



2017

THE ALMOND CONFERENCE

SENSORY AND ANALYTICAL: WHERE SCIENCE MEETS ART

Room 314 | December 6 2017



CEUs – New Process

Certified Crop Advisor (CCA)

- Sign in and out of each session you attend.
- Pickup verification sheet at conclusion of each session.
- *Repeat this process for each session, and each day you wish to receive credits.*

Pest Control Advisor (PCA), Qualified Applicator (QA), Private Applicator (PA)

- Pickup scantron at the start of the day at first session you attend; complete form.
- Sign in and out of each session you attend.
- Pickup verification sheet at conclusion of each session.
- Turn in your scantron at the end of the day at the last session you attend.

Sign in sheets and verification sheets are located at the back of each session room.

AGENDA

- **Steve Lindsay**, Almond Quality Food Safety Committee, moderator
- **Guangwei Huang**, Almond Board of California
- **Ellie King**, MMR Research Worldwide
- **Alyson Mitchell**, UC Davis





MMR Research Worldwide

Sensory & Chemistry Profiling of Raw Almond Varieties (2015/16 & 2016/17 Seasons)

Dr Ellie King

MMR Research Worldwide, Inc., Pleasantville NY

Sensory:

Dr Dawn Chapman
Covance Food Solutions, Livermore CA

Chemistry:

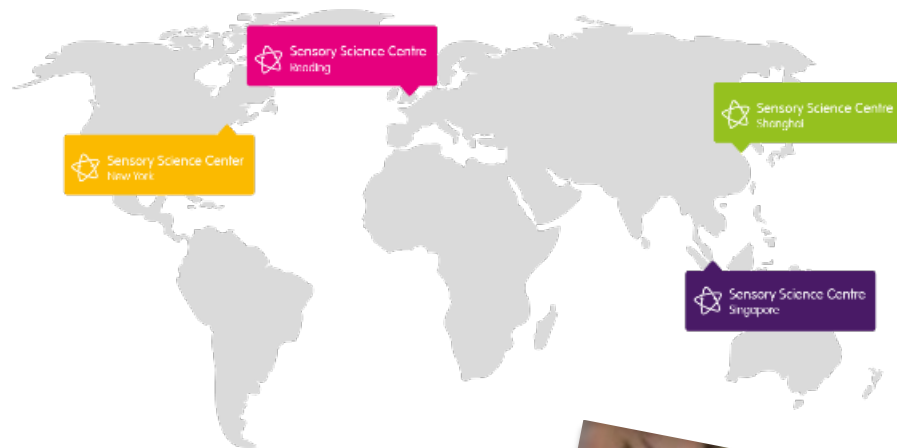
Dr Alyson Mitchell
UC Davis, Davis CA



Content

- About MMR
- Background & Objectives
- Methodology
- Results
- Key Findings





Over 25 years experience and 15 trained sensory panels globally

Each location is **purpose built** and fitted with:

- A kitchen/preparation area
- Large training /discussion rooms
- Light, temperature and odor controlled booths equipped with tablets

There are **3 sensory descriptive analysis panels** in Pleasantville, NY and on-site client panels in the US:

- The first US panel was established in 2011
- These sensory panels consist of 10-15 panelists, who are screened, trained and calibrated to evaluate a **wide range of food, drinks, personal and household care products**

MMR also has a team of **8 statisticians** all experts at analyzing and modeling sensory panel data, with consumer and or analytical data.



Background & Objectives

Background:

- Almond Board of California is interested in better understanding the sensory profiles and chemical composition of raw almond varieties
- 10 raw almond varieties were analyzed over two seasons, using sensory descriptive analysis and chemical analyses

Objectives:

- To determine the sensory signatures of raw almond varieties
- To relate the sensory and chemical analyses and identify trends across the two growing seasons



Almond Varieties	2015-16 season	2016-17 season	Trends over 2 seasons
Monterey	4	4	x
Wood Colony	4	4	x
Aldrich	4	4	x
Padre	1	0	
Carmel	2	4	x
Butte	4	0	
Price	4	4	x
Nonpareil	4	4	x
Sonora	4	4	x
Fritz	4	4	x
Mission	3	0	
Independence	1	4	x
Butte/Padre	3	4	x
TOTAL	42	40	10 varieties

Raw and unpasteurized – samples were sorted and dusted before evaluation

Methodology – Descriptive Sensory Analysis

- Descriptive testing was conducted by Covance (formerly The National Food Lab) using trained sensory panelists
- 10 panelists, 2 replications
- Panelists participated in up to 3 orientation sessions to discuss the samples and review the references
- Samples were blinded using 3-digit codes and served in a randomized and balanced order
- Panelists rated attribute intensities on a 15-point modified Universal line scale
- 40 sensory attributes were evaluated across all modalities



• Aroma and Flavor

- Total Aroma/Flavor Intensity
- Sweet *
- Bitter *
- Sweet Aromatic (non-fruity)
- Marzipan/Benzaldehyde
- Fruity/Sour
- Hay
- Unripe/Beany
- Woody
- Musty/Earthy
- Total Off Aroma/Flavor
 - Rubber/Medicinal

• Appearance

- Average Darkness of Color
- Diversity of Color
- Average Length
- Diversity of Shape/Size
- Appearance of Ridges/Veins

• Texture – Initial (first 3 chews)

- Hardness
- Fracturability
- Crunchy
- Denseness
- Roughness

• Texture – Chewdown

- Chewiness
- Cohesiveness of Mass
- Moistness of Mass
- Mealy Mouthcoating
- Awareness of Skins

• Texture – Residual

- Amount of Residual Particulate
- Residual Toothpack
- Astringent

* Flavor only

Marzipan / Benzaldehyde



Methodology – Chemical Analyses

- 11 physical measures
- 9 vitamins and metals
- **Gas Chromatography** – measured at UC Davis:

Headspace Solid-Phase Microextraction
Gas Chromatography/Mass-Spectrometry
(HS-SPME-GC/MS)

