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

Midwest Winter Production Conference; Jefferson City, MO; 2/11/19

Matt Kleinhennz
Extension Specialist
• consumers  • growers
• distributors  • retailers
• processors (food companies)
• food scientists, technologists
• chefs, food service stewards
• health care providers
• scientists, educators
• organizations

Crop Quality: everyone has an opinion
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

<table>
<thead>
<tr>
<th>(1-5)</th>
<th>Consumers</th>
<th>Producers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasonality</td>
<td>1.98</td>
<td>4.96</td>
</tr>
<tr>
<td>Taste</td>
<td>4.45</td>
<td>5</td>
</tr>
<tr>
<td>Freshness</td>
<td>4.43</td>
<td>4.68</td>
</tr>
<tr>
<td>Salubrity</td>
<td>4.2</td>
<td>4.83</td>
</tr>
<tr>
<td>Price</td>
<td>3.71</td>
<td>4.25</td>
</tr>
<tr>
<td>Ethics</td>
<td>2.1</td>
<td>4.32</td>
</tr>
<tr>
<td>Locally grown</td>
<td><strong>1.99</strong></td>
<td>4.76</td>
</tr>
<tr>
<td>Organic</td>
<td>2.26</td>
<td>3.92</td>
</tr>
<tr>
<td>Shelf-life</td>
<td>2.5</td>
<td>4.1</td>
</tr>
<tr>
<td>Agronomic practices</td>
<td><strong>1.23</strong></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

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Food choice consideration (1-5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taste</td>
<td>4.7</td>
</tr>
<tr>
<td>Cost</td>
<td>4.1</td>
</tr>
<tr>
<td>Nutrition</td>
<td>3.9</td>
</tr>
<tr>
<td>Convenience</td>
<td>3.8</td>
</tr>
<tr>
<td>Weight control</td>
<td>3.4</td>
</tr>
</tbody>
</table>

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.

- Cropping practices (e.g., fertility, pest, disease, weed)
- Soil properties
- Genotype-environment
- Plant physiology (primary, secondary metabolites)
- Crop yield, quality (sensory, nutritional value)
- Post-harvest management
- Input costs
- Market requirements (product quality, environmental stewardship)
- Profitability
### Nutrition Facts

**Serving Size:** 1/2 cup (130g)  
**Servings Per Container:** About 3.5  

<table>
<thead>
<tr>
<th>Amount Per Serving</th>
<th>% Daily Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories 130</td>
<td>Calories from fat 10</td>
</tr>
<tr>
<td>Total Fat 1g</td>
<td>2%</td>
</tr>
<tr>
<td>Saturated Fat 0g</td>
<td>0%</td>
</tr>
<tr>
<td>Trans Fat 0g</td>
<td></td>
</tr>
<tr>
<td>Cholesterol 0mg</td>
<td></td>
</tr>
<tr>
<td>Sodium 30mg</td>
<td>1%</td>
</tr>
<tr>
<td>Potassium 250mg</td>
<td>7%</td>
</tr>
<tr>
<td>Total Carbohydrate 23g</td>
<td>8%</td>
</tr>
<tr>
<td>Dietary Fiber 5g</td>
<td>20%</td>
</tr>
<tr>
<td>Sugars &lt;1g</td>
<td></td>
</tr>
<tr>
<td>Protein 7g</td>
<td>14%</td>
</tr>
</tbody>
</table>

*Percent Daily Values are based on a 2,000 calorie diet.
Not a significant source of Vitamin A & C.
Nutritional parameters based on 13 recognized by USDA as important.

Lettuce, spinach, tomato, potato as target crops.

<table>
<thead>
<tr>
<th>Nutritional Parameter</th>
<th>X</th>
<th>X</th>
<th>X</th>
<th>X</th>
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</thead>
<tbody>
<tr>
<td>Starch (^\text{v})</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Sugars (^\text{v or t})</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Dietary fiber (^\text{v and t})</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Organic acids (^\text{q})</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Sesquiterpene lactones (^\text{q})</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude protein content (^\text{q})</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Nitrates (^\text{q})</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Oxalate (^\text{t or q})</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Minerals (^\text{v})</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
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<tr>
<td>Carotenes (^\text{q})</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Vitamin A (^\text{q})</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Vitamin E (^\text{q})</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Vitamin K (^\text{q})</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thiamin (^\text{v or q})</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Riboflavin (^\text{v or q})</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Niacin (^\text{v or q})</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Vitamin B(_6) (^\text{q})</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Pantothenic acid (^\text{a})</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Folate (^\text{q})</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin (_C) (^\text{v or q})</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Total antioxidant capacity (^\text{m})</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Total phenolic compounds (^\text{v})</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Specific phenolic compounds (^\text{q})</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glycoalkaloids (^\text{q})</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

