UCDAVIS POSTHARVEST TECHNOLOGY

Maturation and Maturity Indices

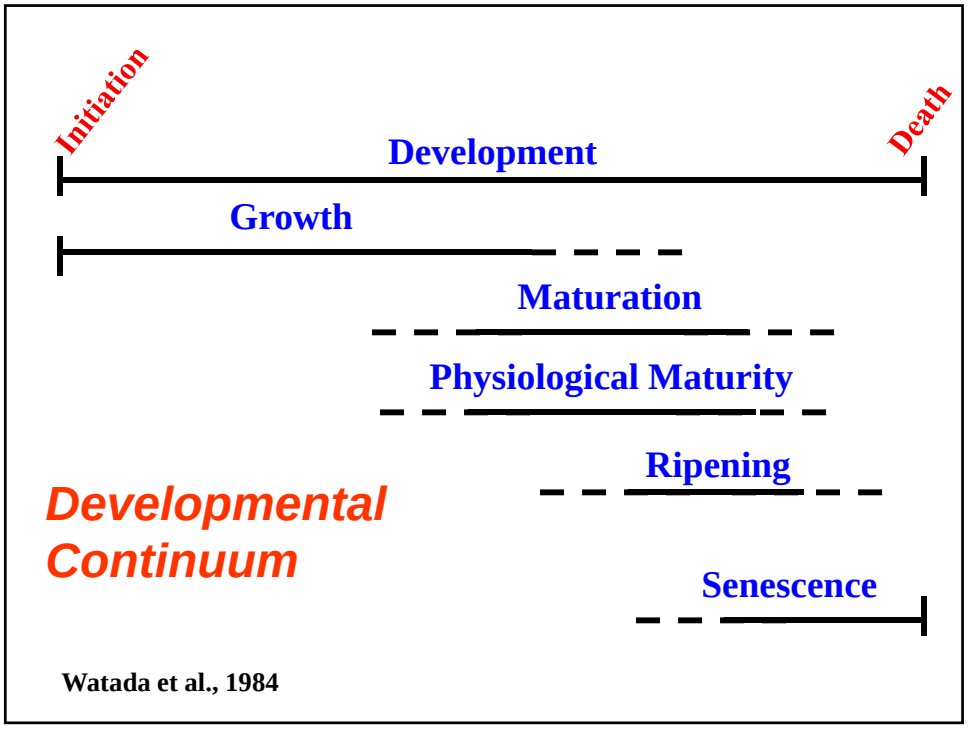
When to Harvest?

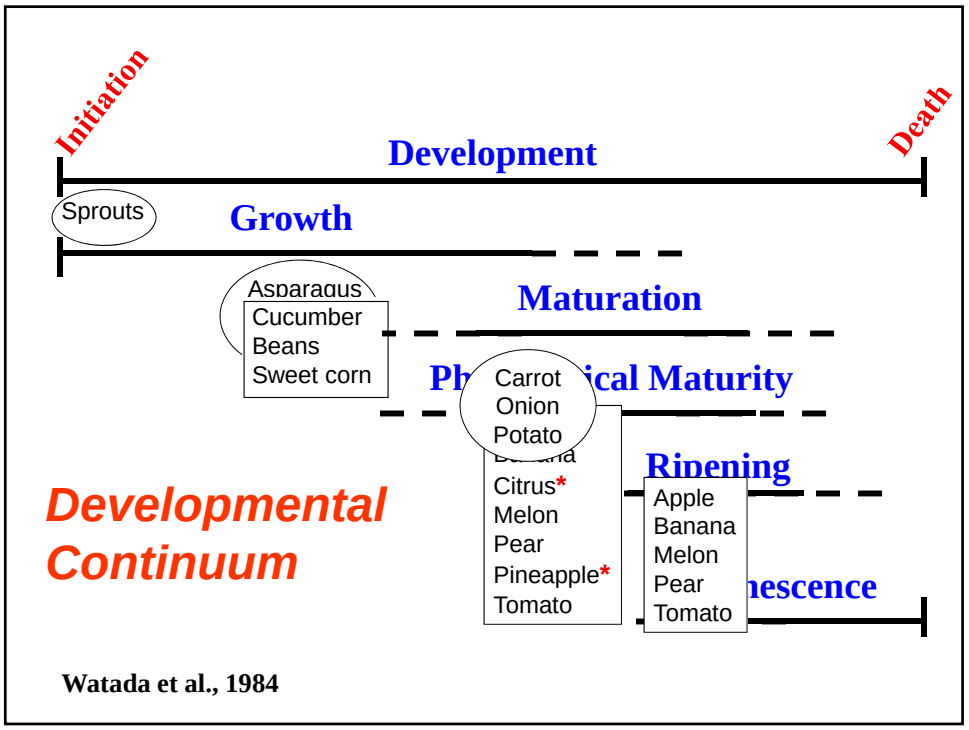
Marita Cantwell, UC Davis
micantwell@ucdavis.edu
http://postharvest.ucdavis.edu

