Crop Quality: An Overview of What We Know and Don’t Know

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Crop Quality
• subjective
• defined by each buyer, whose perspective may change.

Crop Quality
• requires ongoing study to keep up with buyers’ perspectives

quality = loss or gain of repeat sales
• study conducted in 2002 by Slippery Rock University (NW PA)
• 120 consumers, 20 farmers
• quality issues related to fresh fruit and vegetable consumption and production

Fruit and vegetable quality perspectives from producers and consumers at a local university in western Pennsylvania (Borsari, B. Acta Hort 604:69-74).

- Consumers
- Producers

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Consumers</th>
<th>Producers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasonality</td>
<td>3.96</td>
<td>4.16</td>
</tr>
<tr>
<td>Taste</td>
<td>4.45</td>
<td>4.68</td>
</tr>
<tr>
<td>Freshness</td>
<td>4.43</td>
<td>4.68</td>
</tr>
<tr>
<td>Salability</td>
<td>4.2</td>
<td>4.83</td>
</tr>
<tr>
<td>Price</td>
<td>3.73</td>
<td>4.35</td>
</tr>
<tr>
<td>Ethics</td>
<td>2.5</td>
<td>4.32</td>
</tr>
<tr>
<td>Locally grown</td>
<td>1.99</td>
<td>4.76</td>
</tr>
<tr>
<td>Organic</td>
<td>2.26</td>
<td>3.93</td>
</tr>
<tr>
<td>Shelf life</td>
<td>2.5</td>
<td>4.1</td>
</tr>
<tr>
<td>Agronomic practices</td>
<td>1.24</td>
<td>3.79</td>
</tr>
<tr>
<td>Average</td>
<td>2.87</td>
<td>4.46</td>
</tr>
</tbody>
</table>

Preferences of Americans
• taste and cost drove consumer food decisions
• nutrition ranked 3rd and was linked to other demographic factors, such as age (↑), gender (women), and ethnic group but not income

Crop Quality
• ESSENTIAL for direct marketers to manage at the highest level; often THE reason buyers would want their product

Crop Quality
• explains much about the difference between total and marketable yield and, therefore, profit potential

Diagrammatic representation of the functional flow from cropping practices to profitability, via the ability of vegetable growers to meet the food quality-related expectations of their market within an agroecological context.

- Diagram of cropping practices (e.g., fertility, pest, disease, weed) affecting soil properties + genotype-environment + plant physiology (primary, secondary metabolites) leading to crop yield, quality (sensory, nutritional value) + post-harvest management + input costs + market requirements (product quality, environmental stewardship) + profitability

Crop Quality
- BUY FRESH, BUY LOCAL + AICR’S FOODS THAT FIGHT CANCER®
- farm success
Nutritional parameters based on 13 recognized by USDA as important.

Lettuce, spinach, tomato, potato as target crops.

Components of Nutritional Value

1. Mineral Nutrients
2. Total Crude Protein
3. Carbohydrates
4. Other – “phytonutrients” (numerous roles in human health)

Components of Nutritional Value

1. Mineral Nutrients
2. Total Crude Protein
In most crops, can be measured by commercial labs familiar to growers (tissue, soil analysis).

Components of Nutritional Value

3. Carbohydrates
Possibly the least important to health-conscious consumers but very important in other contexts. Sugars can be measured with refractometers and test strips.

Components of Nutritional Value

4. Other – “phytonutrients” (e.g., antioxidants, vitamins)
• sustain
• enrich, fortify
• protect all levels of organization, sub-cellular to organ system
Components of Quality*
- physical
- biological
- chemical
- sensory
*can overlap

Crop Quality
- will never be greater than at the point immediately before harvest
Crop Quality
• lost at every point harvest through delivery

Crop Quality
• components and buyer criteria can be measured or assessed
Tuber Secondary Growth

Internal Brown Spot
small necrotic regions in pith
where tissue died
during tuber
development. Ca
deficiency most
often suspected.
Compare to Internal
Heat Necrosis (small
necrotic specks of
dead tissue in
medulla)

8. Translucent end affecting the stem end of a tuber.
This disorder is usually associated with second growth
and pointed stem end. (Courtesy R. C. Rowe)
Genes: P1, P2 purple root (anthocyanin), Y, Y2, Y3 yellow xylem, xanthophyll (lutein), L, A lycopene synthesis, O, Or orange xylem, carotene