\(^1\)By gravimetric determination. 
\(^2\)By visual inspection and rating. 
\(^3\)By color reflectance values. 
\(^4\)By instron analysis or with a Hunter force gauge. 
\(^5\)By colorimetry. 
\(^6\)By refractometry. 
\(^7\)By gas chromatography. 
\(^8\)By enzyme degradation. 
\(^9\)By titration against base of standardized concentration. 
\(^10\)By high performance liquid chromatography. 
\(^11\)By gas chromatography-mass spectrometry. 
\(^12\)By enzyme-linked immunosorbent assay. 
\(^13\)By the ABTS and FRAP methods of Rice-Evans et al. (1996) and Benzie and Strain (1996), respectively.
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
- other

*can overlap
- easily managed during production
- easily or cheaply assessed during production
- objective
- new
- related to most peoples’ health
- related to crop and soil status
Crop Quality

- will never be greater than at the point immediately before harvest
Primary metabolism provides energy, supports life.
Products of plant primary metabolism are raw material for secondary metabolism upon which human nutrition relies.
Crop Quality

- lost at every point harvest through delivery
Crop Quality

• components and buyer criteria can be measured or assessed
with assistance from Shearer’s Foods
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)
MAJOR CARROT TYPES

**IMPERATOR**
- Spartan Bonus
- Spartan Fancy
- Tendersweet
- Trophy
- King Imperator

**NANTES**
- Nantes Coreless
- Scarlet Nantes
- Spartan Premium
- Sparton Classic

**HALF-LONG**
- Danvers Half-Long
- Danvers 126
- Red Cored Chantenay
- Royal Chantenay

**FINGER**
- Short 'n Sweet
- Goldinhart
- Gold Nugget
- Minipak
- Tiny Sweet
- Little Finger
A LITTLE DIFFERENT. A LOT BETTER.
Vegetable seed companies are often difficult to tell apart, but we take pride in our difference. Members of the Nunhems USA Carrot Crop Team think about carrots all day, every day. Our goal is to put the Nunhems global breeding program and network of carrot information exchange to use in your fields, and to make your operation more profitable.

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Part of Bayer CropScience
Genes: P1, P2 purple root (anthocyanin), Y, Y2, Y3 yellow xylem, xanthophyll (lutein) L, A lycopene synthesis O, Or orange xylem, carotene

courtesy
C.F Quiros,
UC-Davis
Note harvest index
Beets - an annual crop, grown for roots or tops as greens
Various beet shapes

ROUND OR BALL TYPE

Example Varieties:
- Detroit Dark Red
- Early Wonder
- Explorer
- Red Ball
- Ruby Queen
- Pacemaker

CYLINDRICAL TYPE

Example Varieties:
- Formanova
- Cylindra
- Long Dark Blood
- Long Smooth Blood
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,</td>
<td>blue, purple, red, yellow, white</td>
</tr>
<tr>
<td>other flavonoids</td>
<td></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

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
Refractive Index

Academics.skidmore.edu
Primetab.com
Grapestompers.com
<table>
<thead>
<tr>
<th></th>
<th>Portable?</th>
<th>Cost?</th>
<th>Light Source?</th>
<th>Farm Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portable?</td>
<td>yes</td>
<td>$10s</td>
<td>overhead</td>
<td>common</td>
</tr>
<tr>
<td>Cost?</td>
<td>$10s</td>
<td>$100s</td>
<td>internal</td>
<td>less common</td>
</tr>
<tr>
<td>Light Source?</td>
<td>yes</td>
<td>internal</td>
<td>internal</td>
<td>rare</td>
</tr>
<tr>
<td>Farm Use</td>
<td>no</td>
<td>$1000s</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Using °Brix as an Indicator of Vegetable Quality
An Overview of the Practice
Matthew D. Kleinhans and Natalie R. Baumgarner
The Ohio State University, Ohio Agricultural Research and Development Center

Introduction
Many variables are used to assess fruit and vegetable quality. Some quality metrics such as size, shape, and color are relatively obvious and tend to influence “eye appeal.” Others such as flavor, texture, aroma, and nutrient content, however, are more subjective. They may also be reported in values of °Brix. °Brix values are important because they can be measured objectively and they relate to a subjective criterion that buyers and consumers use to assess vegetable quality—flavor or sweetness. When obtained and applied correctly, °Brix values can aid in variety selection, harvest scheduling, and other aspects of vegetable production.

