Chapter 1 section 4

Transpiration & Water Loss

Water Loss

- Typically, 90 to 95% of a commodity is water.
  - Milk has more solids than watermelon (weight basis).
- 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.

% 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 & shrivelling.
6	Loss of textural quality, e.g., softening limpness, flaccidity, & loss of crispness & juiciness.

Percent water loss that results in unmarketability

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

Effect of Water Loss

- Physical Effects.
- Economic Effects.
- Physiological Effects.

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.
  - Shriking produce within a package allows it to move /vibrate during transport = damage

Effects of Water Loss

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

Effects of Water Loss

- Physiological Effects. (% water loss)
  - Beneficial
    - Reduced symptoms of some physiological disorders (~3%).

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 (?%).

甜菜组织脱水同水解酶活性的关系

试验材料	活组织中蔗糖酶的活性（蔗糖mg/10g组织/h）			酵解程度
	合成	水解	合成/水解率	
新鲜甜菜	29.8	2.8	10.64	4.3
脱水6.5%的甜菜	27.0	4.5	6.0	9.6
脱水15%的甜菜	19.4	6.1	2.4	10.6

萎蔫对甜菜腐烂率的影响

萎蔫程度	腐烂率（%）
新鲜材料	—
失水7%	37.2
失水13%	55.2
失水17%	65.8
失水28%	96.0

一些蔬菜贮藏中的自然损耗率（%）

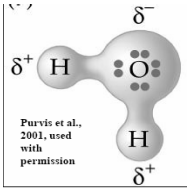
种类	贮藏天数		
	1d	4d	10d
油菜	14	33	—
续表2-11			
菠菜	24.2	—	—
莴苣	18.7	—	—
黄瓜	4.2	10.5	18.0
茄子	6.7	10.5	—
番茄	—	6.4	9.2
马铃薯	4.0	4.0	6.0
洋葱	1.0	4.0	4.0
胡萝卜	1.0	9.5	—

一些水果在贮藏期间的失重率

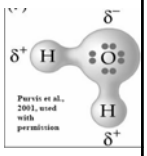
水果种类	温度（℃）	相对湿度（%）	贮藏时间（周）	失重率（%）
香蕉	12.8~15.6	85~90	4	6.2
伏令夏橙	4.4~6.1	88~92	5~6	12.0
甜橙（暗柳）	20	85	1	4.0
番石榴	8.3~10.0	85~90	2~5	14.0
荔枝	约30	80~85	1	15~20
芒果	7.2~10.0	85~90	2.5	6.2
菠萝	8.3~10.0	85~90	4~6	4.0

Water – The molecule

- O atom covalently bonded by 2H
  - 105° bond angle.



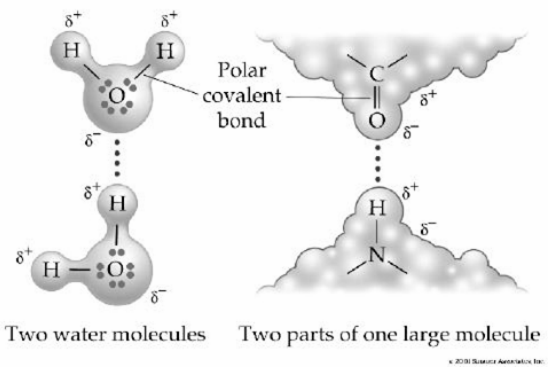
Water – The molecule



- 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).

H-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).



为何大多生物体的主要构成成分是

水？

Properties of Water

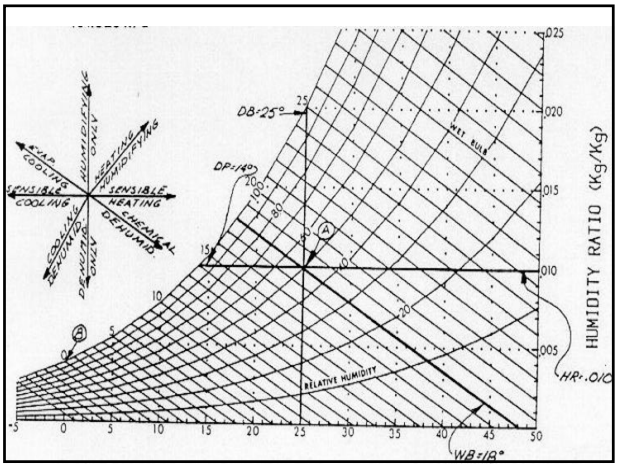
- High Specific Heat (S.H.) (1 kcal/kg/°C)
  - Lots of energy required to raise the temperature of water 1 °C
- High Thermal Conductivity (T.C) (5.2 kcal/kg/h/ °C)
  - Water rapidly conducts heat away from the point of application.
  - Disperses heat quickly (reason for effectiveness for hydro-cooling).

High S.H. & T.C.

- Results In:
  - Heat energy absorbed /distributed without increase in temperature.
  - Temperature stability.
  - Prevention of localized overheating.

Properties of Water

- High heat of vaporization (540 kcal/kg/°C)
  - 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.



