Annual Central Coast
Caneberry Meeting
January 28, 2014, San Luis Obispo

Postharvest Quality Considerations for Blackberries

Overview Berry Composition
CDFA Berry Irrigation Project
Postharvest Handling Resources

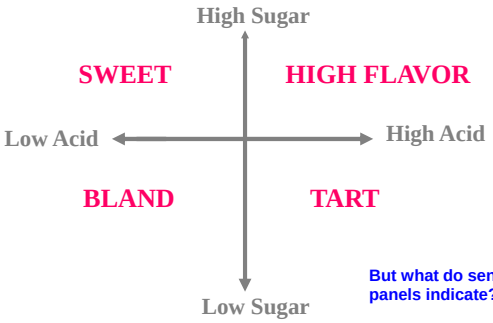
Marita Cantwell, UC Davis
Postharvest Specialist Vegetables
micantwell@ucdavis.edu

UC DAVIS POSTHARVEST TECHNOLOGY

University of California Agriculture and Natural Resources

Sugars, Acids, Aroma Volatiles = Flavor

Fruit Composition & Flavor



But what do sensory panels indicate?

Measuring Sugar Concentrations

- ✓ Both °Brix and % soluble solids can be measured by a refractometer
- ✓ °Brix is a measurement of solids in a pure sucrose solution
- ✓ % soluble solids is an estimate of sugars because a juice solution contains sugars, but also other soluble constituents: organic acids, amino acids, soluble pectins and other soluble compounds.
- ✓ A fruit juice sample is composed of various sugars and soluble components; therefore "% soluble solids" should be used.

Composition of 'Seascape' Strawberries

Constituent	Concentration (%)	Percent of SS
Total sugars	5.28	57.3
Total acids	0.97	10.6
Others	2.95	32.1
Total Soluble solids	9.20	100.0

What are the Other Constituents?

Constituent	Contribution to refractometer reading	% of TSS
Anthocyanins	1.95	21.2
Soluble pectins	0.60	6.5
Ascorbic acid	0.21	2.3
Phenolics	0.19	2.1
Total	2.95	32.1

A. Kader and colleagues, UC Davis

Relative Sweetness of Sugars

- 15% solutions
- Sucrose = 100
- Fructose = 150-160
- Glucose = 70-80

Pancoast & Junk. 1980. Handbook of sugars. AVI

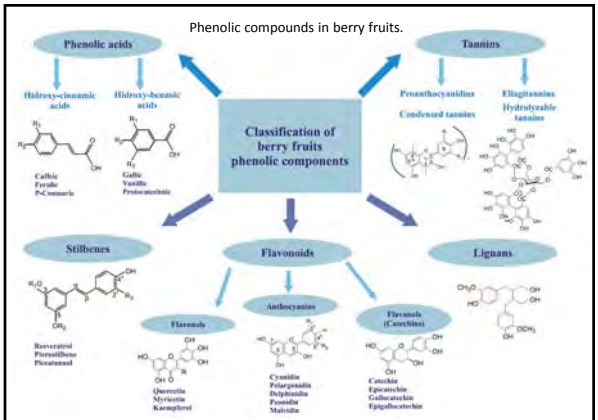
Range of reported composition of 4 berries (from Talcott, S. 2007. Berry Fruit Ch. 2)

