Texture Measurement of Fresh Produce

STEVEN A. SARGENT
SASA@UFL.EDU
PROFESSOR AND EXTENSION POSTHARVEST SPECIALIST
HORTICULTURAL SCIENCES DEPARTMENT
UNIVERSITY OF FLORIDA/IFAS
GAINESVILLE

UF UNIVERSITY of FLORIDA IFAS

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Harvest and Handling Operations Significantly Impact Quality and are Affected by:

1. **Crop Morphology**
2. **Maturity At Harvest**
3. **Handling Operations**
4. **Examples Of Texture Measurement**

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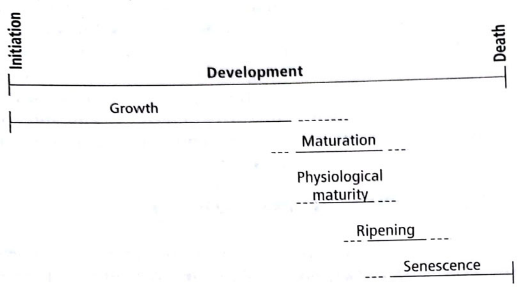
Developmental Stages of Plants

Figure 6.1

Horticultural maturity in relation to developmental stages of the plant. (Watada et al. 1984)



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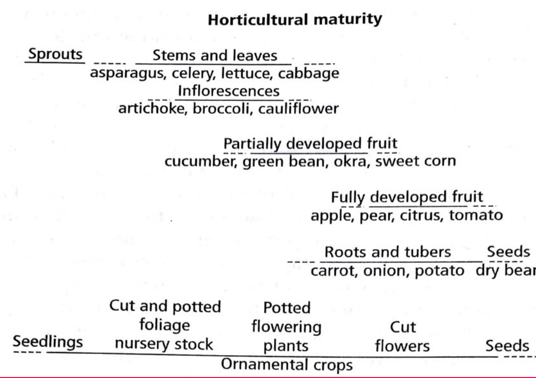
Horticultural Maturity Varies Widely



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Texture Measurement

- **Subjective**
  - **Tactile**
  - **Varies by evaluator**
- **Objective**
  - **Instrument**
  - **Precision & repeatability are critical**

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Texture Measurement Examples

- **Strawberry**
- **Tomato**

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Strawberry Texture and Relationship to Shelf life

STEVEN A. SARGENT
UNIVERSITY OF FLORIDA-IFAS
POSTHARVEST HORTICULTURE LAB
HORTICULTURAL SCIENCES DEPARTMENT, GAINESVILLE
SASA@UFL.EDU

UF IFAS UNIVERSITY of FLORIDA

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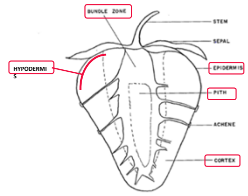
Strawberry morphology: Five zones



Swollen receptable tissue supporting the achenes, the true fruits

1. Epidermis: polygonal cells (stomata)
2. Hypodermis: meristematic cells; no interstitial air spaces
3. Cortex: rounded cells (true flesh); contains interstitial air spaces
4. Bundle zone: conducting tissues (xylem, phloem
5. Pith: thin-walled cells that can separate during fruit expansion

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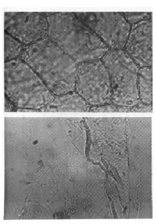
Why so perishable?



Nonclimacteric fruit: harvested at ripe stage

During ripening:
- Cells enlarge and cell walls become thinner
  - TOP Image: Epidermal cells
  - BOTTOM Image: Cortex cells becoming less organized (Szczesniak and Smith, 1969)
- Cellulase activity increases (Abeles & Takeda, 1990)

All contribute to fruit softening and fragility

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Current strategies for quality maintenance

- Manually harvested
- Field-packed
- Forced-air cooled to near 1 °C

2 to 3 hours after harvest

Texture measurement is a key quality parameter in predicting postharvest (shelf) life

- For industry
- For evaluation of breeding material

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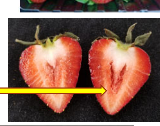
Challenges to accurate texture measurement

Fruit shape, size and ripeness stage

- Varies from conical to elongated to spherical to flattened

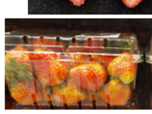
Internal structure

- May have void space during rapid cell expansion



Storage Tests: Repeated measurements

- Variability within a sample can lead to apparent increase in firmness
- Riper fruit removed over time, leaving less ripe for firmness measurement