Liquid – Gas Equilibrium

Psychrometrics

- Humidity Ration (HR):
  - Vertical axis on right.
    - Shows the moisture content of the air (=water content mass of water per mass of air)
    - Also called the mixing ration or absolute humidity.
    - Water vapor is often only = 0.4 to 1.5% of the weight of air.

Liquid – Gas Equilibrium

Psychrometrics

- Dry-bulb temperature:
  - Horizontal axis
- Wet-bulb temperature:
  - Diagonal lines sloping upward from right to left.

Liquid – Gas Equilibrium

Psychrometrics

- Vapor pressure:
  - Not usually shown on psychrometric charts but is directly proportional to humidity ratio.

$$VP = \frac{HR * (\text{Atmospheric Pressure in Pa})}{0.622}$$

  - Shows the partial pressure of water vapor in the air (in mm or inches of mercury (Hg)).

Liquid – Gas Equilibrium

Psychrometrics

- Dew-point temperature:
  - Where the horizontal lines intersect the wet-bulb temperature line.
- Relative humidity (RH):
  - Curves sloping upward from left to right.
  - Corresponds to the ratio of actual water content of the air to the maximum water content at a given temperature.

Liquid – Gas Equilibrium

Abbreviations

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

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

Liquid – Gas Equilibrium

Key concepts

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

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.

露点

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 (“sweating”).

发汗

Liquid – Gas Equilibrium

Key concepts

- Placing a warm commodity in room with cold, moist air will warm the air contacting the commodity and reduce the humidity around the commodity.
  - Increased water loss until the commodity is cooled.
- Delayed cooling results in greater water loss.

Liquid – Gas Equilibrium

Transpiration

- 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.

Liquid – Gas Equilibrium

Transpiration

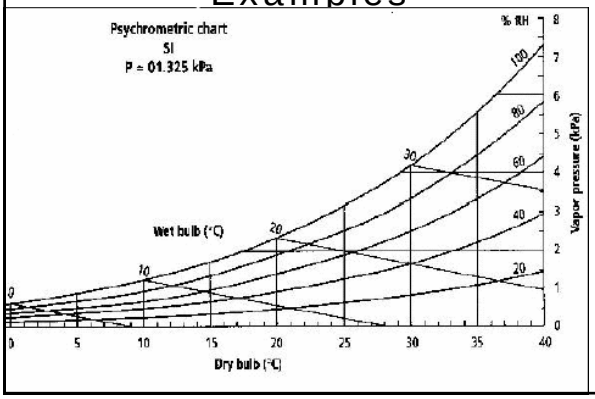
- $VPD = SVP_{tissue} - VP_{air}$
- SVP_{tissue} =Saturation vapor pressure of the air at a given temperature.
  - Air within a commodity is nearly saturated (no less than 95%, usually estimated at 100%)
- VP_{air} = Vapor pressure of the air at a given temperature, pressure & RH.

Liquid – Gas Equilibrium

Transpiration

- For each commodity, the rate of water loss (J) = VPD * K
- K=proportionality constant.
  - Depends on different features of the commodity.

Examples



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.

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 - Curticular waxes
      - Lenticels - Trichomes
      - Surface imperfections - Architecture

表：部分果蔬的表面积比(W.G. Burton,

表面积/体积	果蔬种类
50~100	食用叶菜
10~15	较小的软果实
5~10	较小的果实
2~5	豆类果实、坚果（椰子除外）、葱、大个软果实（草莓）、大黄
0.5~1.5	块根、块茎、仁果、柑桔类、香蕉、洋葱、葫芦科果实（南瓜除外）
0.2~0.5	萝卜、山药、芜菁、椰子

Factors Affecting Water Loss

- Commodity factors (continued)
  - Physiological state of the commodity.
    - Stage of maturity or stage of ripeness.
  - Cultivar.
  - Cultural conditions.
    - Weather or growing practices.

洋葱和马铃薯的贮藏失重比较

蔬菜种类	含水量（%）	在0℃下贮藏3个月的失重（%）
洋葱	86.3	1.1
马铃薯	73.0	2.5

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.

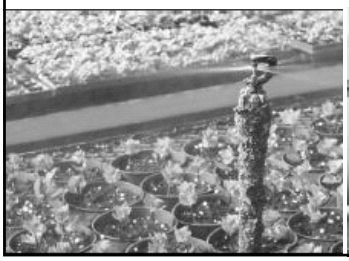
Factors Affecting Water Loss

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

Reducing Water Loss

Commodity Treatment

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



Reducing Water Loss

Commodity Treatment

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

Reducing Water Loss

Commodity Treatment

- Rapid cooling & keeping cold.

Reducing Water Loss

Commodity Treatment

- Curing of certain root, bulb, and tuber vegetables.

Reducing Water Loss

Commodity Treatment

- Waxing and other surface coatings.

Reducing Water Loss

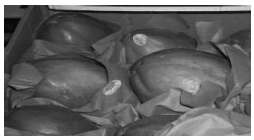
Commodity Treatment

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

Reducing Water Loss

Commodity Treatment

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



Reducing Water Loss

Manipulating the Environment

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

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.
  - Polymeric films for packaging produce.
- Wet the floor in storage rooms.

Reducing Water Loss

Manipulating the Environment

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

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).