	Sucrose (%)	Glucose (%)	Fructose (%)	°Brix	Total solids (%)	Ascorbic acid (mg/100 g)	Citric acid (%)	Malic acid (%)	pH	Titratable acidity (%)
Strawberry										
	0.06–2.27	1.33–2.66	2.18–4.18	7.1–10.8	—	37–104	0.09–2.03	0.12–0.54	3.29–3.43	0.60–0.97
	—	—	—	—	3.77–10.5	13.6–33.9	—	—	—	—
	0.11–1.85	1.63–2.82	2.05–3.30	—	5.2–8.7	—	0.45–1.03	—	—	—
	0.66–1.80	0.71–1.71	1.23–1.93	5.4–9.4	6.9–10.3	40.1–85.3	0–0.71	—	—	—
	—	—	—	5.8	—	—	—	—	3.28	0.53
	0.14–1.22	0.96–2.30	1.46–2.89	9.18–13.1	—	42.7–91.8	—	—	—	0.97–1.20
	0.78–1.63	1.50–1.69	1.84–2.05	6.0–8.2	—	—	0.55–0.72	0.21–0.28	3.57–3.59	0.72–0.88
	0.53–0.74	3.47–6.64	2.78–6.27	—	8.79–13.78	301–313	0.44–0.75	0–0.13	3.67–3.70	0.67–0.72
	—	—	—	—	7.6–9.7	—	—	—	3.18–3.49	0.91–1.07
Raspberry										
	—	—	—	9.26–10.54	14.69–17.98	21.3–31.1	1.27–1.78	0.13–0.18	2.65–2.88	1.67–2.32
	—	—	—	—	14.2–14.8	15.4–32.0	—	—	2.85–3.06	1.90–2.52
	—	—	—	10.0–13.0	—	16.1–28.9	—	—	2.78–3.03	1.71–2.30
	—	—	—	10.5–13.0	—	11.8–29.8	—	—	3.20–3.45	0.16–0.29
	—	—	—	9.26–10.5	15.2–17.9	21.3–31.1	1.27–1.78	0.13–0.18	2.88–3.87	—
	—	—	—	9.7–10.9	—	—			2.99–3.08	1.75–2.38
Blackberry										
	0.12–0.26	1.58–2.61	2.11–3.38	—	—	—	—	0.06–1.10	—	—
	—	—	—	—	—	18.0	—	—	—	—
	—	—	—	—	—	12.4–13.1	—	—	—	—
	—	—	—	—	8.20–13.6	—	—	—	—	0.84–2.62
	—	—	—	10.8–11.4	—	12.7–38.7	—	—	3.06–3.20	0.16–0.30
	—	—	—	—	—	—	—	—	2.55–4.28	1.02–4.22
Blueberry										
	0.12–1.14	3.28–3.87	3.34–3.88	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	0.06–1.10	—	—

Vitamin C and Antioxidant Activity

- **Vitamin C**
  - a specific vitamin required by humans
  - Active forms are sum of ascorbic acid and dehydroascorbic acid
  - 90% of Vitamin C comes from fruits and vegetable
  - needed for cell repair; protects against oxidative stress
  - Is a labile vitamin (degrades easily)
  - Often measured in storage studies of fruits and vegetables
- **Antioxidant activity**
  - With aging, there is increase in oxidative damage
  - Antioxidants can reverse early stages of oxidation
  - In fruits and vegetables, many constituents provide antioxidant activity (phenolics, Vitamin C, Vitamin E, carotenoids and others
  - Various assays can estimate total activity of antioxidant compounds in fruits and vegetables

Phenolic compounds in berry fruits.



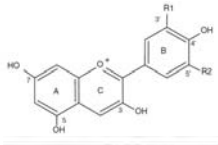
From Berries: Improving human health and healthy aging and promoting quality life—a review. O. Paredes-López et al. 2010. Plant Foods Human Nutrition 65: 299-308.

Total phenolics, flavonoids and anthocyanins of selected berries.

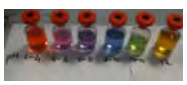
Berries	Scientific name	Phenolics mg/g FW	Flavonoids mg/g FW	Anthocyanins mg/g FW
Bilberry	*Vaccinium myrtillus*	525	44	300
Blackberry	*Rubus fructicosus*	486	276	82-326
Blueberry	*Vaccinium corymbosum*	261-585	50	25-495
Lingonberry	*Vitis vitis-idea*	652	74	77
Raspberry	*Rubus ideaous*	121	6	99
Red currant	*Ribes rugrum*	1400	9	22
Strawberry	*Fragaria x ananassa*	313	--	54

Modified from Berries: Improving human health and healthy aging and promoting quality life—a review. O. Paredes-López et al. 2010. Plant Foods Human Nutrition 65: 299-308.