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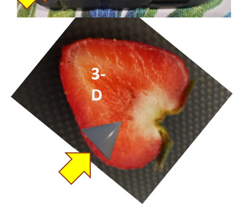
Bruise concepts

Bruise develops when force exerted on the fruit exceeds its integrity

- Impact energy dissipates through tissue (like my phone screen protector!)
- Disrupts epidermal layer, facilitating moisture loss
- Cells rupture, contents spilled into intercellular air spaces (watersoaking)



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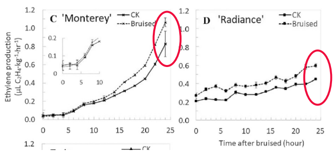
Bruise concepts

<u>Impact bruise</u>: a sudden event

- Drop onto a hard surface
- Being struck by a hard object
- Consequences:
  - Increased respiration, ethylene production, leading to accelerated fruit softening
  - Increased moisture loss during storage

Impact and ethylene production



(Chang and Brecht, 2020)

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Bruise concepts

<u>Compression bruise</u>:

Static load (constant pressure) ruptures cells over time

- At harvest – picker holds several fruits in hand; can compress them
- Clamshell can be overfilled

Compression from fruit-to-fruit contact

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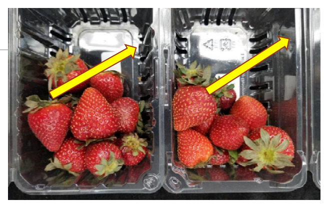
Bruise concepts



Clamshell design can also induce bruising

- Pressure exerted on lower fruit
- Smooth vs. ribbed sidewalls

Compression from top edge (L) and

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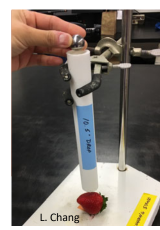
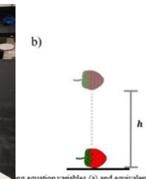
Texture measurement techniques

Impact tests

- Fruit drop impact test – simulate actual heights
  - Difficult to impact same location on each fruit
    - Higher variability, therefore higher sample size required
- Equivalent impact tests – calculate impact energy equivalent to impact energy for drop test
  - Steel sphere: Height, mass of sphere, acceleration due to gravity
  - Impact site and opposite side





Tamashiro et al., 2018

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Texture measurement techniques

Impact tests: Equivalent impact energy

- Fruit drop impact test – simulate actual heights
  - Difficult to impact same location on each fruit
    - Higher variability, therefore higher sample size required
- Equivalent impact tests – calculate impact energy equivalent to impact energy for drop test
  - Pendulum impact test – angular velocity, mass of sphere
  - Impact site only

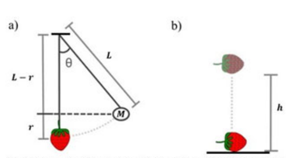

Fig. 1. Diagram of pendulum impactor showing equation variables (a) and equivalent drop height (b).

$$m.g.h = M.g.H$$

Tamashiro et al., 2018

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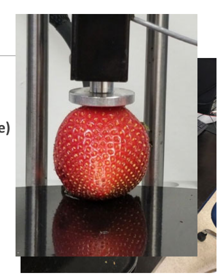
Texture measurement techniques

Compression tests (tissue resistance to constant force)

- <u>Nondestructive</u>: simulates manual squeezing
- Flat plate probe
  - Compress 2-3 mm
  - Read force



FirmTech II analyzer: flat plate probe

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Texture measurement techniques

Compression tests

- Nondestructive: portable
- Flat plate probe
  - Compress 2-3 mm
  - Read force (resistance)

Imada portable meter: flat plate probe

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Texture measurement techniques

Compression tests

- Nondestructive:
- Convex or flat tip cylindrical probe
  - Compress 2-3 mm
  - Read force
- For destructive Puncture Test: epidermis may interfere with accurate measurement

Texture Analyzer: convex tip probe

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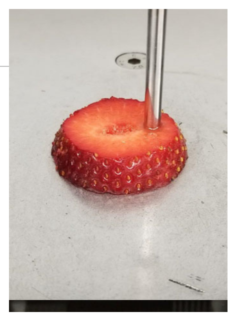
Texture measurement techniques