Using °Brix as an Indicator of Vegetable Quality
Linking Measured Values to Crop Management
Matthew D. Kleinhans and Natalie R. Baumgarner
The Ohio State University, Ohio Agricultural Research and Development Center

Crop quality is important to fruit and vegetable growers, buyers, and handlers. °Brix readings indicate soluble solids content. Since soluble solids represent a product’s potential sweetness (an aspect of quality), °Brix readings can assist many throughout the value chain. Three steps to linking °Brix values to crop management are: 1) determine the optimal °Brix level for each crop, 2) monitor °Brix levels on a regular basis, and 3) adjust harvest schedules to meet consumer preferences.

Using °Brix as an Indicator of Vegetable Quality
A Summary of the Measurement Method
Natalie R. Baumgarner and Matthew D. Kleinhans
The Ohio State University, Ohio Agricultural Research and Development Center

Farmers, as well as produce managers and handlers, need straightforward, reliable, proven, and inexpensive criteria, tools, and techniques to gauge the potential quality of their fresh fruits and vegetables. The level of soluble solids in a fruit or vegetable is often used as an indicator of the sugars present in it. Soluble solids levels are usually reported in values of °Brix. °Brix values can be measured easily and reliably in the field, shop, or shed using a relatively inexpensive piece of equipment able to sheet provide specific instructions for the taking of °Brix readings in five vegetable crops and guidance in making the best use of the values obtained.

Equipment, Material, and Sample Considerations
Soluble solids (°Brix) values are obtained using refractometers. These instruments measure the degree to which light is bent as it passes through a sample (i.e., the refractive index). Refractometers vary in design.

Using °Brix as an Indicator of Vegetable Quality
Instructions for Measuring °Brix in Cucumber, Leafy Greens, Sweet Corn, Tomato, and Watermelon
Natalie R. Baumgarner and Matthew D. Kleinhans
The Ohio State University

Crop quality is important to everyone in the vegetable value chain, including growers, buyers, managers, handlers, processors, restaurateurs, and consumers. Various measures are used to assess and describe different aspects of quality but few may be as popular and important as soluble solids or °Brix. As described in other fact sheets in this series, °Brix has the attention of many throughout the vegetable value chain. For those interested in °Brix, this fact sheet includes specific methods for measuring °Brix in several vegetable crops.

For specific methods refer to:
Cucumber—page 2
Leafy Greens—page 4
Sweet Corn—page 6
Tomato—page 8
Watermelon—page 10
°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
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  Sugars
431 mg  K  2.3 g  glu
9 mg  Na  2.5 g  fru
0.31 mg  Zn  4.8 g  suc

Vitamins
24.9 mg  Vit C
67 μg  Thiamin
23 μg  Riboflavin
1.1 mg  Niacin
109 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

18 types of amino acids

46 mg Leu-
49 mg Lys-
33 mg Val-
33 mg Isoleucine

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 (3’dia.) 182 g tomato
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>Abundance by Weight Relative to Sucrose</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

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

![Diagram showing correlation between °Brix and perceived sweetness](Purdue.edu)

**MAGNITUDE ESTIMATION SCALE**

Fig. 1. Quantitative descriptive analysis profiles of mean judge scores from taste evaluations I and II arranged according to the genetic sources from which breeding lines were derived (see Table 1 for endpoint descriptions).

THANK-YOU and GOOD LUCK!

QUESTIONS?