Anthocyanins



Anthocyanidins	Substitutes R_1	Substitutes R_2	λ_{max} nm visible spectra
Pelargonidin	H	H	494 (orange)
Cyanidin	OH	H	506 (orange-red)
Delphinidin	OH	OH	508 (red)
Peonidin	OCH_3	H	505 (orange-red)
Petunidin	OCH_3	OH	508 (red)
Malvidin	OCH_3	OCH_3	510 (bluish-red)



Color is pH sensitive

Berry Fruit

Ch. 4

California Berry Crops: Improving Water-Use Efficiency While Maintaining Crop Quality

- Shermain Hardesty PI, UCCE Ag Econ Nat. Res. UC Davis
- Elizabeth Mitcham, UCCE Postharvest specialist, UC Davis
- Marita Cantwell, UCCE Postharvest specialist, UC Davis
- Larry Schwankl, Irrigation specialist, KAC
- Aziz Baameur, UCCE Santa Clara County
- Mark Gaskell, UCCE Santa Barbara County
- Manuel Jimenez, UCCE Tulare County
- Ramiro Lobo, UCCE San Diego County
- Cooperating growers
- 2011-2014, Blackberry, blueberry, strawberry
- 4 irrigation regimes, 50, 75, 100, 125% CIMIS
- Field performance and yields, marketable quality, composition, postharvest quality, consumer sensory

Irrigation Project
Composition of Berries

- **Soluble solids** (refractometer)
- **pH and titratable acidity** (pH meter, titration)
- **Sugars** (individual sugars by HPLC)
- **Acids** (individual acids by HPLC)
- **Vitamin C** (ascorbic + DHAA by HPLC)
- **Anthocyanins** (total by spectrophotometry)
- **Phenolics** (total by spectrophotometry)
- **Antioxidant Activity** (FRAP, spectrophotometric assay)

Berries harvested during peak of production
Berries harvested at typical commercial maturity
Berries were of marketable quality, no defects

Blackberry Irrigation Project
2012 and 2013 Samples
Fruit weight, % Dry weight

Table 1. Berry weight and percent dry weight of 2012 and 2013 'Ouchita' blackberries grown under 4 irrigation regimes. For each trial, data are averages from 4 field replicates of marketable quality fruit.

Irrigation Treatment	Weight per berry, g				Dry weight, %			
	KAC 2012 Jimenez	Santa Clara 2012 Baameur	KAC 2013 Jimenez	SLO 2013 Gaskell	KAC 2012 Jimenez	Santa Clara 2012 Baameur	KAC 2013 Jimenez	SLO 2013 Gaskell
50% ET	7.04	4.95	7.12	ND	20.18	22.31	17.11	ND
75% ET	6.96	5.76	7.12	ND	19.52	21.17	17.26	ND
100% ET	8.29	5.39	7.32	ND	19.91	20.00	16.88	ND
125% ET	7.69	6.11	6.89	ND	18.88	19.50	17.71	ND
Average	***7.50***	***5.55***	***7.11***		***19.62***	***20.74***	***17.24***	
LSD.05	ns	ns	ns		ns	1.60	ns	

Blackberry Irrigation Project
2012 and 2013 Samples
Sugars and Acids

Table 2. Total sugar and total acid concentrations of 2012 and 2013 'Ouchita' blackberries grown under 4 irrigation regimes. For each trial, data are averages from 4 field replicates of marketable quality fruit.

Irrigation Treatment	Total Sugars, mg/g FW				Total acids, mg/g FW			
	KAC 2012 Jimenez	Santa Clara 2012 Baameur	KAC 2013 Jimenez	SLO 2013 Gaskell	KAC 2012 Jimenez	Santa Clara 2012 Baameur	KAC 2013 Jimenez	SLO 2013 Gaskell
50% ET	129.9	61.22	82.52	77.82	7.82	10.27	8.70	12.26
75% ET	112.3	54.46	89.26	76.36	7.65	10.69	8.10	11.66
100% ET	108.2	59.15	86.58	77.96	6.84	11.05	8.44	11.70
125% ET	110.6	57.15	92.43	77.14	7.32	11.36	7.55	11.22
Average	***115.25***	***58.00***	***87.70***	***77.32***	***7.41***	***10.84***	***8.20***	***11.71***
LSD.05	13.5	ns	ns	ns	0.71	ns	ns	*ns*

In blackberry, sugars are about 50% glucose, 50% fructose
In blackberry, acids are 40% citric, 30% malic and 30% tartaric