- 52 volatile compounds, most confirmed with authentic standards
- 2 replicates

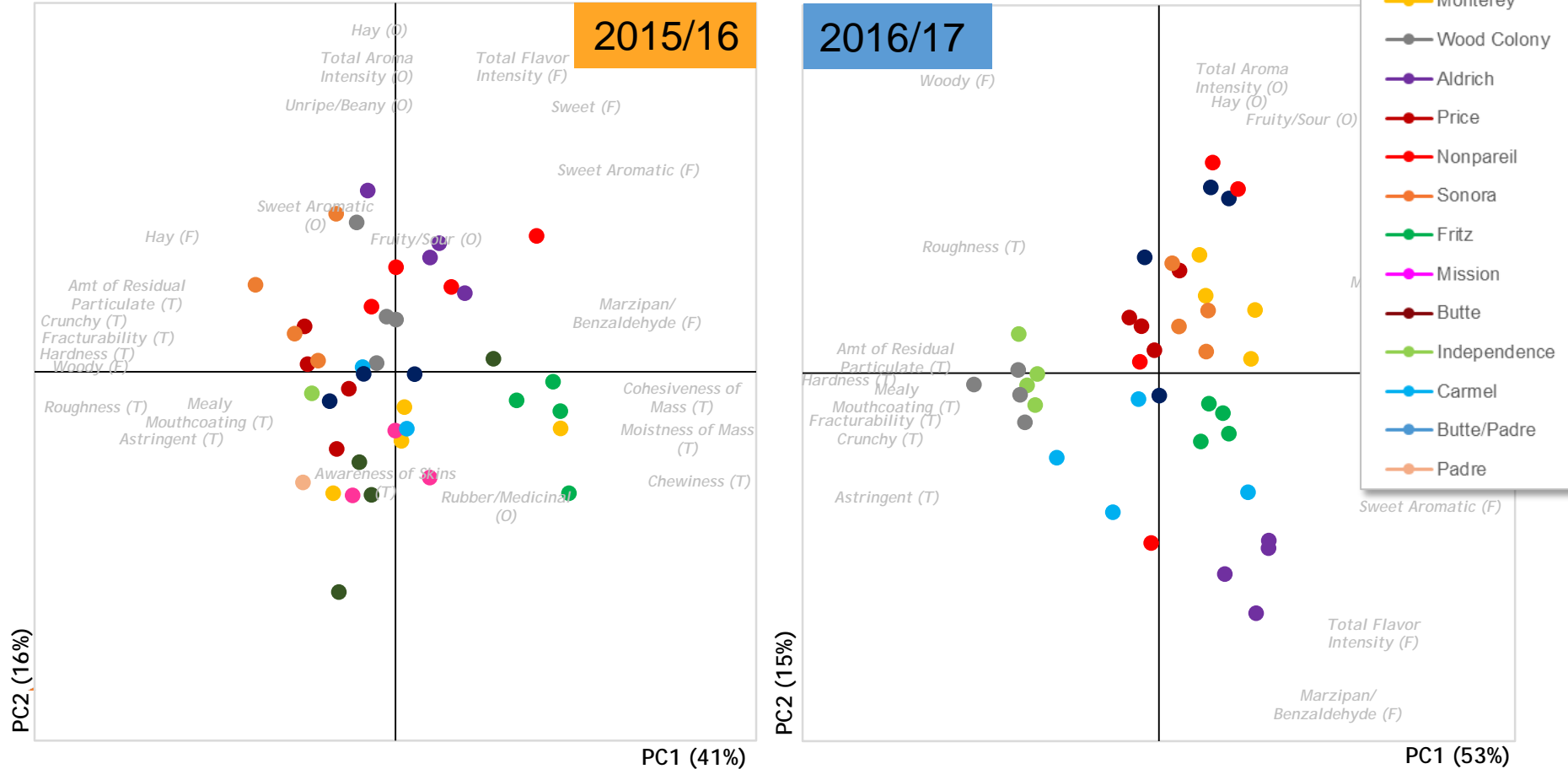




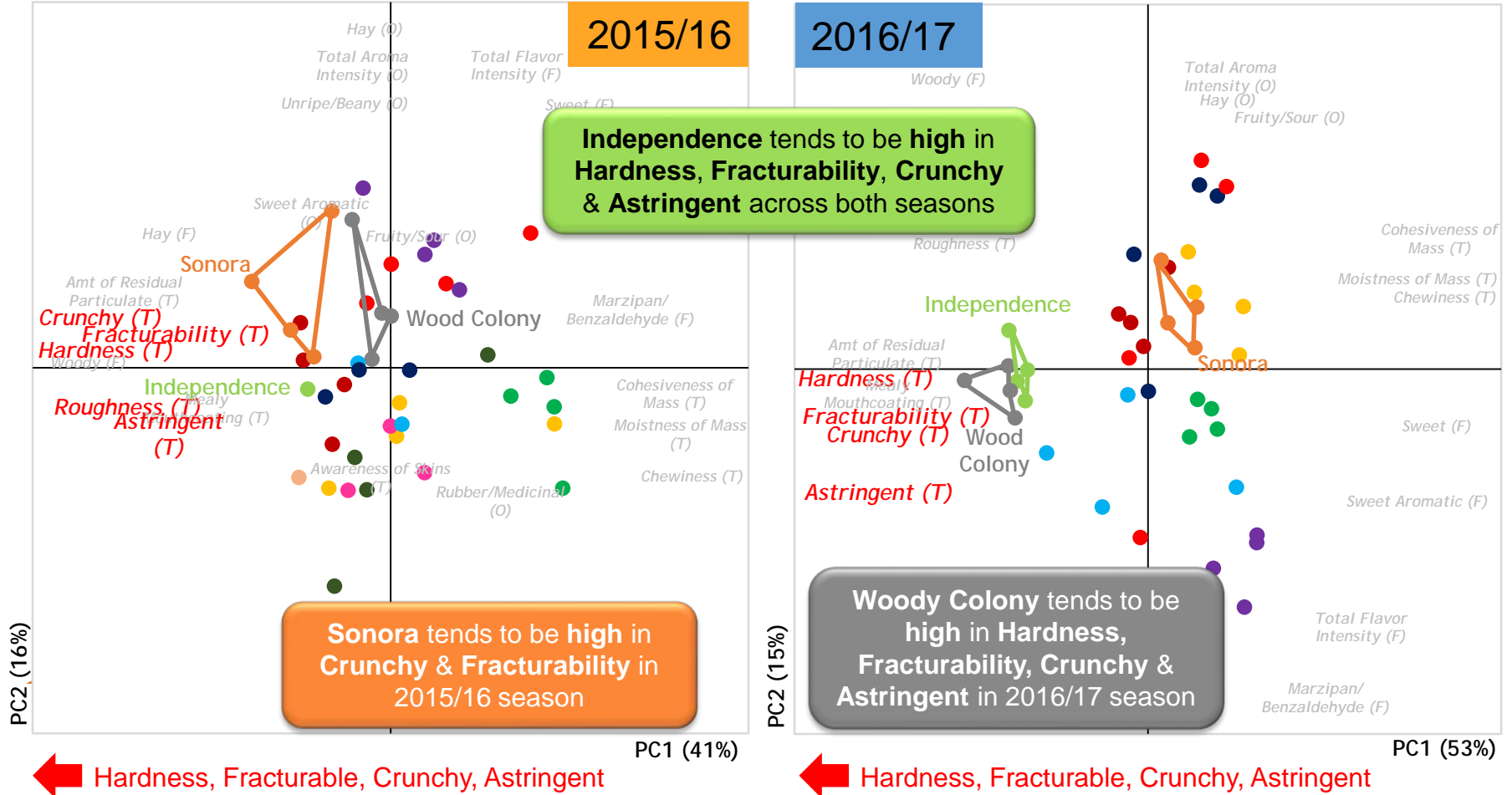
Descriptive Sensory Results

(2015/16 and 2016/17 seasons)

