Water Loss and Postharvest Quality

- How does water loss occur?
- What are critical levels of water loss?
- Where does water loss occur in handling?
- How to control water loss?

Postharvest Water Relations
Water loss
Water gain
Fresh Produce and Water Loss

- Fresh produce contains 65% (garlic) to 95% (lettuce) water; water content for most products is 85-90%
- Harvested products begin to lose moisture immediately upon cutting from the plant
- Water loss = transpiration
- Water loss = weight loss (except if dry matter loss in storage)
- Water loss is water vapor movement from product to the environment
- Water loss is affected mainly by packaging, temperature, relative humidity and airflow

Water loss

- Through stem end
- Through epidermis and stomates
- Through peel and lenticels
- Through damaged areas

**Water loss is Cumulative**

**Impacts on Quality**
- Loss of Salable Weight
- Loss of Fresh Appearance
  - Gloss
  - Shriveling
  - Pitting, sunken areas
- Loss of Texture, Turgidity
- Changes in Product Physiology

**Critical levels for many products**
- <3% no visual effect, texture
- 3-5% visual quality affected
- >5% shriveling, lose salability

<table>
<thead>
<tr>
<th>Weight loss</th>
<th>1 = 2%</th>
<th>2 = 4-5%</th>
<th>3 = 7-8%</th>
<th>4 = 10-12%</th>
<th>5 = 15-17%</th>
</tr>
</thead>
</table>

These berries were kept cold and lost less than 1% weight and look fresh.

Romaine Lettuce is marketable until 5% weight loss.

These berries were held at ambient temperature and lost more than 10% weight and look old and tired.

Ripened at 15C
- Higher gloss
- Less weight loss
- Firmer

Tomatoes Ripened at 20C
**Texture and Water loss**

% Firmness loss vs % Weight loss

\[ y = 5.68x + 9.69 \]

\[ R^2 = 0.80 \]

**ICELESS BROCCOLI**
- Minimize delay from harvest to cooling
- Use plastic liners with holes to reduce water loss
- Keep it cold
- About 3-4% weight loss = soft head

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**Water Loss and Fruit Physiology**

**Water Loss and Fruit Ripening**

Water loss during initial phase of ripening affects rates of ripening. Water loss is a stress and caused increased synthesis of ethylene. Therefore minimize water loss during initial 72 hours after harvest.

<table>
<thead>
<tr>
<th>Stage when induce water loss</th>
<th>Total % Water loss</th>
<th>Days to ripen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-climacteric</td>
<td>5.6</td>
<td>14.1</td>
</tr>
<tr>
<td>Climacteric</td>
<td>5.3</td>
<td>15.7</td>
</tr>
<tr>
<td>Post-climacteric</td>
<td>5.2</td>
<td>17.0</td>
</tr>
</tbody>
</table>

Early season fruit; Induced water loss conditions: 20°C with 20%RH
Decay was less on fruit from treatments with water loss than on control fruit.

**Fruit**
100% RH in air spaces
Assume 25°C 100% RH

**Environment**
Temperature
Relative Humidity—less than 100%
Air velocity
Assume 25°C with 40%RH

**Skin/epidermis**

**Water loss and temperature**

\[
\text{Wt loss (%/day)} = \text{product } K \times \text{VPD}
\]

**Psychrometric Chart**
Thermodynamic properties of air
Temperature and Water Content

VPD increases exponentially with rising temperature
VPD increases linearly with falling humidity

**Field conditions**

**Storage conditions**
Handling at harvest is critical for water loss management

**Basil**
Highly susceptible to water loss
Very chilling sensitive

**Situation:**
Excellent quality crop
Harvesting late in day
High temperatures, ~30° C
Low RH, ~50%;
Little protection from ambient
Long delays to packinghouse

What can be done to improve this handling???

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**% Water Loss**

From G. Mitchell, UC Davis

<table>
<thead>
<tr>
<th>Delay Before Cooling</th>
<th>6 hours Cooling</th>
<th>7 day Storage</th>
<th>7 day Transit</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Water Loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Table Grapes</td>
<td>Ideal vs Poor Postharvest Handling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cool at 32°F, 95% RH</td>
<td>Stored at 32°F, 75% RH, air at 2 mph</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load at 32°F, 95% RH</td>
<td>Cooled at 40°F, 75% RH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load at 40°F, Transport at 40°F</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Weight loss of Tuscan melons held for different periods at 37°C (99°F) before cooling, storage and shelf-life.