Blackberry Irrigation Project
2012 and 2013 Samples
Sugars: Acid Ratio and Vitamin C

Irrigation Treatment	Sugar: Acid Ratio			
	KAC 2012 Jimenez	Santa Clara 2012 Baameur	KAC 2013 Jimenez	SLO 2013 Gaskell
50% ET	16.64	6.02	9.69	6.38
75% ET	14.74	5.12	11.09	6.55
100% ET	16.09	5.36	10.33	6.67
125% ET	15.22	5.09	12.34	7.19
Average	***15.67***	***5.40***	***10.86***	***6.70***
LSD.05	ns	ns	ns	ns

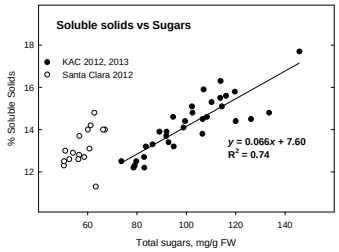
Irrigation Treatment	Vitamin C, mg/100g FW	
	KAC 2012 Jimenez	Santa Clara 2012 Baameur
50% ET	24.77	31.46
75% ET	24.10	27.28
100% ET	25.33	33.63
125% ET	24.70	28.84
Average	***24.98***	***30.30***
LSD.05	ns	3.12

Blackberry Irrigation Project
2012 and 2013 Samples
Anthocyanins and Phenolics

Table 4. Anthocyanin and phenolic concentrations of 2012 and 2013 'Ouchita' blackberries grown under 4 irrigation regimes. For each trial, data are averages from 4 field replicates of marketable quality fruit.

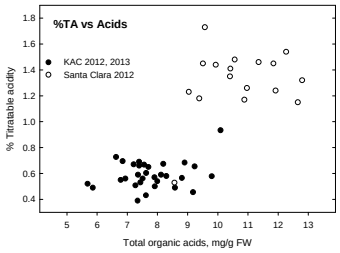
Irrigation Treatment	Anthocyanins, mg/100g FW				Phenolics, mg/100g FW			
	KAC 2012 Jimenez	Santa Clara 2012 Baameur	KAC 2013 Jimenez	SLO 2013 Gaskell	KAC 2012 Jimenez	Santa Clara 2012 Baameur	KAC 2013 Jimenez	SLO 2013 Gaskell
50% ET	173.1	132.9	177.4	ND	576.7	578.0	456.2	ND
75% ET	209.7	133.4	173.7	ND	529.9	557.3	460.9	ND
100% ET	211.2	134.7	184.9	ND	545.2	508.3	472.9	ND
125% ET	237.9	130.1	184.2	ND	498.2	496.5	452.5	ND
Average	***208.0***	***132.8***	***180.1***		***537.3***	***535.0***	***460.6***	
LSD.05	23.1	ns	ns		ns	ns	ns	

Blackberry
Relationship between
Soluble solids (refractometer) and Total sugars (HPLC)



Analysis from separate sets of berries (postharvest and composition

Blackberry
Relationship between
Titratable acidity (titration) and Total acids (HPLC)



Analysis from separate sets of berries (postharvest and composition

Berry Irrigation Project
Conclusions to date-composition

- For blackberry, berry weight not affected by irrigation regimes
- Only in 1 of 4 blackberry trials were sugars and acids affected by irrigation regimes
- Variation from location to location much greater than for irrigation regimes
- 1 more year of data to obtain

Berry Quality Resources

- UC Postharvest website
  http://postharvest.ucdavis.edu/libraries/publications/
- USDA Handbook 66, The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks
  http://www.ba.ars.usda.gov/hb66/contents.html
- Berry Fruit. Value-added Products for Health Promotion. Ed. Y. Zhao. 2007. CRC Press.
- Soft Fruit by L.A. Terry. 2012. In: Crop Postharvest Science and Technology, Wiley Publisher.
- Bioavailability of Antioxidant Compounds from Fruits. I.F.F. Benzie and S.Wachtel-Galor. 2013. In: Bioactives in Fruit. Health Benefits and Functional Foods. Wiley.
- Bioactive Compounds and Health-Promoting Properties of Berry Fruits: A Review. 2008. A. Szajdek, E.J. Borowska. Plant Foods Human Nutrition 63: 147-156.