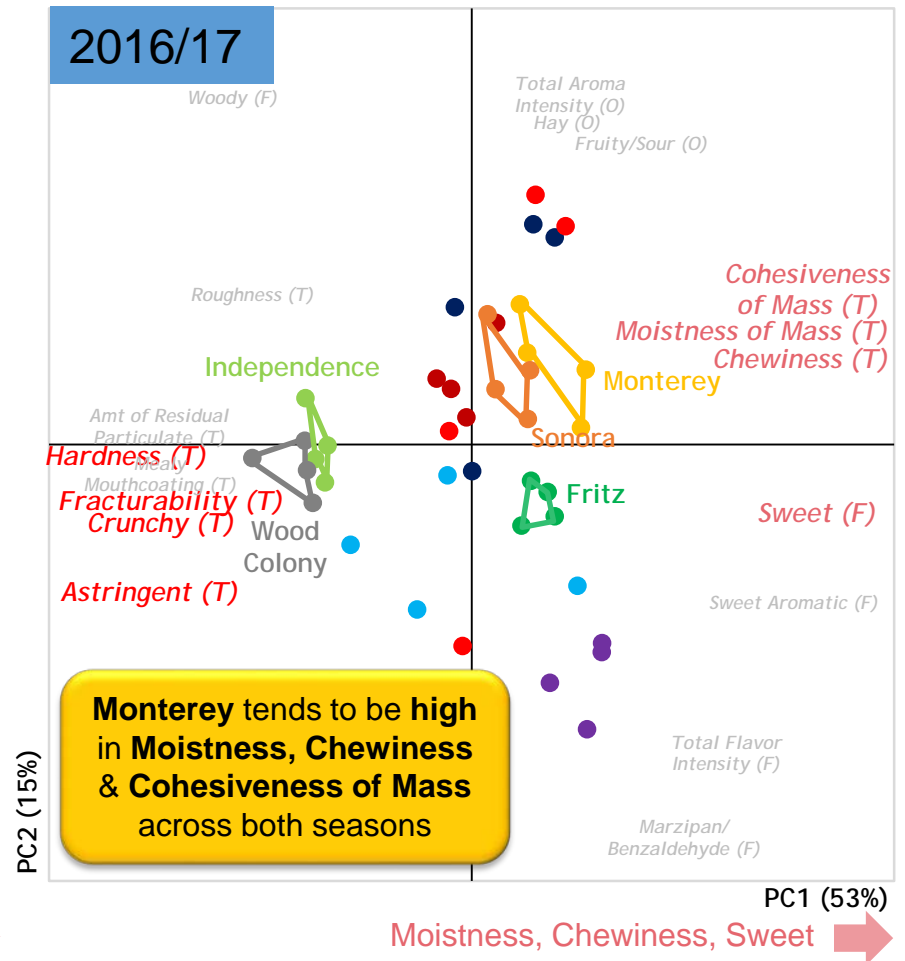
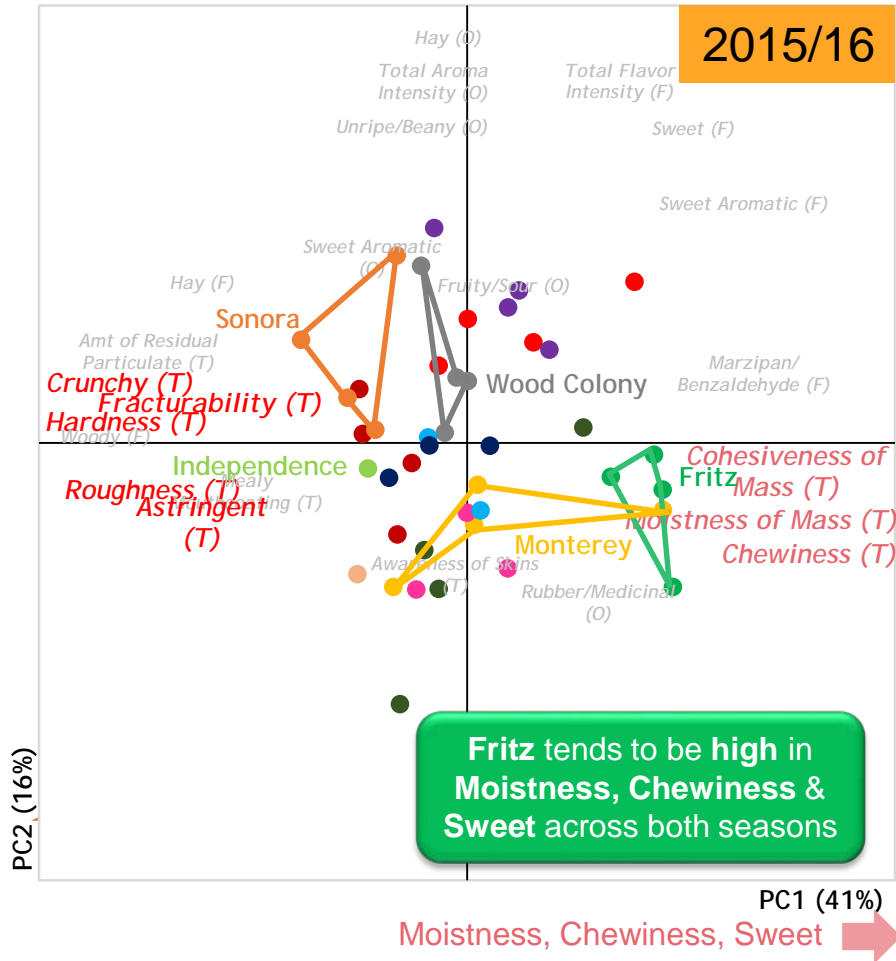
Sensory profiles of raw almonds across 2 growing seasons



Key difference among samples is driven by TEXTURE (Hardness)