Note harvest index

Beets - an annual crop, grown for roots or tops as greens
Various beet shapes

Duke Univ campus farm

http://mchale.chem.wsu.edu/?s=betalains

farmer-friendly tools for measuring fruit and vegetable crop quality

<table>
<thead>
<tr>
<th>Major Plant Pigment</th>
<th>Prominent Color(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Anthocyanins, other flavonoids</td>
<td>blue, purple, red, yellow, white</td>
</tr>
<tr>
<td>2. Betalains</td>
<td>red-violet, yellow-orange</td>
</tr>
<tr>
<td>3. Carotenoids</td>
<td>pink, orange, red, yellow</td>
</tr>
<tr>
<td>4. Chlorophylls</td>
<td>green</td>
</tr>
</tbody>
</table>

A: carotenes (α, β)  
B: carotenes + anthocyanins  
C: lycopene  
D: xanthophylls


http://horticulture.wisc.edu/faculty-and-staff/2/faculty-and-staff/
Colorimeter: sensitive, standardized measure and expression of color, but not grower-friendly.

Royal Horticultural Society Colour Charts Edition V. Version 2 (measured with spectrophotometer)

Colours in sRGB, CIE L*a*b* (CIELab) and CIE LCh system
Illumination: D65, Observer: 10°, specular component: SCE

yellow-red purple-blue turquoise-green brown-grey

http://azaleas.org/index.pl/azcolorsystems.html

color solid | munsell | rhs | ucl | hcc | ridgway || related pages

lowes.com

Refractive Index

| Portable? | yes | yes | no |
| Cost?     | $10s | $100s | $1000s |
| Light Source? | overhead | internal | internal |
| Farm Use | common | less common | rare |
**°Brix**

**Accepted by Nearly Everyone**
- important
- used for many years
- objective (method, underlying principles)

**°Brix**

**Accepted by Nearly Everyone**
- easily, inexpensively, and reliably measured
- fluctuates with genetics, growing conditions, timing

**°Brix**

**Debated by Many**
- relation to ...
  ... taste, nutritional value
  ... crop and soil status

**°Brix**

**Debated by Many**
- ease of management during soil-based production, especially outdoor, and of consistently achieving target values in multiple crops

**°Brix**

**Debated by Many**
- the ‘correctness’ of certain published Brix values describing crop quality and health (bad-excellent)
°Brix
Understood by Few

- the importance of a measurement protocol consistent with key facts and
  of following the protocol strictly

Plant cells contain many parts and compounds:

- Organic Acids
- Flavor Compounds
- Sugars and Soluble PS
- DNA
- Other
- Amino acids and Proteins
- Pigments
- Phytonutrients

General
172.0 grams water
1.6 grams Protein
0.4 grams Lipids
7.1 grams carbohydrates
2.2 grams fiber
33 calories

Minerals
18 mg Ca
49 mg Fe
20 mg Mg
44 mg P
431 mg K 2.3 g glu 49 mg Lys
9 mg Na 2.5 g fru 33 mg Val
0.31 mg Zn 4.8 g suc 33 mg Isoleucine

Vitamins
24.9 mg Vit C
67 μg Thiamin
23 μg Riboflavin
1.1 mg Niacin
108 μg Pantothenic Acid
146 μg Vit B6
27 μg Folic Acid
12.2 mg Choline
200 μg Betaine
76 μg Vit A
817 μg Beta carotene
184 μg Alpha carotene
224 μg Lutein + zeaxanthin
4.7 mg Lycopene
980 μg Vit E
14.4 μg Vitamin K

USDA Nutritional Database for Standard Reference Release 28
Full Report (All Nutrients) 11529, Tomatoes, red, rip, raw, year round average
Report Date: December 31, 2015
Data based on 1 large whole (2½in) 182 g tomato

From Fruit Composition to °Brix

- all of the components of a tissue (leaf, fruit, etc) are NOT included in sap
  used to measure °Brix … some locked in ‘dry matter’

Abundance by Weight of Major Constituents of Raw Tomato Fruit Relative to each Unit of Sucrose