Maturation and Maturity Indices

IMPORTANCE

- ✓ **Maturity Indices = Harvest Indices**
- ✓ **Sensory and Nutritional Quality**
- ✓ **Use—Fresh market or Processed**
- ✓ **Adequate shelf-life**
- ✓ **Facilitate marketing—standards**
- ✓ **Productivity—yield at harvest and use**


Initiation
Death
Development
Growth
Maturation
Physiological Maturity
Ripening
Senescence
Developmental Continuum
Watada et al., 1984


Initiation
Death
Development
Sprouts
Growth
Asparagus
Cucumber
Beans
Sweet corn
Maturation
Carrot
Onion
Potato
Citrus*
Melon
Pear
Pineapple*
Tomato
Ripening
Apple
Banana
Melon
Pear
Tomato
Developmental Continuum
Watada et al., 1984

Terminology

PHYSIOLOGICAL MATURITY

The stage of development when a plant part will continue development even if detached; mature fruits

HORTICULTURAL MATURITY

The stage of development when a plant part possesses the necessary characteristics for use by consumers

Physiological Maturity

FRUITS

- Immature
- Mature
- Ripening
- Ripe
- Overripe

Horticultural Maturity

VEGETABLES

- Immature
- Mature
- Overmature

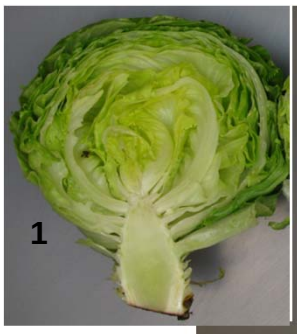
Maturity Indices

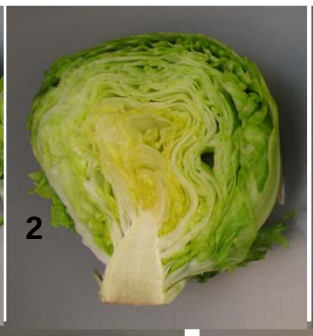
- **Asparagus**
  - Size
  - Apex closed
- **Broccoli/Cauliflower**
  - Size
  - Florets closed
- **Carrot**
  - Size
- **Lettuce, head**
  - Size
  - Firmness, solidity
  - Flavor-sweetness, bitterness
- **Lettuce, Romaine**
  - Size
  - Number of leaves