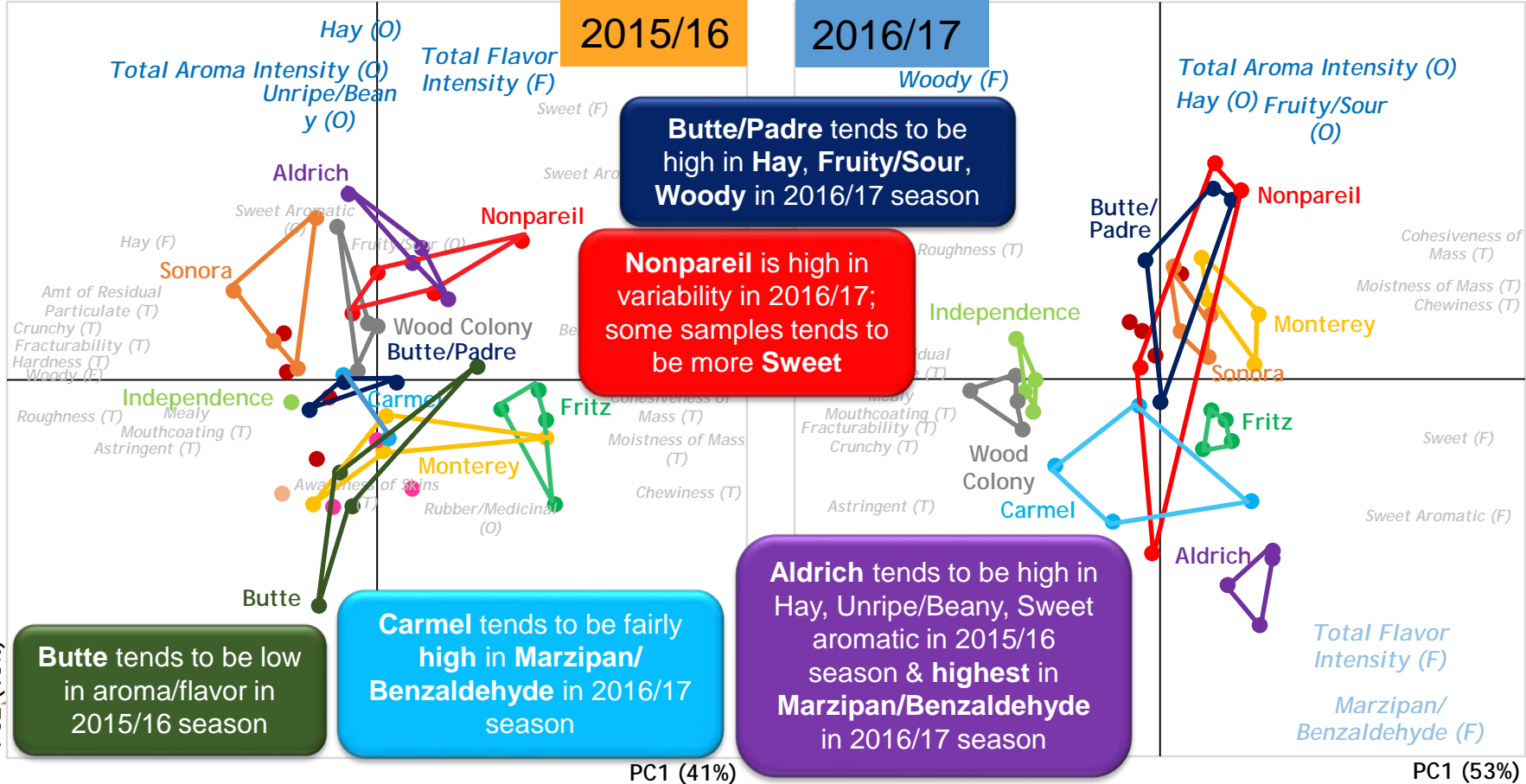
Key difference among samples is TEXTURE (Hardness to Chewiness) mmr



Samples further differentiated by FLAVOR (Hay/Woody and Marzipan) **mmr**

↑
Hay, High aroma/flavor

↓
Low aroma/flavor
PC2 (16%)



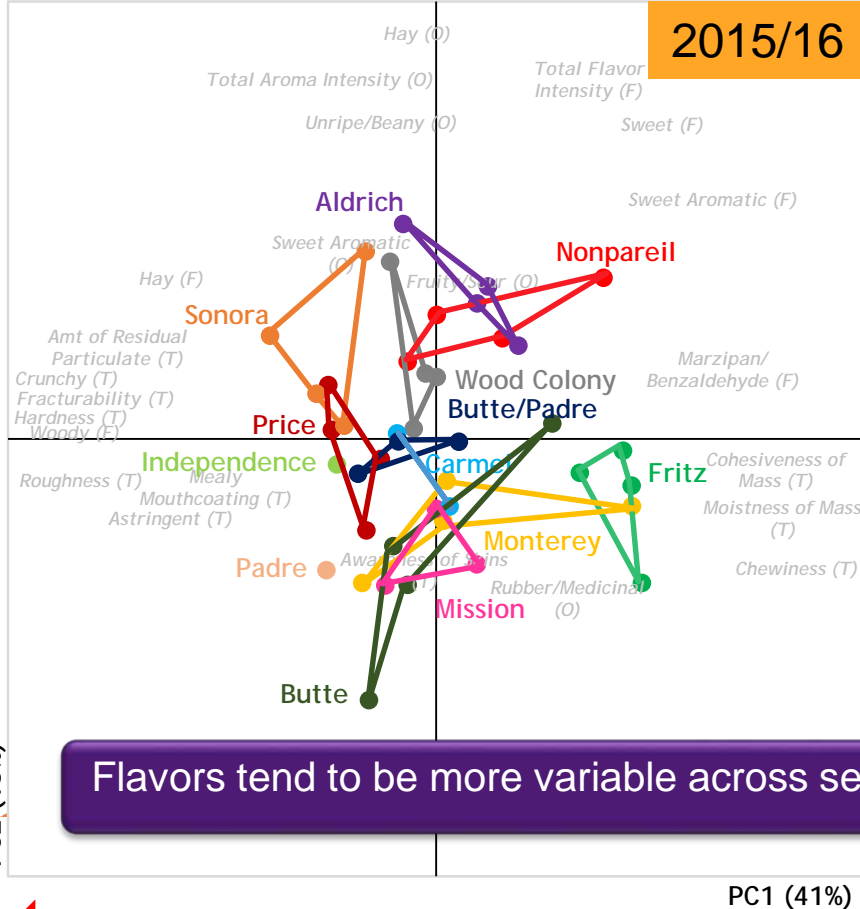
↑
Woody/Hay, High aroma

↓
Marzipan, High flavor

Padre, Sonora and Mission have no distinct sensory profiles

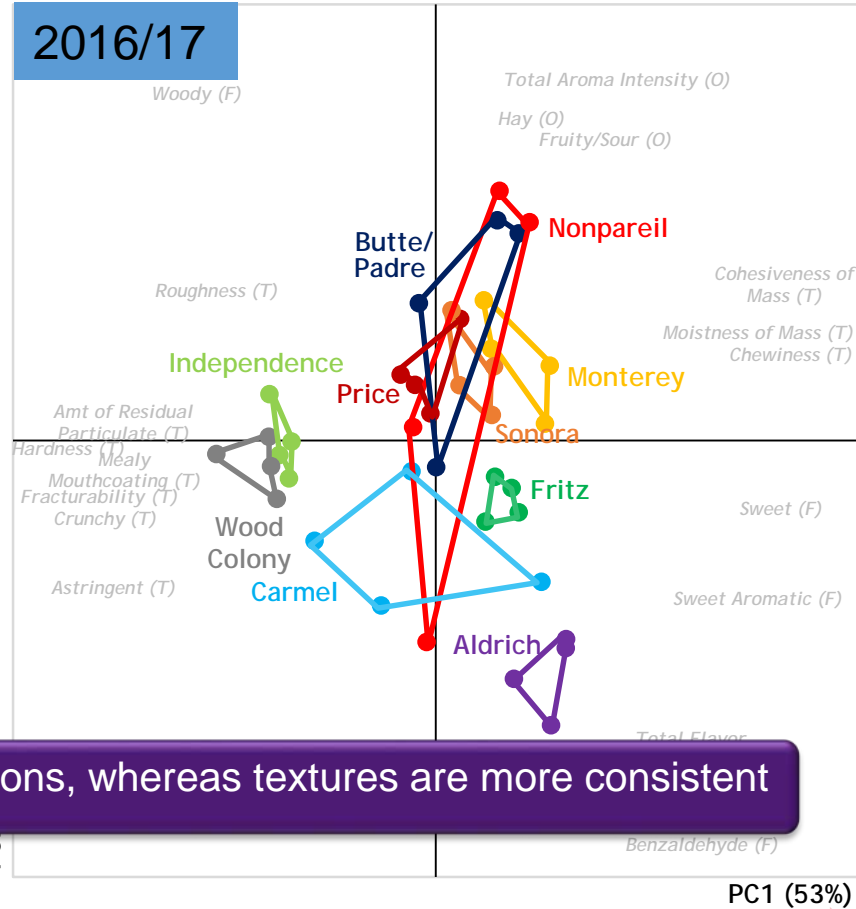
↑
High aroma/flavor

↓
Low aroma/flavor
PC2 (16%)