<table>
<thead>
<tr>
<th>Cooling delay</th>
<th>% weight loss before cool</th>
<th>% weight loss storage 10D 5°C</th>
<th>% weight loss shelf-life 4D 20°C</th>
<th>Total Weight loss %</th>
<th>Suture browning score</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 h delay</td>
<td>0.00</td>
<td>2.14</td>
<td>0.97</td>
<td>3.08</td>
<td>1.2</td>
</tr>
<tr>
<td>4 h delay</td>
<td>0.38</td>
<td>1.95</td>
<td>0.96</td>
<td>3.25</td>
<td>1.3</td>
</tr>
<tr>
<td>8 h delay</td>
<td>0.85</td>
<td>1.85</td>
<td>0.78</td>
<td>3.45</td>
<td>1.3</td>
</tr>
<tr>
<td>12 h delay</td>
<td>1.19</td>
<td>1.62</td>
<td>0.79</td>
<td>3.56</td>
<td>1.4</td>
</tr>
<tr>
<td>16 h delay</td>
<td>1.50</td>
<td>1.32</td>
<td>0.85</td>
<td>3.63</td>
<td>2.8</td>
</tr>
<tr>
<td>20 h delay</td>
<td>2.06</td>
<td>1.47</td>
<td>0.68</td>
<td>4.15</td>
<td>4.0</td>
</tr>
<tr>
<td>24 h delay</td>
<td>2.80</td>
<td>1.41</td>
<td>0.71</td>
<td>4.85</td>
<td>4.2</td>
</tr>
</tbody>
</table>

LSD.05 0.21 0.42 ns 0.60 0.8

Water loss is Cumulative

Cantwell, UC Davis
Melon visual quality after delays to cool, storage at 10d 5°C + 4d 20°C

<table>
<thead>
<tr>
<th>Stage</th>
<th>Temp. (°C)</th>
<th>RH (%)</th>
<th>Wind speed (m s⁻¹)</th>
<th>Duration (h)</th>
<th>Predicted moisture loss (%)</th>
<th>Cumulative moisture loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvest</td>
<td>30</td>
<td>65</td>
<td>1.5</td>
<td>3</td>
<td>1.87</td>
<td>1.87</td>
</tr>
<tr>
<td>Pre-cooling</td>
<td>5</td>
<td>75</td>
<td>1</td>
<td>5</td>
<td>0.38</td>
<td>2.25</td>
</tr>
<tr>
<td>Storage</td>
<td>5</td>
<td>75</td>
<td>0</td>
<td>5</td>
<td>0.06</td>
<td>2.31</td>
</tr>
<tr>
<td>Transport</td>
<td>7</td>
<td>66</td>
<td>0</td>
<td>12</td>
<td>0.23</td>
<td>2.54</td>
</tr>
<tr>
<td>Wholesale</td>
<td>5</td>
<td>75</td>
<td>0</td>
<td>3</td>
<td>0.04</td>
<td>2.58</td>
</tr>
<tr>
<td>Wholesale display</td>
<td>25</td>
<td>22</td>
<td>0</td>
<td>2</td>
<td>0.27</td>
<td>2.85</td>
</tr>
<tr>
<td>Transport</td>
<td>7</td>
<td>66</td>
<td>0</td>
<td>2</td>
<td>0.04</td>
<td>2.89</td>
</tr>
<tr>
<td>Retail</td>
<td>20</td>
<td>50</td>
<td>0.5</td>
<td>6</td>
<td>3.79</td>
<td>38h</td>
</tr>
</tbody>
</table>


Litchi Browning:
Water loss is a major contributor: **8% water loss for peel browning.** Mechanical damage, senescence, improper storage temperature, and postharvest pathogens also contribute.
Litchi