<table>
<thead>
<tr>
<th></th>
<th>water</th>
<th>carbs</th>
<th>fructose + glucose</th>
<th>proteins + lipids + fiber</th>
<th>minerals + major amino acids + vitamins</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>36</td>
<td>1.48</td>
<td>1.0</td>
<td>0.87</td>
<td>0.16</td>
</tr>
</tbody>
</table>

From Fruit Composition to °Brix

- the relative abundance of molecules in sap (a solution) affects its refractive index (°Brix)
From °Brix to Quality
• because of what °Brix measures and does not measure, it is best as a first-cut assessment of potential sweetness

Relationship between °Brix and perceived sweetness of table carrots

Correlation between °Brix and perceived sweetness = 0.38

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QUESTIONS?

perspectives on or definitions of quality
Differ with person, place, crop, time, and other factors.
Product weight and other physical, chemical, biological and chemical properties that affect buyer acceptance change continuously ... changes and their rates differ among commodities and varieties.

Quality has many individual components; they are grouped into various categories.

Factors contributing to Postharvest Loss
• Temperature
• Water relations
• Damage
• Ethylene
• Nutrition

Five Major Stages of Commercial Vegetable Production
1. Before Planting
2. Planting
3. Planting-Harvest
4. Harvest
5. After Harvest

Bridging gaps in understanding and practice takes resources, work, and communication.
Measuring and Using Brix Values on Vegetable Farms

- equip growers
- Brix measured on 24 crops on 11 farms and at OARDC (July-November 2011)

<table>
<thead>
<tr>
<th>Crop</th>
<th>°Brix average</th>
<th>°Brix range</th>
<th># obs</th>
<th># Farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beet</td>
<td>7.8</td>
<td>2.8 - 13.6</td>
<td>36</td>
<td>4</td>
</tr>
<tr>
<td>Bean</td>
<td>6.9</td>
<td>2.9 - 15.7</td>
<td>56</td>
<td>3</td>
</tr>
<tr>
<td>Swiss Chard</td>
<td>4.6</td>
<td>2.6 - 6.5</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>Cucumber</td>
<td>3.3</td>
<td>2.2 - 5.4</td>
<td>59</td>
<td>4</td>
</tr>
<tr>
<td>Squash</td>
<td>4.3</td>
<td>3.5 - 5.3</td>
<td>42</td>
<td>4</td>
</tr>
<tr>
<td>Sweet corn</td>
<td>16.2</td>
<td>9.5 - 26.5</td>
<td>65</td>
<td>2</td>
</tr>
<tr>
<td>Ch. Tomato</td>
<td>7.5</td>
<td>4.5 - 11.7</td>
<td>99</td>
<td>5</td>
</tr>
<tr>
<td>Tomato</td>
<td>4.7</td>
<td>2.3 - 8.2</td>
<td>440</td>
<td>10</td>
</tr>
<tr>
<td>Turnip</td>
<td>6.0</td>
<td>4.5 - 6.9</td>
<td>19</td>
<td>3</td>
</tr>
<tr>
<td>Watermelon</td>
<td>10.8</td>
<td>9.0 - 12.8</td>
<td>65</td>
<td>4</td>
</tr>
<tr>
<td>Zucchini</td>
<td>4.0</td>
<td>2.4 - 6.0</td>
<td>70</td>
<td>5</td>
</tr>
</tbody>
</table>

Aspects of Management that Affect Brix (within one crop)

- variety
- population
- irrigation
- fertility
- post-harvest
Aspects of Crop Environment or Sample that Affect Brix (within one crop)

- plant part
- age (maturity, position)
- time of day
- temperature-light

Conclusions

- within-head variation in Brix unimportant in manufacturing but key in sampling, analysis