PC1 (41%)

← Hardness, Fracturable, Crunchy, Astringent



PC1 (53%)

→ Moistness, Chewiness, Sweet

↑
Woody/Hay, High aroma

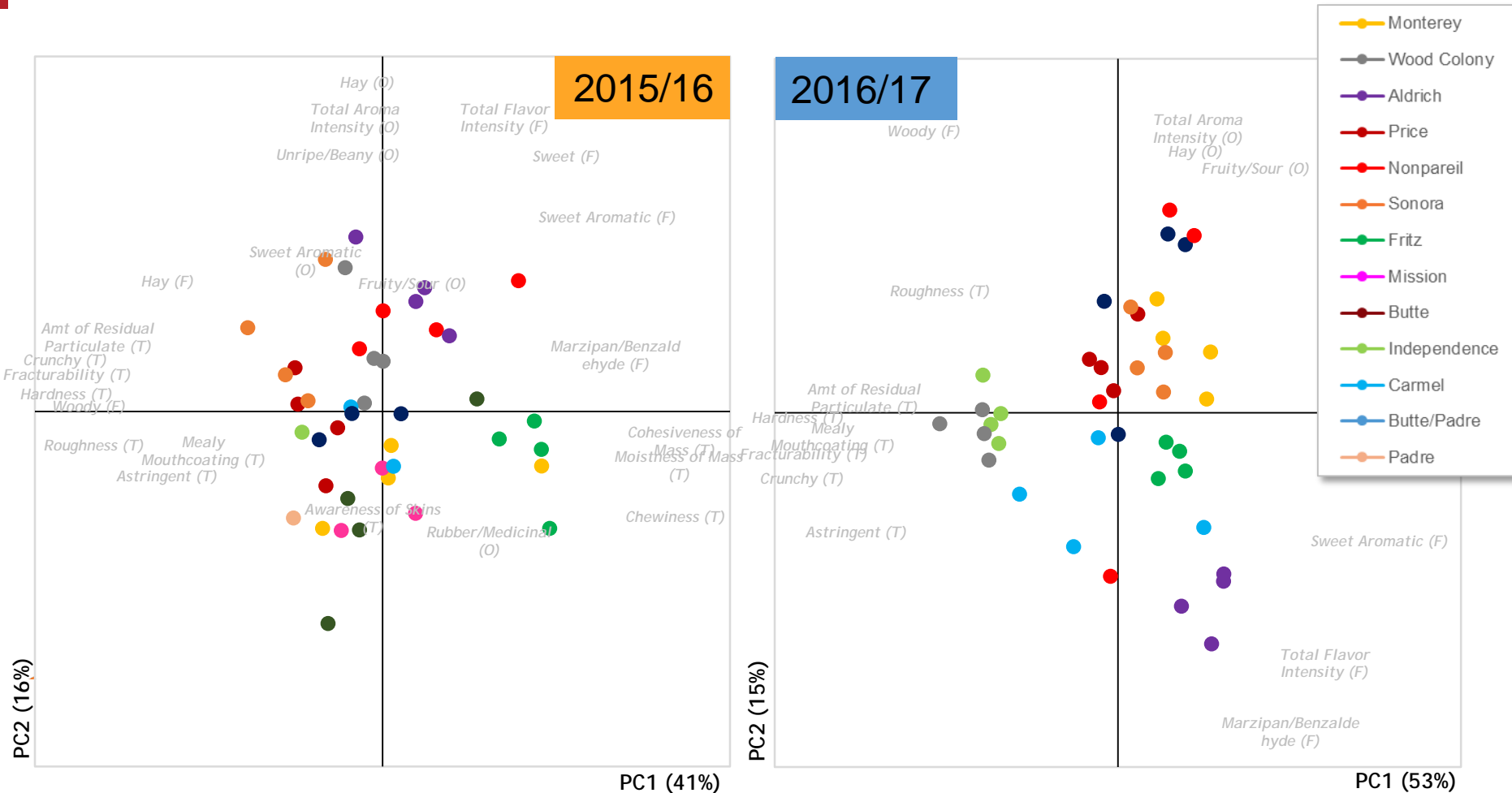
↓
Marzipan, High flavor

Flavors tend to be more variable across seasons, whereas textures are more consistent

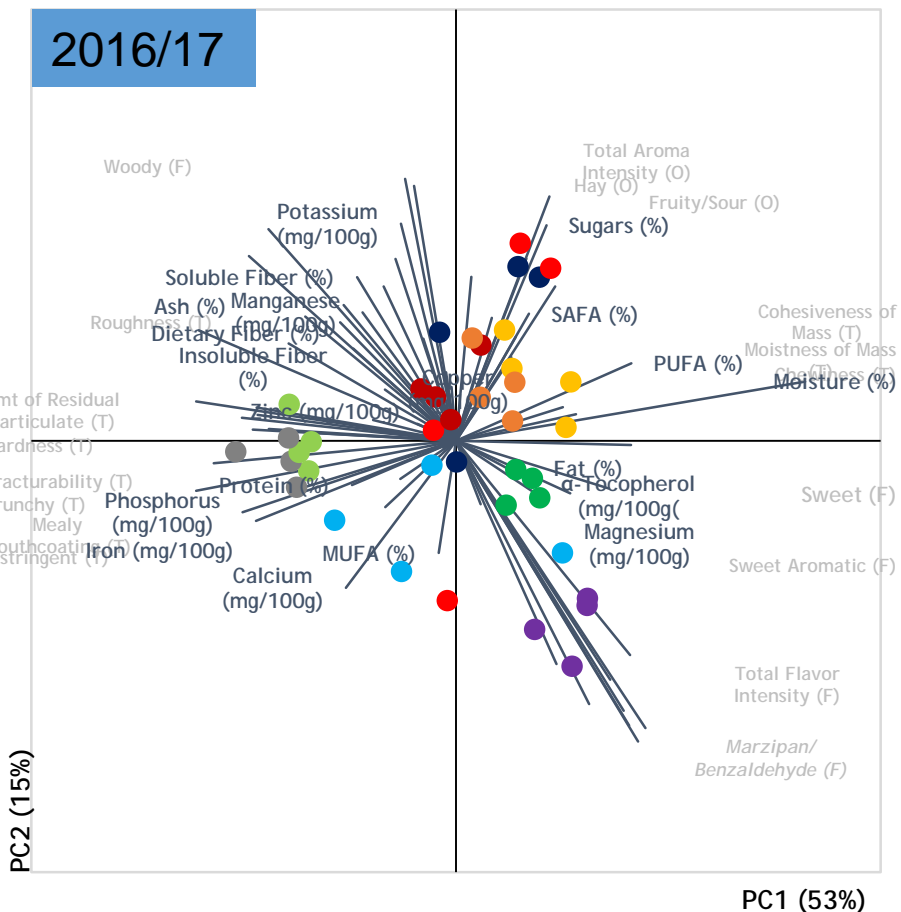
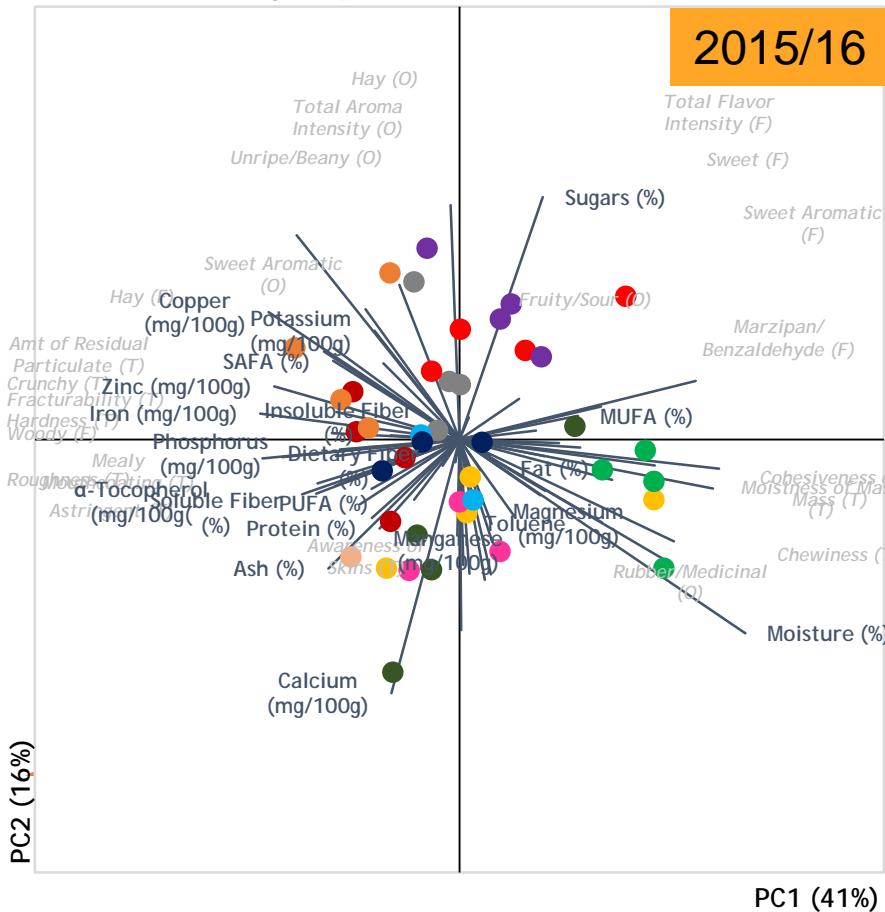