Causes of Quality & Postharvest Losses

Fruits

Banana
Apple
Avocado
Melons
Citrus
Mango
Tomato
Chiles
Berries

- **Mechanical damage**
- **Maturity, immature, overmature**
- **Poor ripening, conditioning**
- **Softening, texture loss**
- **Changes in composition**
- **Water loss**
- **Chilling injury**
- **Microbial growth**

Example of strawberry is true for all berries

Composition of Ripe Strawberry

Harvested at different stages; held at 70°F (21°C)

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

What do all these fruits have in common?

Flavor determined by maturity at harvest
Flavor declines with storage time

Higher respiration rates are generally correlated with shorter postharvest life

Repiration Rates and Ethylene Production

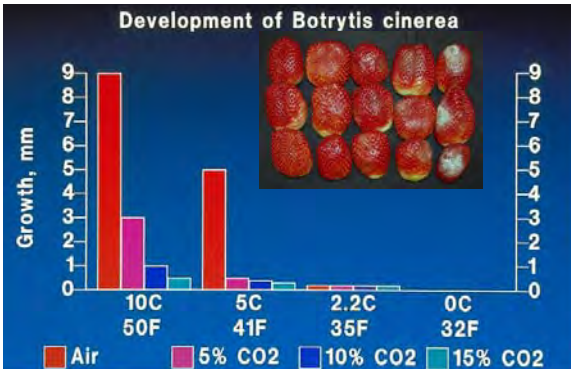
Fruit	Respiration @ 0°C	Respiration @ 20°C	Ethylene @ 5°C
Blackberry	22	155	<0.1
Blueberry	6	68	0.1 to 1.0
Cranberry	3	18	
Raspberry	24	200	
Strawberry	15	127	<0.1
Currant	16	130	
Gooseberry	10	58	

From EJ Mitcham, UC Davis

Cooling and Cold Storage
Forced-Air Cooling is Standard for Berries

- **Cool fruit to 0°C as quickly as possible**
  - **Cool within 2 hours of harvest**
- **When cooled, 90 – 95% RH**
  - **Reduce water loss**
  - **Reduce decay**
  - **Reduce respiration rate and extend postharvest life**
- **Maximum postharvest life**
  - **Strawberry – 2 to 3 weeks**
  - **Raspberry and blackberry – 1 week**
  - **Blueberry – 4 weeks**

Effect of Temperature and Carbon Dioxide on Growth of *Botrytis cinerea*



10 Basic Postharvest Principles

1) Harvest at correct maturity
2) Reduce physical handling
3) Protect product from sun
4) Keep packingline or area simple and clean; ensure good worker hygiene
5) Select, classify, and pack carefully
6) Align cartons, strap pallet
7) Cool as soon as possible
8) Know market and product requirements
9) Coordinate efficient & rapid handling
10) Train and compensate workers adequately

http://postharvest.ucdavis.edu

Produce Facts
- Harvest indices
- Quality indices
- Temperature and RH
- Freezing point/damage
- Respiration rates
- Ethylene production
- Effects of ethylene
- Effects of modified atmospheres
- Physiological disorders
- Postharvest diseases
- Mechanical injury
- Photos

140
Fruits
Vegetables
Flowers

English, Spanish, French, Arabic

Free, content-rich website averages over 3 million views annually, And encompasses more than 640 pages and 1750 pdf documents.

http://postharvest.ucdavis.edu

Upcoming Workshops at UC Davis

- **Methods of Measuring Fruit and Vegetable Quality: Color, Flavor, Texture.** January 22, 2014.
- **Fruit Ripening and Retail handling Workshop**. March 25-26, 2014. 20th Annual.
- **Postharvest Technology Short Course.** 36th annual. This course will be held June 16-20, 2014 at UC Davis with an optional Field Tour June 23-27.
- **Fresh-cut Products: Maintaining Quality and Safety**. Workshop, 19th annual, September 23-25, 2014.
- **Produce Safety: A Science based Framework Workshop**. 2nd annual. November 4-6, 2014.