Compression tests

- Destructive:
  - Compress until tissue fails (Bioyield Point)
- Flat plate or cylindrical probe
- Record maximum force or depth



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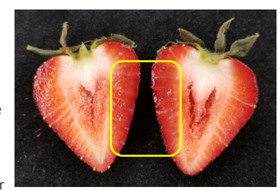
Quantifying bruises

Bruise size measurement

- When to measure (how long after impact?)
  - Immediate vs. 24 hr @ 20 °C vs. during storage

Calculating bruise volume

- Remove watersoaked tissue, determine weight or volume
  - Very time-consuming but most accurate
- Calculate volume based on equation for a cone
  - Measure major/minor axes on surface; slice center for depth
- Calculate bruise surface area based on an ellipse



Cutaway of bruise showing watersoaked cortex tissue

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Effect of impact energy

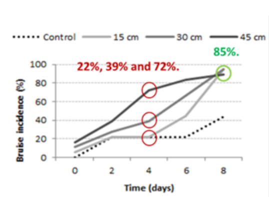
Pendulum impacts at ambient temperature

- Impacted within 2 hr of harvest
- 15, 30, 45 cm height equivalents
- Stored @ 5 °C for 8 days

- Initial bruise incidence: 5, 11, 17%
- Day 4: 22, 39 and 72%
- Day 8: 85% for all treatments
- Why bruises on control fruit?
  - Bruises visible on Day 2; due to clamshell

Tamashiro et al., 2018

'Sweet Sensation'



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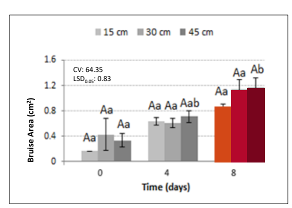
Effect of impact energy



Tamashiro et al., 2018

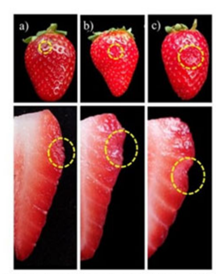


Fig. 4. Top row: external bruising induced from equivalent drop heights of (a) 15 cm, (b) 30 cm or (c) 45 cm on day 8 of storage at 5 °C and 90% RH. Bottom row: respective cross-sections of these same fruit.

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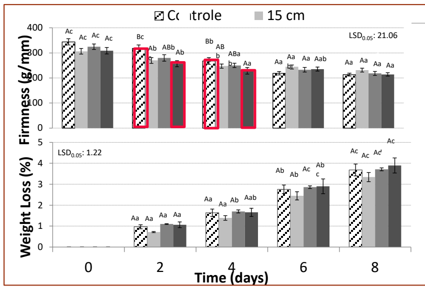
Effect of storage time



Tamashiro et al., 2018

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Pulp temperature and texture measurement

Impact versus compression bruises

- Simulated harvest and field packing (20 °C)
  - Fruit more resistant to impacts (drop; tissue more flexible)
  - Less resistant to compression (9.8 N, 5 sec)
- After cooling (1 °C)
  - Fruit more resistant to compression
  - Less resistant to impacts
  - Hydrocooled fruit more resistant to impacts than forced-air cooled

(Ferreira et al., 2009)

Table 3. Bruise volume for 'Sweet Charlie' strawberries dropped from 38 cm after hydrocooling or forced-air cooling to 1 or 20 °C.

Cooling method	Pulp temp (°C)	Bruise volume[z] (cm^3) Evaluation 1	Evaluation 2
Forced-air	1	0.307	0.427
Forced-air	20	0.167	0.088
Hydrocooling	1	0.116	0.059
Hydrocooling	20	0.238	0.176
Least significant difference at $P = 0.05\%$		0.103	0.118
Cooling method		NS[y]	**[y]
Temperature		NS	**
Cooling method × temperature		**	****

[z]Bruise volume evaluated after 24 h at 24 °C (Evaluation 1) or after 7 d at 1 °C (Evaluation 2).
[y]NS, **Nonsignificant or significant at $P = 0.01$, respectively, by the F-test.