Relating Sensory & Chemical Analyses (2015/16 and 2016/17 seasons)

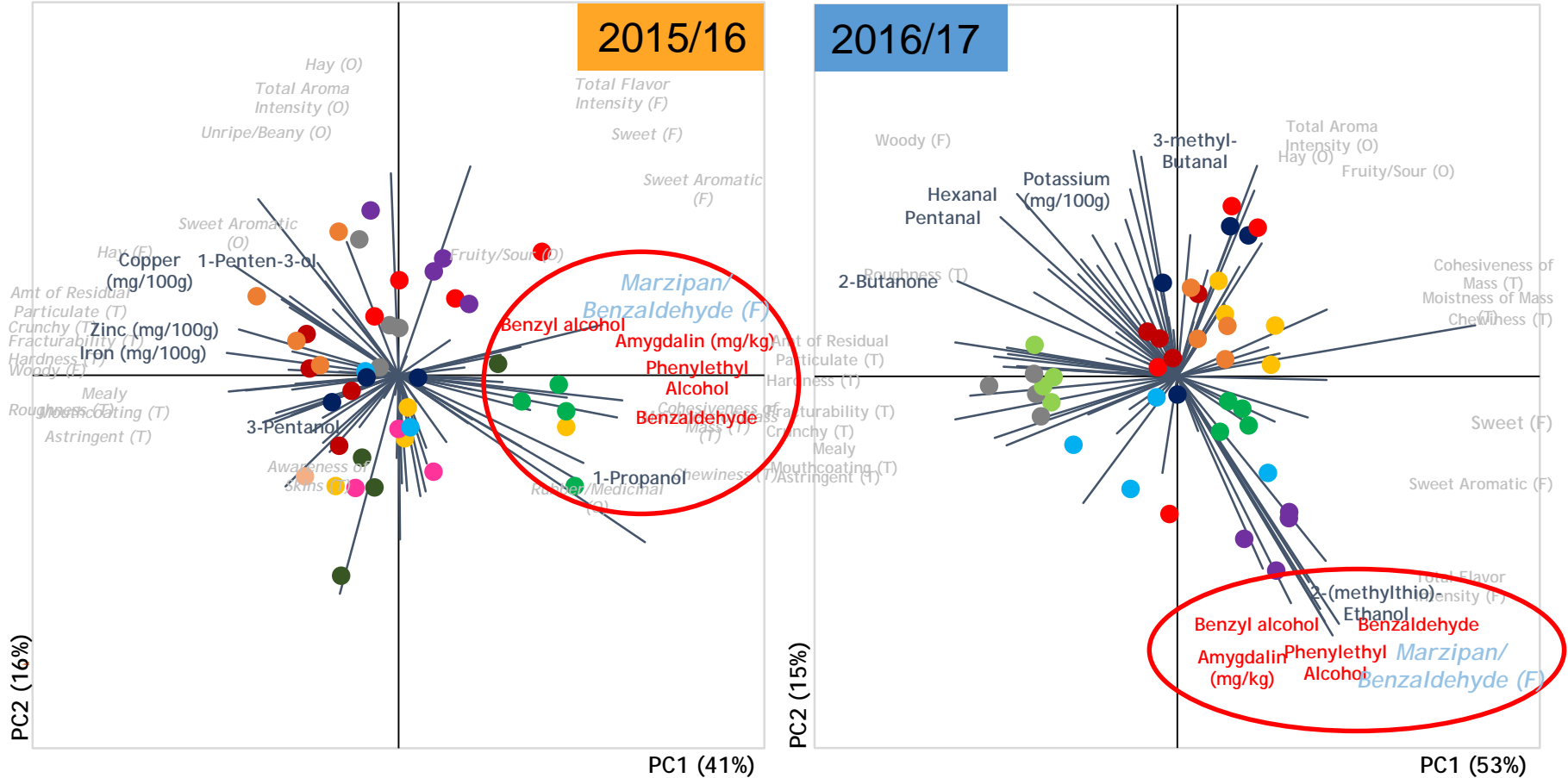
Descriptive sensory profile of 2015/16 and 2016/17 seasons



Mapping the relationship of physical measures, vitamins & metals on the sensory space



Marzipan/Benzaldehyde flavor is driven by benzaldehyde, amygdalin, phenylethyl alcohol & benzyl alcohol across the 2 seasons

