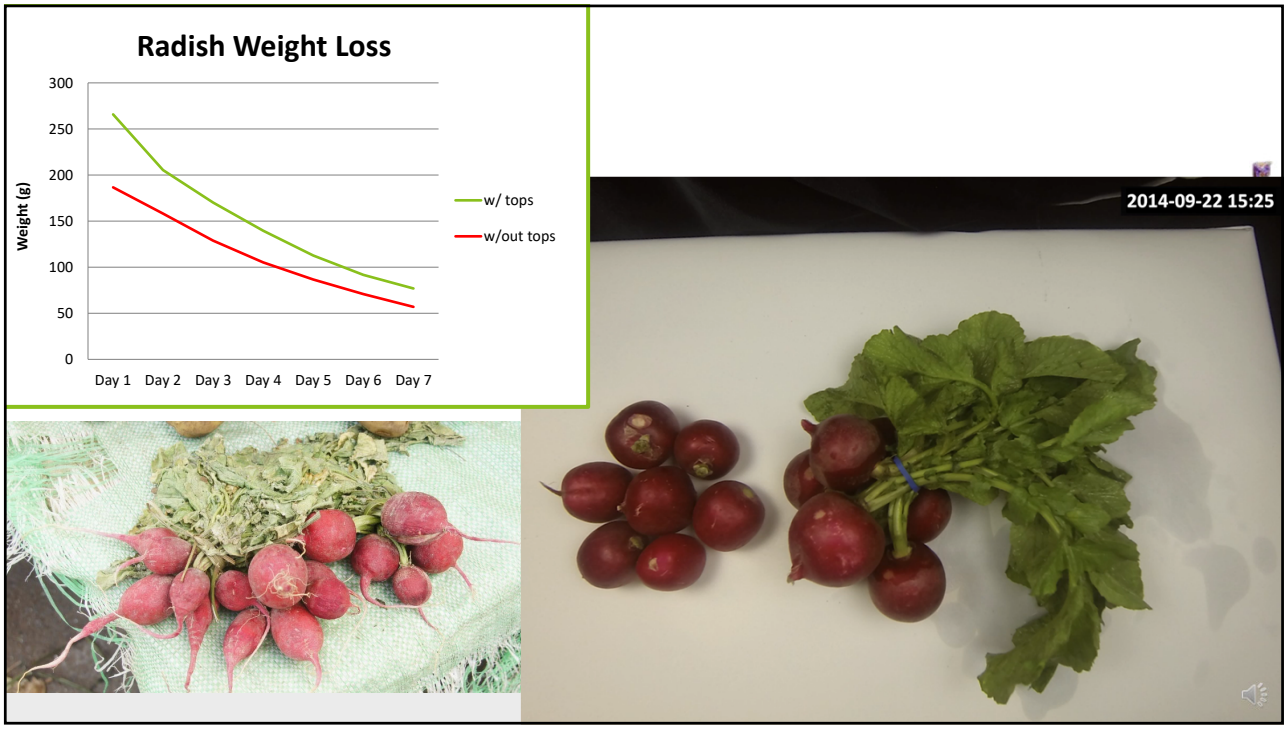
- Calculating RH, dew-point, vapor pressure (humidity ratio) based on wet-bulb & dry-bulb measurements
- How do these change when air is warmed and cooled. When does air loose water or dry commodities out?
- What happens when air moves over refrigeration coils?
- Boundary air layer – effects of wraps, packaging, and air speed

37

Factors Affecting Water Loss

- Commodity factors
  - Surface to volume ratio
  - Routes of water loss
    - Epidermal cells vs. periderm & other cells
    - Structure of the surface
      - Stomates -Cuticular waxes
      - Lenticels -Trichomes
      - Surface imperfections -Architecture

38



39

Factors Affecting Water Loss

- Commodity factors (continued)
  - Physiological state of the commodity
    - Stage of maturity or stage of ripeness – more mature commodities generally loose less water
  - Cultivar
  - Cultural conditions
    - Weather or growing practices