Days from seeding, transplant

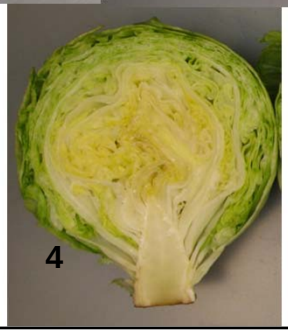
Immature Mature Overmature

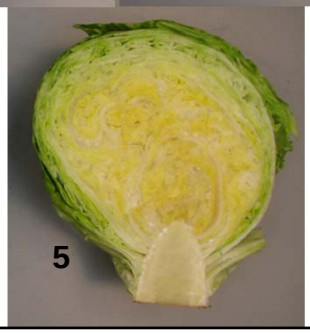
Maturity Stages of Iceberg Lettuce





Weight
Firmness
% Green
Sweetness
Bitterness
Phenolics

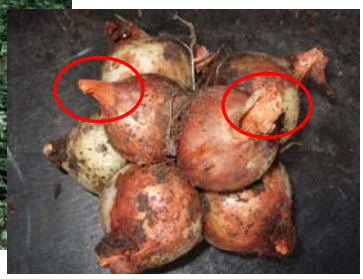








Maturity Indices Bulb Onions



Composition of Potato Tubers

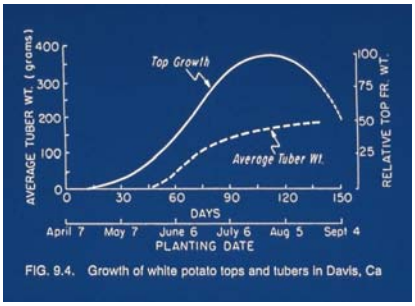


FIG. 9.4. Growth of white potato tops and tubers in Davis, Ca

	Weight g	dry wt, %	Starch %	Sugar %	
Flowering	9	16	64	4.8	
Flowering ends	11	17	66	5.2	"new potatoes"
Leaves decline	28	19	72	2.9	
80% leaves dead	33	21	73	0.8	
100% leaves dead	51	20	72	0.7	mature potatoes

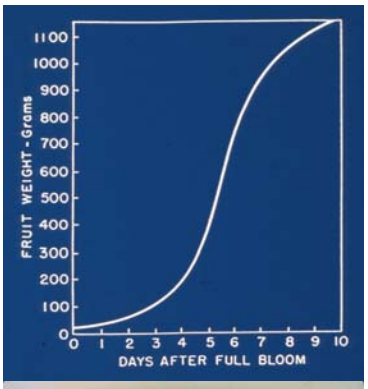
cv. Irish Cobbler; data from Burton, 1966

Maturity Indices

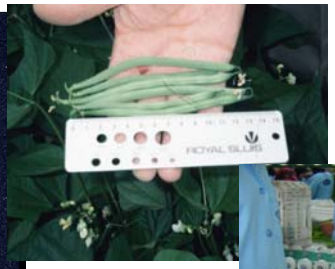
- **Onions/Garlic**
  - **Size**
  - **Drying and collapse of the "neck"**
  - **Drying of leaf scales**
- **Potatoes**
  - **Death of the plant**
  - **Size of tubers**
  - **Starch content; specific gravity**
  - **Periderm development**

Maturity Indices

- **Beans**
  - Size
  - Seed development
- **Cucumber**
  - Size
  - External color
- **Okra**
  - Size
  - External color
- **Summer Squash**
  - Size
  - External color



Immature fruit vegetables: very rapidly developing and changing



Harvest Maturity

Maturity Indices for fruit vegetables

- **Peppers**
  - Size
  - Color
  - Firmness
  - Seed and locule development
- **Tomato**
  - External and Internal color
  - Development of locules (jelly)
  - Firmness
  - Size
  - Development of cuticle

Harvest & Maturity Indices Peppers & Chiles

Jalapeños

European Color Chart 12 colors

Tomato Maturity & Ripening Stages

1 
GREEN The tomato surface is completely green. The shade of green may vary from light to dark.

2 
BREAKERS There is a definite break of color from green to bruised fruit tannish-yellow, pink or red or 10% or less of the tomato surface.

3 
TURNING Tannish-yellow, pink or red color shows on over 10% but not more than 30% of the tomato surface.

4 
PINK Pink or red color shows on over 30% but not more than 90% of the tomato surface.

5 
LIGHT RED Pinkish-red or red color shows on over 60% but red color covers not more than 90% of the tomato surface

6 
RED Red means that more than 90% of the tomato surface, in aggregate, is red

Checker boarding

Due to poor separation of maturity stages of round tomatoes at packing

TOV at harvest and after 4 days at distribution center Likely these green fruit will not ripen

Composition of Ripe Grape Tomato Harvested at 3 Stages of Maturity

Initial Maturity Stage	Weight fruit, g	Red color, hue	Firmness, N force	Soluble solids, %	Sugars mg/mL	Titratable acidity, %	Vitamin C mg/100mL
3	4.9	36.8	11.5	5.9	27	0.59	96
4	5.7	36.3	13.6	6.7	30	0.68	97
5	5.9	37.7	13.7	7.5	33	0.67	99
LSD.05	0.6	ns	1.5	0.8	3	0.09	ns

Minimum harvest stage should be Stage 4 (pink-orange)

Cantwell, UC Davis, 2003

Physalis (Goldenberry; Cape Gooseberry) & Stage of Maturity/Ripeness

Color	1	2	3	4	5
Weight, g	1.78	1.94	2.07	1.76	2.16
% SS	10.8	11.7	12.8	13.6	13.8
pH	3.99	4.23	4.62	4.95	5.05
% TA	1.06	0.78	0.50	0.34	0.32
SS/TA	10.2	15.0	25.6	40.0	43.1

Cantwell, UC Davis, 2007

Group 1* Non climacteric Fruits

Fruits that are not capable of continuing ripening process (physiological changes) once removed from the plant.