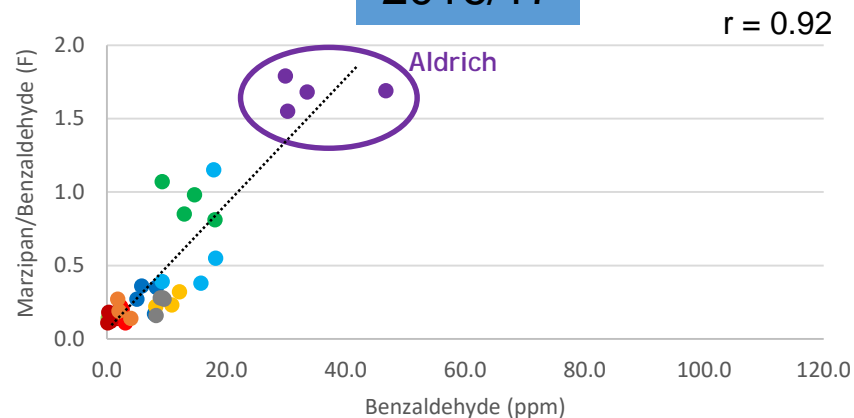
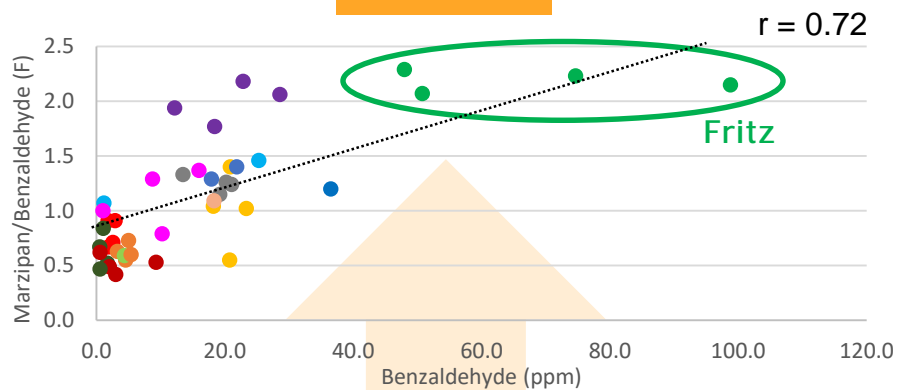


Marzipan/Benzaldehyde flavor is positively correlated with Benzaldehyde & Amygdalin

2015/16

Benzaldehyde

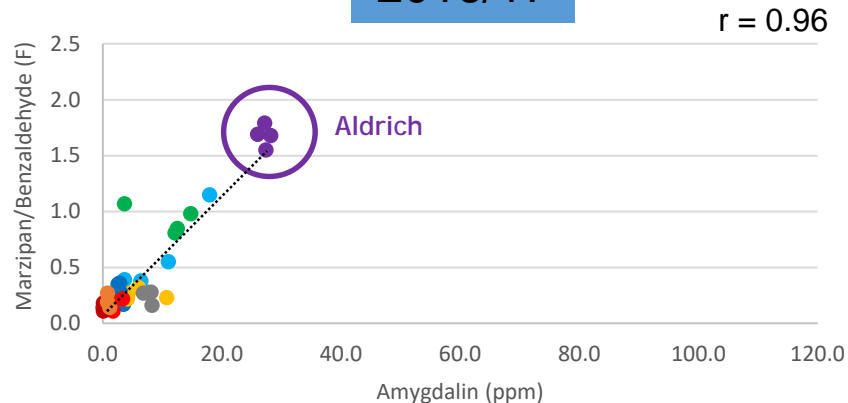
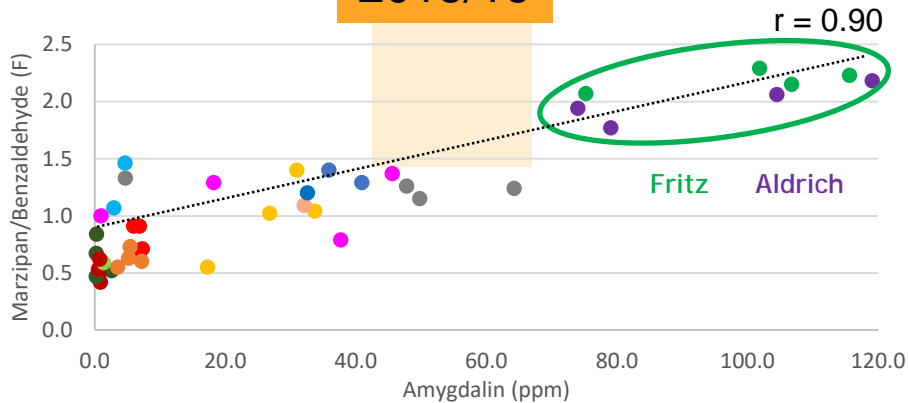
2016/17