~8% weight loss = desiccation browning

<table>
<thead>
<tr>
<th>Harvest Conditions</th>
<th>Temp. (°C)</th>
<th>RH (%)</th>
<th>Wind speed (m s⁻¹)</th>
<th>Duration (h)</th>
<th>Predicted moisture loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>30</td>
<td>65</td>
<td>1.5</td>
<td>3</td>
<td>1.9</td>
</tr>
<tr>
<td>No wind</td>
<td>30</td>
<td>65</td>
<td>0</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td>Delay</td>
<td>30</td>
<td>65</td>
<td>1.5</td>
<td>6</td>
<td>3.6</td>
</tr>
<tr>
<td>Extreme</td>
<td>35</td>
<td>50</td>
<td>1.5</td>
<td>6</td>
<td>6.3</td>
</tr>
</tbody>
</table>


Cultivar Shrivel * | % weight loss
---|---
Ahern 299 3.5 | 13.2
Amsterdam 3.2 | 15.2
Harris LI-34 4.6 | 15.6
Hazera 1319 4.3 | 18.0
Rotterdam 2.4 | 11.8
TC 1260 3.6 | 14.9

LSD.05 0.6 | 1.5

*Shriveling score - 1-5 scale, 1=none, 2=slight, 3=moderate, 4=moderately severe, 5=severe

Cantwell, UC Davis
Simple packaging to reduce water loss. Need to cool product before packaging (room or hydrocool) or use vented packaging and vacuum cool (romaine lettuces).

### Peppers on a tray exposed to the environment for 1 day

<table>
<thead>
<tr>
<th>Temperature</th>
<th>7.5°C</th>
<th>12.5°C</th>
<th>20°C</th>
<th>29°C</th>
<th>37°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>RH</td>
<td>67%RH</td>
<td>52%RH</td>
<td>37%RH</td>
<td>20% RH</td>
<td>17%RH</td>
</tr>
<tr>
<td>Weight Loss</td>
<td>1.1</td>
<td>3.2</td>
<td>5.6</td>
<td>12.9</td>
<td>17.8% wt loss</td>
</tr>
</tbody>
</table>

### Peppers on a tray covered with a plastic bag (not sealed)

<table>
<thead>
<tr>
<th>Temperature</th>
<th>7.5°C</th>
<th>12.5°C</th>
<th>20°C</th>
<th>29°C</th>
<th>37°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>RH</td>
<td>85%RH</td>
<td>87%RH</td>
<td>83%RH</td>
<td>85%RH</td>
<td>80%RH</td>
</tr>
<tr>
<td>Weight Loss</td>
<td>1.0</td>
<td>1.2</td>
<td>1.6</td>
<td>2.3</td>
<td>3.3</td>
</tr>
</tbody>
</table>
Broccoli weight loss and firmness loss can be minimized with plastic liners.

Liners placed in field
And product vacuum cooled
Simple perforated PE lettuce or basil liners perform as well as more expensive plastic films.

Condensation—worse than water loss for many products

Strawberries do not tolerate free moisture

Salad kale does not tolerate free moisture
A small amount of controlled water loss leads to longer postharvest life; Avoid free moisture

Weight loss in relation to VPD in 4 products

- Strawberry: \( y = 0.506x + 0.35 \), \( R^2 = 0.91 \)
- Broccoli: \( y = 1.01x + 0.34 \), \( R^2 = 0.97 \)
- Romaine: \( y = 0.64x + 0.43 \), \( R^2 = 0.94 \)
- Mushroom: \( y = 1.48x + 0.21 \), \( R^2 = 0.98 \)

“Cold and Dry”

Bacterial growth: temperature and moisture

“Cold and Dry” Handling

Leafy green grower, Singapore. Product harvested in afternoon, cooled overnight in marine container, slightly dehydrated (5-8% weight loss) and then consumer packaged the following day.
Water loss control
Low temperature
Packaging appropriate
Minimize time

Water loss and Retail Handling—potentially very high rates of water loss

- Display ready reusable crates—what are advantages and disadvantages
- For product to tolerate such conditions at retail, must minimize water loss at earlier steps in handling chain
- Additional paper or plastic packaging can notably reduce water loss
Water Loss and Postharvest Quality

- Water loss occurs through natural pores and damaged areas
- Environmental conditions at harvest cause high water loss
- Harvest when cool
- Protect and shade in the field
- Reduce delays from harvest to start cooling
- Cool efficiently, then reduce air flow over product
- Temperature, RH, air flow during storage and transport
- Use protective packaging
- Protective treatments in some cases (waxes, coatings)
- Weight loss is cumulative, store only as long as necessary
- Problem conditions are at the beginning and end of the cold chain

REFERENCES