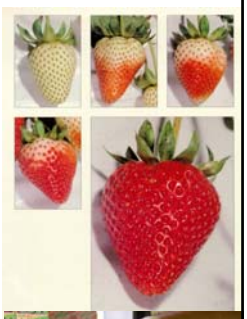
***No increase in sugar content; decrease in respiration after harvest. Changes in firmness, external color, and aroma may occur**

Blackberry	Loquat	Pomegranate
Cherry	Litchi	Prickly Pear
Grape	Mandarin	Rambutan
Grapefruit	Muskmelons	Raspberry
Lemon	Orange	Strawberry
Lime	Pepper (Bell)	Tamarillo
Longan	Pineapple	Watermelon

Composition of Ripe Strawberry

Harvested at different stages.
Held at 70°F (21°C) to complete color change.

Maturity	% SS	% Acid	Ratio
25% color	4.28	0.80	5.35
50% color	4.56	0.79	5.77
75% color	4.98	0.68	7.32
100% color	5.48	0.59	9.28



Maturity and Ripeness Stages of Cherries

Harvest too early
- Small size
- Poor color
- Poor flavor

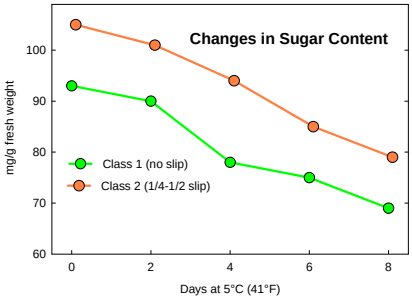
Harvest too late
- Soft fruit
- Increased decay susceptibility
- More shrivel, stem browning and pitting

California strawberries and cherries
Distribution Center Singapore
May 16, 2008

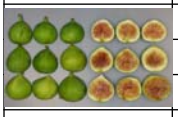
Strawberries from Oxnard; Cherries from Lodi
Air-shipped

Cantaloupe Maturity/Ripeness

- Fruit begins to separate from the stem
- Abscission zone; “slip”
- External color between net
- Net well developed with wax
- Subtending leaf dries up
- Internal color, firmness, soluble solids

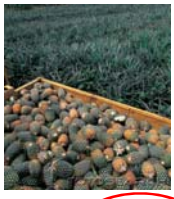


Composition of fig cultivars separated by stage of maturity (ripeness). All the fruit were in boxes of ‘Commercial Maturity” (Cantwell & Crisosto, 2010)

Cultivar	Maturity stage	Weight, g	Firmness, N	Soluble solids, %	Titratable acidity, %
	Under-ripe	29.9	12.1	14.3	0.38
	Commercial maturity	32.2	7.2	17.5	0.19
	Tree ripe	34.5	4.0	21.0	0.22
Black Mission					
	Under-ripe	45.1	11.0	15.2	0.36
	Commercial maturity	56.3	4.4	15.9	0.34
	Tree ripe	57.6	2.4	17.9	0.28
Kadota					
	LSD.05	3.7	1.3	1.9	0.05

Lack of sufficient uniformity of maturity/ripeness within a box leads to repacking or marketing losses