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Cooling and texture measurement

Delays to cooling test: 1 vs. 6-hr delay to forced-air cooling

(Nunes et al., 1995)

Fruit ('Sweet Charlie', 'Oso Grande', 'Chandler')

Delayed 6-hour @ 30 °, stored 7 days @ 1 °C + 1 day @ 20 °C:

- Compared to control (1 hr delay):
  - Softer, more shriveled, lower soluble solids content and total titratable acidity

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Cooling and texture measurement

Partial Cooling to 10 °C + Delays to Final Cooling
(Guamán et al., 2017)

Fruit: 'Radiance'
Forced-air cooling (FA) vs. hydrocooling (HY)

Cooling Treatments:
- Immediate HY to 10 °C (in field); others held at ambient
- After 2 hr:
  - HY 10 °C to 3 °C
  - FA to 3 °C (conventional delay)
  - All other fruit FA or HY to 10 °C, then delay 4, 8 or 24 hr to final FA to 3 °C
- Store @ 1 °C for 12 days

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No difference in firmness, SSC or TTA due to cooling method or delay

	Initial	Day 12
Firmness (N)	2.00	2.11
SSC (%)	6.46	5.53
TTA (%, citric acid)	0.76	0.62

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Visual appearance rating
9=Excellent; 5=limit of marketability; 1= extremely poor

TREATMENTS	Storage Period (days) 0	3	6	9	12
Forced-air cooling delay					
4 hours	9.0 ± 0.0^{ax*}	7.0 ± 0.0^{ay}	5.0 ± 0.0^{bz}	5.0 ± 0.00^{bz}	5.0 ± 0.0^{az}
8 hours	9.0 ± 0.0^{ax}	7.0 ± 0.0^{ay}	5.0 ± 0.0^{bz}	5.0 ± 0.00^{bz}	5.0 ± 0.0^{az}
24 hours	9.0 ± 0.0^{ax}	7.0 ± 0.0^{ay}	5.0 ± 0.0^{bz}	5.0 ± 0.00^{bz}	5.0 ± 0.0^{az}
Conventional	9.0 ± 0.0^{ax}	7.0 ± 0.0^{ay}	7.0 ± 0.0^{ay}	5.0 ± 0.00^{bz}	5.0 ± 0.0^{az}
Hydrocooling delay					
4 hours	9.0 ± 0.0^{ax}	7.0 ± 0.0^{ay}	7.0 ± 0.0^{ay}	6.3 ± 1.15^{aby}	5.0 ± 0.0^{az}
8 hours	9.0 ± 0.0^{ax}	7.0 ± 0.0^{ay}	7.0 ± 0.0^{ay}	7.0 ± 0.0^{ay}	5.0 ± 0.0^{az}
24 hours	9.0 ± 0.0^{ax}	7.0 ± 0.0^{ay}	6.3 ± 1.15^{ayz}	5.6 ± 1.15^{aby}	5.0 ± 0.0^{az}
Field	9.0 ± 0.0^{ax}	7.0 ± 0.0^{ay}	7.0 ± 0.0^{ay}	6.3 ± 1.15^{aby}	5.6 ± 1.15^{ay}

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Cooling and texture measurement

Fruit quality differences after 6 days of storage:

- Potential for partial cooling to 10 ° C + 4-hour delay
- Delays of 4, 8 or 24 hours to final cooling
  - Forced-air fruit had slightly worse appearance and more decay than hydrocooled fruit
  - Conventional forced-air cooling with 2-hour delay was generally comparable to Field hydrocooling to 50 °F + 4 or 8-hr delays to final forced-air cooling

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Tomato Firmness: comparison of two firmness devices

Portable (Imada) vs. Benchtop (Texture Analyzer)

- 12 tomato breeding lines at red, firm stage
- Flat plate probe placed over the locule
- Force (N) measured at 2 mm deformation

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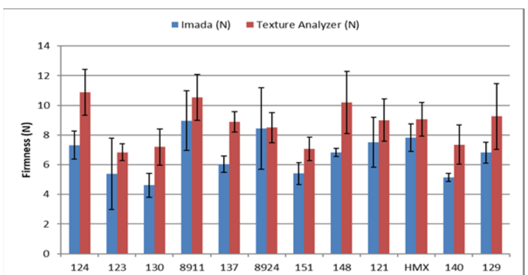
Tomato selections at red firm stage
Firmness was measured over the locule at 2 mm deformation flat plate probe with an Imada DS-4 (N) and Texture Analyzer (N).



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Florida Postharvest Horticulture Tour Class of 2015

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