Brix Samples

- top-outer
- top-inner
- bottom-inner
- bottom-outer

Variety Effects on Brix at Two Populations

<table>
<thead>
<tr>
<th>Variety</th>
<th>low</th>
<th>high</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaitlin</td>
<td>6.7 a</td>
<td>7.1 ab</td>
</tr>
<tr>
<td>Krautman</td>
<td>5.3 b</td>
<td>6.0 c</td>
</tr>
<tr>
<td>Megaton</td>
<td>5.9 ab</td>
<td>7.3 a</td>
</tr>
<tr>
<td>SG 3378</td>
<td>6.7 a</td>
<td>7.1 ab</td>
</tr>
<tr>
<td>SuperKraut</td>
<td>6.4 a</td>
<td>6.3 bc</td>
</tr>
<tr>
<td>TransAm</td>
<td>6.7 a</td>
<td>7.0 bc</td>
</tr>
<tr>
<td>XBC 2329</td>
<td>6.6 a</td>
<td>7.3 a</td>
</tr>
<tr>
<td>17-698</td>
<td>5.9 ab</td>
<td>6.3 bc</td>
</tr>
<tr>
<td>Pr &gt; F</td>
<td>0.0085</td>
<td>0.0029</td>
</tr>
<tr>
<td>LSD</td>
<td>0.87</td>
<td>0.79</td>
</tr>
</tbody>
</table>

Reducing soil moisture and altering K rates increased tomato Brix.

Sample (plant part) affects Brix.*

High tunnel and float-bed hydroponic lettuce sampled in October (OARDC 2012)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Fresh wt. (grams/head)</th>
<th>Immature leaf °Brix</th>
<th>Mature leaf °Brix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution 1</td>
<td>138</td>
<td>3.8</td>
<td>2.4</td>
</tr>
<tr>
<td>Solution 2</td>
<td>115</td>
<td>5.8</td>
<td>4.2</td>
</tr>
</tbody>
</table>

* Data also show that nutrient solution and lettuce head size may also affect Brix.

Maturity and harvest practices affect Brix.

Table 1—Comparison of the analysis of Laura tomatoes ripened on and off the vine under the same environmental conditions. The results show the mean and the confidence interval.

<table>
<thead>
<tr>
<th>Analysis</th>
<th>On</th>
<th>Off</th>
<th>Difference, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lycopene, mg/100 g</td>
<td>6.63 (0.9)</td>
<td>5.00 (0.6)</td>
<td>32.51 *</td>
</tr>
<tr>
<td>β-carotene, mg/100 g</td>
<td>0.18 (0.01)</td>
<td>0.13 (0.01)</td>
<td>32.66 **</td>
</tr>
<tr>
<td>Soluble solids, EBrix</td>
<td>5.50 (0.01)</td>
<td>5.00 (0.01)</td>
<td>10.00 **</td>
</tr>
<tr>
<td>Total solids, %</td>
<td>5.88 (0.09)</td>
<td>5.46 (0.05)</td>
<td>7.61 **</td>
</tr>
<tr>
<td>Ascorbic acid, mg/100 g</td>
<td>20.17 (0.40)</td>
<td>20.09 (0.37)</td>
<td>0.42</td>
</tr>
</tbody>
</table>


Sucrose levels fluctuate with time of day, so Brix readings will, too.

So, when looking to manipulate Brix, ...

Sampling to Measure Brix

Vegetables:
- below-ground
  - rhizome, root, stolon, tuber
- near surface
  - hypocotyl
- above-ground
  - stem, petiole, leaf;
  - flower, fruit, seed, pod

Greenhouse tomato growers tend to know that higher light and temperature levels can increase tomato Brix values.

Fruit fresh weight and Brix (OARDC studies 2011)
Sampling to Measure Brix and Using Readings

Consider …
• plant part
• age (maturity, position on plant)
• condition of plant part
• (recent) growing conditions
• time of day

Sampling to Measure Brix and Using Readings

• correct techniques and tools
• know the plant, plant part
• long-term approach to using readings … keep records
• know what Brix measures

So, when looking to manipulate Brix, …
**Sampling to Measure Brix**

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  - hypocotyl
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---

**Sampling to Measure Brix and Using Readings**

Consider …
- plant part
- age (maturity, position on plant)
- condition of plant part
- (recent) growing conditions
- time of day

---

**Research Conclusions**

1. Clear potential to alter crop properties associated with nutrition and health outcomes following consumption.

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**Research Conclusions**

2. Secondary metabolites are amenable to on-farm manipulation and, perhaps, most worthy of attention in enhancing human health.

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**Research Conclusions**

3. Enhancing secondary metabolite production currently can result in penalties, especially to growers.
As we work toward creating a higher quality, more nutritious supply of fresh food …

**Operational Principle**

1. Set baseline and target levels carefully, using a wide range of input and with growers and consumers in mind.

2. Coordinate education on what “nutritionally enhanced” truly means in practical, clear, and substantiated terms.