Indian Kew Pineapples and Composition at Different Stages of Ripeness

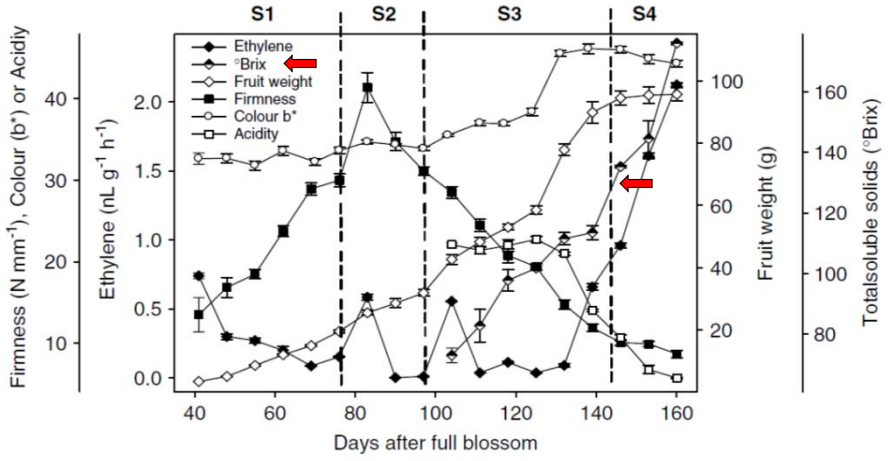


Days from Anthesis	Shell Color	Chl mg/g	Dry wt. %	Soluble solids %	Titratable acidity %	Total sugar %	Vit C mg/100g	Sensory score*
115-120	Green	0.77	12.97	7.9	0.66	6.49	13.7	3.0
135-140	1/8	0.76	15.26	12.6	0.74	8.87	13.9	4.6
141-145	1/4	0.63	16.09	18.2	0.77	11.25	14.4	5.4
146-150	1/2	0.53	17.65	18.9	0.77	11.99	14.9	6.8
151-155	2/3	0.21	17.76	18.0	0.83	12.44	15.3	6.7
156-160	Full	0.14	19.89	16.3	0.96	12.74	14.5	6.4
LSD.05		0.01	0.17	0.87	0.07	0.08	0.5	0.2

* Sensory determined by panel of 10 untrained members based on nine point hedonic scale

Deka et al. 2005. Standardization of maturity indices of 'Kew' pineapple. Acta Hort. 682: 2215.

Large increase in %SS during last days development



Evolution of some physical, chemical and physiological parameters during fruit development and ripening on the tree of 'Golden Globe' Plum.

Diaz-Mula et al., 2008. J. Sci. Food Agric 88:2499-2507

Relationship between sugar/acid ratio and sensory panelist's Response to the question about **Willingness to Buy** navel oranges

		Number of responses	
Sampling week	% samples below sugar/acid Ratio of 8.1*	**YES**	**NO**
Nov 14-18	39	42	58
Nov 28-Dec 2	27	53	47
Dec 12-16	13	63	37

***from California A grade standard**

Source: Ivans and Feree, 1987

California Navel Maturity Standards

The California Standard is easily converted to a table format, similar to the SSC/TA tables currently in use

It is a slight modification of the BrimA calculation proposed by Jordan et al

Steps involved in determining the California Standard

- Juice sample using Boswell Press
- Determine Brix using standard protocols
- Determine Titratable Acidity using standard protocols
- Use Table or formula to determine California Standard

Formula for California Standard:

California Standard = (Brix – (TA * 4)) * 16.5

M.L. Arpaia, UC

D. Obenland, USDA

http://www.cdfa.ca.gov/is/i_%26_c/citrus.html

Group 2* Climacteric Fruits

Fruits that can be harvested and ripened off the plant.
Fruits undergo significant physiological changes.

‡ have large increases in sugar during ripening because they have starch

Apple‡	Mango ‡	Pepper (chili)
Apricot	Mangosteen	Persimmon ‡
Avocado	Nectarine	Plum
Banana ‡	Papaya	Quince ‡
Cherimoya ‡	Passion fruit	Sapodilla ‡ (chico)
Guava ‡	Peach	Sapotes ‡
Kiwifruit ‡	Pear ‡	Tomato

*Except for avocado, banana, mango and pear, best flavor if ripened on the plant

Papaya (Exotica2), slow ripening cultivar (Malaysia)

Harvest at first color
PH treatment with Ethrel

2days after treatment, Differences in maturity Accentuated; some fruit overripe

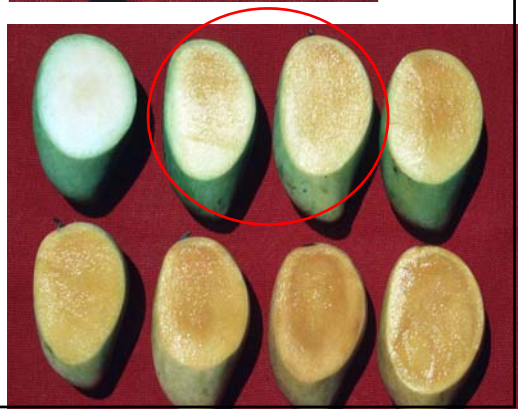
What should be done?
When should harvest?