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The OSU-OARDC

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**Facebook:** [www.facebook.com/osuvpslab](http://www.facebook.com/osuvpslab)

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Use of trade names does not imply endorsement of the products named nor criticism of similar ones not named.
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.
• customer base
• prices and receipts
• bank account
Quality has many individual components; they are grouped into various categories.
Five Major Stages of Commercial Vegetable Production

1. Before Planting
2. Planting
3. Planting-Harvest
4. Harvest
5. After Harvest
Factors contributing to Postharvest Loss

- Temperature
- Damage
- Ethylene
- Nutrition
- Water relations
- Diseases
- Continued growth
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>
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<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>
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<tr>
<td>Swiss Chard</td>
<td>4.6</td>
<td>2.6 - 6.5</td>
<td>14</td>
<td>2</td>
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<tr>
<td>Cucumber</td>
<td>3.3</td>
<td>2.2 - 5.4</td>
<td>59</td>
<td>4</td>
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<tr>
<td>Squash</td>
<td>4.3</td>
<td>3.5 - 5.3</td>
<td>42</td>
<td>4</td>
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<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>
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<tr>
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<td>10.8</td>
<td>9.0 - 12.8</td>
<td>65</td>
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<td>Zucchini</td>
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<td>2.4 - 6.0</td>
<td>70</td>
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For Fresh Raw Produce Only
Comparison Chart for Brix Readings - Vegetables

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<tr>
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<th>Poor</th>
<th>Average</th>
<th>Good</th>
<th>Excellent</th>
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<tbody>
<tr>
<td>Asparagus</td>
<td>2</td>
<td>8</td>
<td>11</td>
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</tr>
<tr>
<td>Beets</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>14+</td>
</tr>
<tr>
<td>Bell Peppers</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>12+</td>
</tr>
<tr>
<td>Broccoli</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>12+</td>
</tr>
<tr>
<td>Cabbage</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>12+</td>
</tr>
<tr>
<td>Carrots</td>
<td>4</td>
<td>6</td>
<td>12</td>
<td>18+</td>
</tr>
<tr>
<td>Cantaloupe</td>
<td>8</td>
<td>12</td>
<td>14</td>
<td>16+</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10+</td>
</tr>
<tr>
<td>Celery</td>
<td>4</td>
<td>6</td>
<td>10</td>
<td>12+</td>
</tr>
<tr>
<td>Cow Peas</td>
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<td>Cucumbers</td>
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<td>6</td>
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<td>6</td>
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<td>10+</td>
</tr>
<tr>
<td>Field Peas</td>
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<td>12</td>
<td>14+</td>
</tr>
<tr>
<td>Green Beans</td>
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<td>6</td>
<td>8</td>
<td>10+</td>
</tr>
<tr>
<td>Honeym dew</td>
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<td>12</td>
<td>14+</td>
</tr>
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<td>Hot Peppers</td>
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<td>10+</td>
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<table>
<thead>
<tr>
<th>CROP</th>
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<th>Good</th>
<th>Excellent</th>
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<tbody>
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<td>4</td>
<td>6</td>
<td>8</td>
<td>10+</td>
</tr>
<tr>
<td>Onions (regular varieties)</td>
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<td>8</td>
<td>10</td>
<td>16+</td>
</tr>
<tr>
<td>Onions (green)</td>
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<td>12</td>
<td>16</td>
<td>20+</td>
</tr>
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<td>Potatoes</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>12+</td>
</tr>
<tr>
<td>Rutabagas</td>
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<td>6</td>
<td>10</td>
<td>12+</td>
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<td>Spinach</td>
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<td>8</td>
<td>12+</td>
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<td>Squash</td>
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<td>8</td>
<td>12</td>
<td>16+</td>
</tr>
<tr>
<td>Sweet Corn</td>
<td>6</td>
<td>8</td>
<td>18</td>
<td>24+</td>
</tr>
<tr>
<td>Sweet Potato</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>14+</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>12+</td>
</tr>
<tr>
<td>Tomatoes (cherry)</td>
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<td>14</td>
<td>16</td>
<td>22+</td>
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<tr>
<td>Turnips</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10+</td>
</tr>
<tr>
<td>Watermelon</td>
<td>8</td>
<td>12</td>
<td>14</td>
<td>16+</td>
</tr>
</tbody>
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Extracted from The Pelly Chart courtesy of Beda Biologics, Kitchener, Ontario (519-895-2798)
# The Reams Composite Chart - Vegetables