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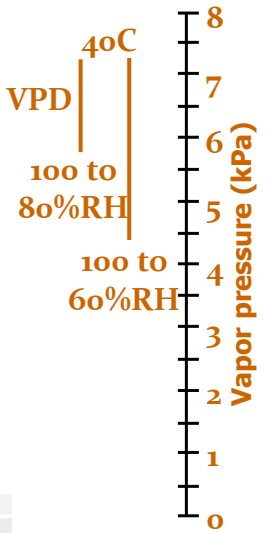
40

Factors Affecting Water Loss

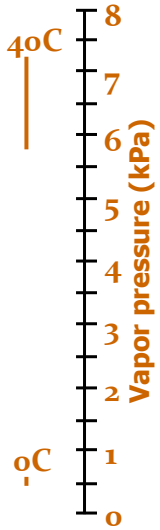
- Environmental factors
  - Humidity
    - Lower humidity => greater VPD => greater water loss
  - Diffusion shells and air velocity
    - Outside the epidermis, there is a thin layer of air that maintains high humidity ("diffusion shell"). Surface features (e.g. hairs) strongly influence the thickness of this shell
    - Faster air flow => decreases thickness of the diffusion shell => increases water loss



41

Factors Affecting Water Loss

- Environmental factors (continued)
  - Temperature
    - Higher temperatures => generally greater VPD => greater water loss
  - Atmospheric pressure
    - Lower pressures (high altitudes) increases water loss



42

Reducing Water Loss

Commodity Treatment

- Addition of water to some commodities (incl. cut flowers, potted plants)

43

Reducing Water Loss

Commodity Treatment

- Careful handling
  - Injury and punctured surfaces greatly increase water loss
  - Proper temperature, R.H., packaging, etc.

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44

Reducing Water Loss

Commodity Treatment

- Rapid cooling & keeping cold

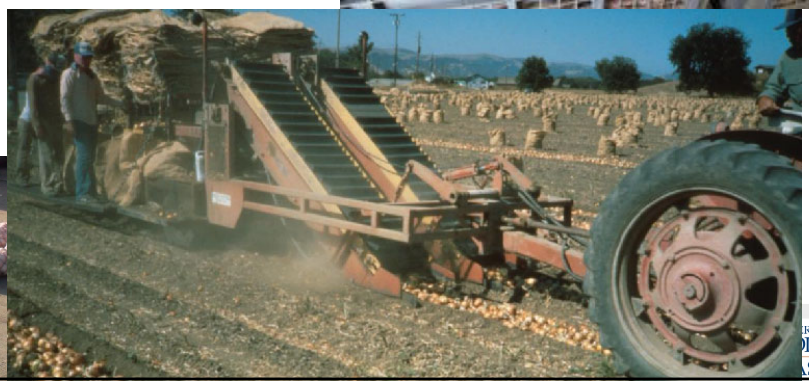
45

https://uapbnews.wordpress.com/2015/10/13/sweet-potatoes-proper-curing-improves-quality-shelf-life/

Reducing Water Loss

Commodity Treatment

- Curing of certain root, bulb, and tuber vegetables



46

Reducing Water Loss

Commodity Treatment

- Waxing and other surface coatings

47

Reducing Water Loss

Commodity Treatment

- Use of plastic films (wraps) that act as moisture barriers

48

Reducing Water Loss

Commodity Treatment

- Packaging
  - Polyethylene or plastic liners
  - Wood or plain fibreboard boxes can absorb water

49

Reducing Water Loss

Manipulating the Environment

- Maintaining temperature of refrigeration coils within 1°C of the air temperature
  - Larger evaporator coils
- Minimizing air movement around the commodity & reducing room air exchanges
- Addition of moisture to the air (humidifiers)

50

Reducing Water Loss

Manipulating the Environment

- Moisture barriers, e.g.
  - In the walls of storage rooms and transport vehicles
  - Polyethylene liners or curtains within shipping containers
- Wet the floor in storage rooms

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51

Reducing Water Loss

Manipulating the Environment

- Use crushed ice in shipping containers and in retail display of commodities that tolerate direct contact with ice

52

Reducing Water Loss

Manipulating the Environment

- Sprinkle produce with water during retail marketing
  - Can be used on leafy vegetables, cool-season root vegetables, and immature fruit-vegetables (e.g., snap beans, peas, sweet corn, and summer squash)

http://www.groceryheadquarters.com/October-2013/UltraMist-Guarantees-Leak-Free-Spray/

53