Mangosteen and eating Quality—maturity issues

Color Index	Color of Fruit
1	Pale yellow green
2	Blotchy pink
3	Pinkish red
4	Maroon Red
5	Dark maroon violet
6	Violet black

Mango maturity indices

- Fullness of shoulders
- Internal and external color
- Lenticels and hairs on pit
- Starch content
- Specific gravity



Golden Delicious at Retail Market: How is the maturity in this box?

Indicators of Harvest Maturity: **APPLES**

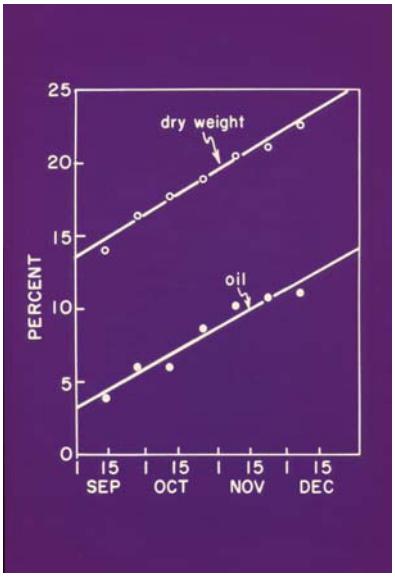
- Days from full bloom
- Time/temp (heat units) from anthesis
- Days from harvest to onset of ethylene production
- Ground color
- Soluble solids content (SSC)
- Flesh firmness and SSC
- Starch disappearance pattern
- Internal ethylene concentration
- Changes in firmness or starch content

For many products it is necessary to use several indices to accurately determine maturity

Streif Index considers starch, sugar, firmness

% Dry Weight and Maturity

- Vegetables
  - Potato
  - Onion
  - Garlic
- Fruits
  - Avocado
  - Apples
  - Mango
  - Kiwi



Oil content avocado linearly correlated with % dry weight

Maturity Indices
Requirements for establishing

- Simple, easy to carry out
- Objective vs subjective indicators
- Related to quality
- Related to storage life
- Represents a progressive change with maturity
- Permits prediction of maturity from year to year
- Inexpensive

Use of Maturity Indices
Limitations

- Soil conditions, nutrition, irrigation
- Season, climate
- Position on the plant
- Pruning, other cultural practices
- Varieties

Predicting Maturity

- **Days from planting to harvest**
- **Progressive changes in size, composition**
- **Difficult to predict; need new tools and methods**
  - **Nondestructive firmness measurement,** fruits
  - **Chlorophyll fluorescence,** broccoli; green tissues
  - **NIR spectroscopy,** sugar concentration in melon
  - **MR imaging** constituents, internal defects
  - **Gene expression** rapid assessment

Maturity and Shelf-life

….Quality is maximized when the product is harvested more mature or ripe, whereas shelf- and storage life are extended if the product is harvested less mature or unripe….

Toivonen, P. 2007. Fruit maturation and ripening and their relationship to quality. Stewart Postharvest Review 2:7.

Lower maturity	Higher maturity
Never ripens	More decay
Shrivels	Better flavor
Poor flavor	Too soft
No repeat buys	Bruises easily
Long shelf-life	Poor shelf-life

Discerning consumers say…..
This fruit looks great, but ……

Maturity Indices Exercise

Fruit or Vegetable	Possible Maturity Indices	Currently Used Maturity Indices	Current indices adequate or Not	What practical indicators could add?

Maturity and Product Quality

- Know the consequences of harvesting at different stages of maturity/ripeness on final eating quality.
- Make sure workers involved in harvest and selection are well trained to ID correct maturity/ripeness.
- Most indices are a compromise between eating quality and shelf-life
- As consumers, take back fruit with poor eating quality