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<thead>
<tr>
<th>CROP</th>
<th>Poor</th>
<th>Avg</th>
<th>Good</th>
<th>Excellent</th>
<th>Disease Free</th>
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<tbody>
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<td>Asparagus</td>
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<td>6</td>
<td>12</td>
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</tr>
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<td>12</td>
<td>14</td>
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<td>Carrots</td>
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<td>18</td>
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<td>Cauliflower</td>
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<td>8</td>
<td>12</td>
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<td>10</td>
<td>12</td>
<td>(16)</td>
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<tr>
<td>Corn, Sweet</td>
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<td>18</td>
<td>24</td>
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<td>Cucumber</td>
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<td></td>
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<tr>
<td>Eggplant</td>
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<td></td>
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<td>Garlic</td>
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<td>8</td>
<td>14</td>
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<td>12</td>
<td>14</td>
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<table>
<thead>
<tr>
<th>CROP</th>
<th>Poor</th>
<th>Avg</th>
<th>Good</th>
<th>Excellent</th>
<th>Disease Free</th>
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<td>(12)</td>
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<tr>
<td>Onions</td>
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<td>6</td>
<td>8</td>
<td>13</td>
<td>(13)</td>
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<td>Pea, Blackeye</td>
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<td>12</td>
<td>14</td>
<td>(14)</td>
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<td>(13)</td>
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<td>10</td>
<td>14</td>
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<td>Pumpkin</td>
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<td>Romaine</td>
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<td>12</td>
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<td>8</td>
<td>12</td>
<td>14</td>
<td>(15)</td>
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<td>4</td>
<td>6</td>
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<td>12</td>
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<tr>
<td>Turnips</td>
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<tr>
<td>Watermelon</td>
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<td>12</td>
<td>14</td>
<td>16</td>
<td>()</td>
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</tbody>
</table>

Extracted from the Reams Composite Chart courtesy of Pike Agri-Lab Supplies Inc., Strong, ME (207-684-5131)
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
Brix Samples

top-outer

top-inner

bottom-inner

bottom-outer
Conclusions

- within-head variation in Brix unimportant in manufacturing but key in sampling, analysis
<table>
<thead>
<tr>
<th>Variety</th>
<th>Effects</th>
<th>on Brix</th>
<th>at Two Populations</th>
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</thead>
<tbody>
<tr>
<td>Variety</td>
<td>Effects</td>
<td>on Brix</td>
<td>at Two Populations</td>
</tr>
<tr>
<td>Kaitlin</td>
<td>6.7 a</td>
<td>7.1 ab</td>
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<tr>
<td>Krautman</td>
<td>5.3 b</td>
<td>6.0 c</td>
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<td>Megaton</td>
<td>5.9 ab</td>
<td>7.3 a</td>
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<td>SG 3378</td>
<td>6.7 a</td>
<td>7.1 ab</td>
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<td>SuperKraut</td>
<td>6.4 a</td>
<td>6.3 bc</td>
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<td>TransAm</td>
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<td>7.0 ab</td>
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<tr>
<td>XBC 2329</td>
<td>6.6 a</td>
<td>7.3 a</td>
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<tr>
<td>17-698</td>
<td>5.9 ab</td>
<td>6.3 bc</td>
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<tr>
<td>Pr &gt; F</td>
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<td>0.0029</td>
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<tr>
<td>LSD</td>
<td>0.87</td>
<td>0.79</td>
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</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>
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<tr>
<td>Solution 1</td>
<td>138</td>
<td>3.8</td>
<td>2.4</td>
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<tr>
<td>Solution 2</td>
<td>115</td>
<td>5.8</td>
<td>4.2</td>
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</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>
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<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>
Fruit fresh weight and Brix (OARDC studies 2011)

tomato

zucchini
Sucrose levels fluctuate with time of day, so Brix readings will, too.
Greenhouse tomato growers tend to know that higher light and temperature levels can increase tomato Brix values.

**Light**

\[ \text{SSC (°Brix)} = a + b \times \text{PAR}_{\text{cum}} \text{ (mol photon m}^{-2}\text{)} \]

\[ r = 0.56; P < 0.0001 \]

**Temperature**

\[ \text{SSC (°Brix)} = a + b \times T_{\text{cum}} \text{ (°C)} \]

\[ r = 0.84; P < 0.0001 \]
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
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
AICR's Foods That Fight Cancer™

http://www.aicr.org/foods-that-fight-cancer/

Scientific Report of the 2015 Dietary Guidelines Advisory Cmte

Appendix E-3.2: Food Group Contributions to Nutrients in USDA Food Patterns and Current Nutrient Intakes

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
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
1. Clear potential to alter crop properties associated with nutrition and health outcomes following consumption.
2. Secondary metabolites are amenable to on-farm manipulation and, perhaps, most worthy of attention in enhancing human health.
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.
Operational Principle

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