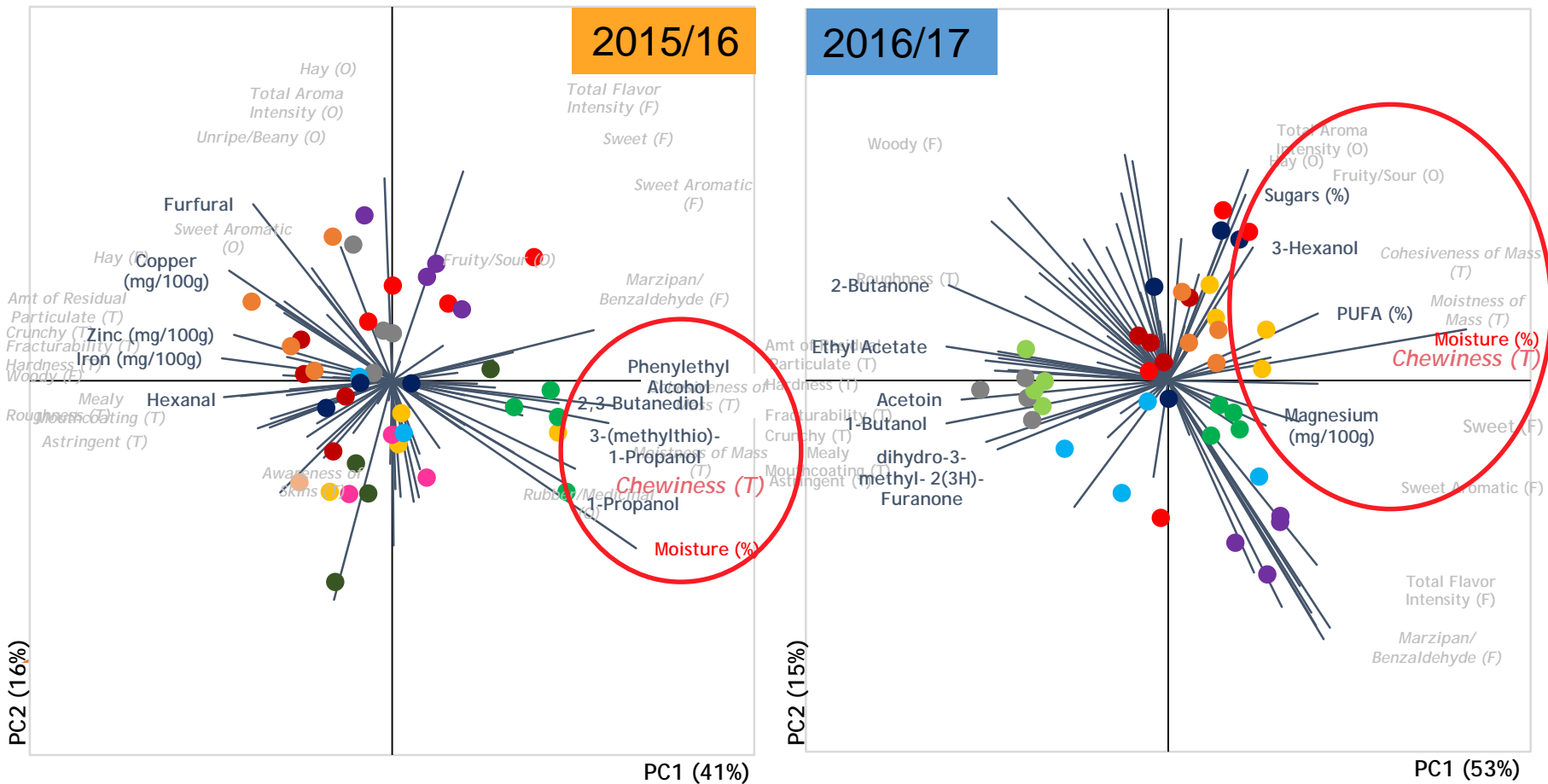
2015/16

Amygdalin

2016/17



Chewiness is driven by the presence of Moisture across the 2 seasons

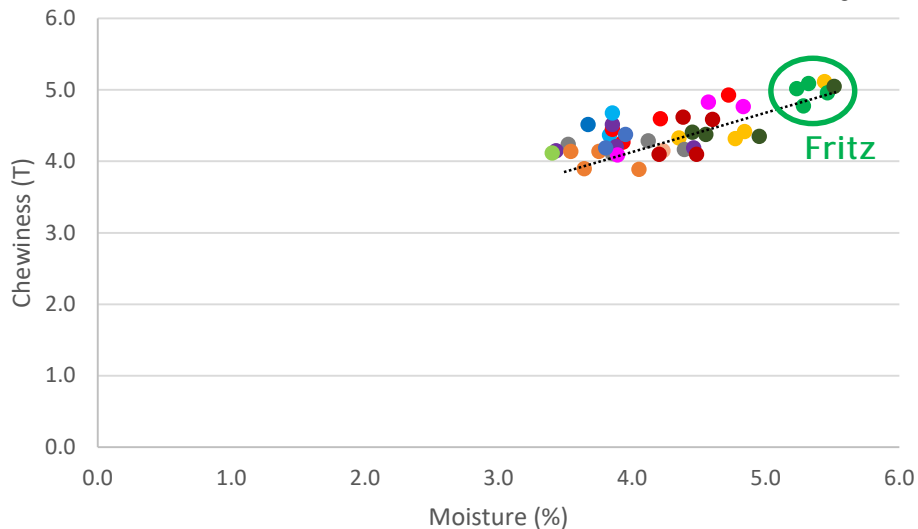


Chewiness is positively correlated with Moisture

2015/16

Moisture (%)

$r = 0.74$



2016/17

$r = 0.87$



Monterey

Nonpareil

Butte

Padre

Wood Colony

Sonora

Independence

Aldrich

Fritz

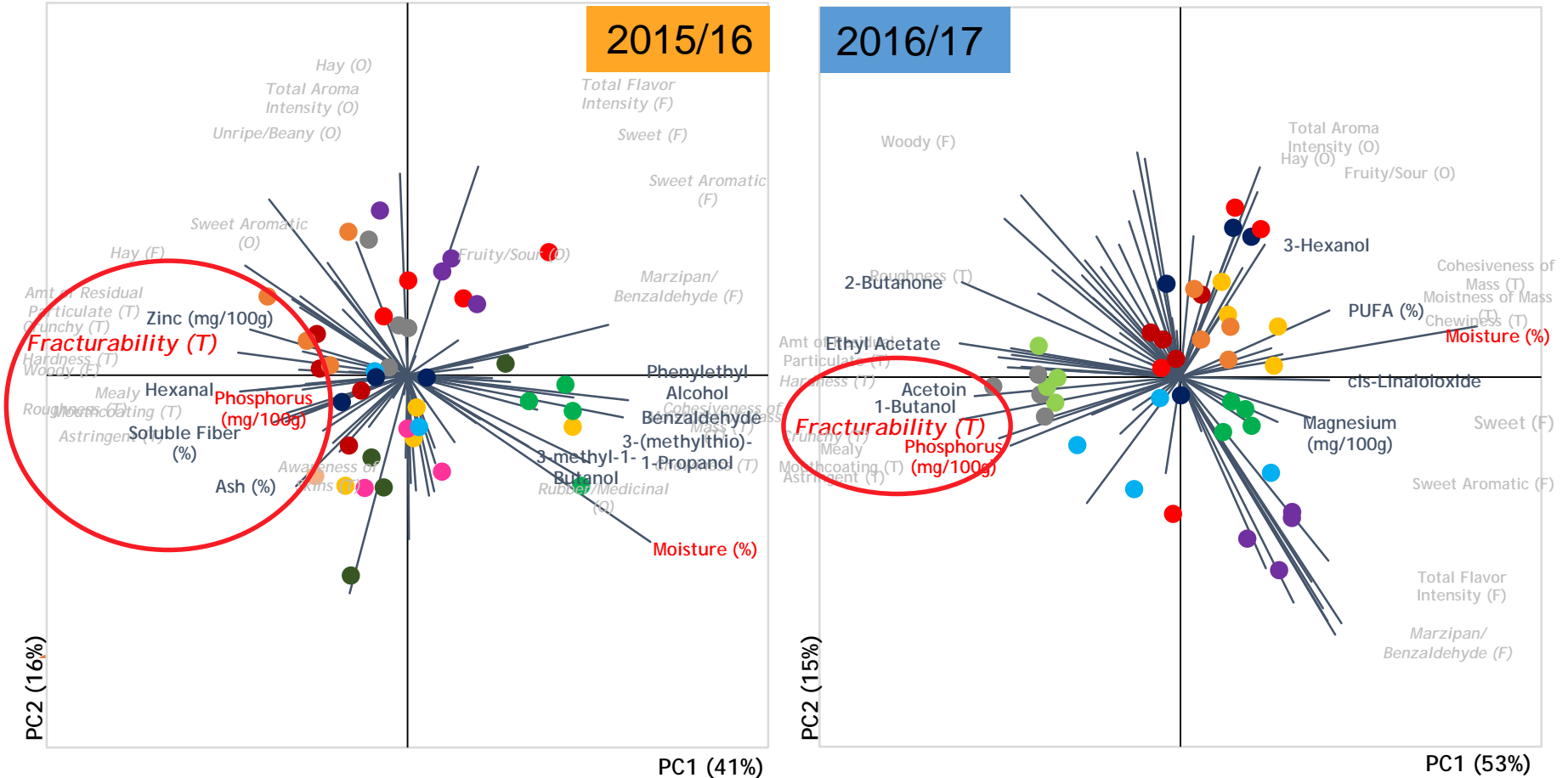
Carmel

Price

Mission

Butte/Padre

Conversely, Fracturability is driven by the absence of Moisture and the presence of Phosphorus across the 2 seasons

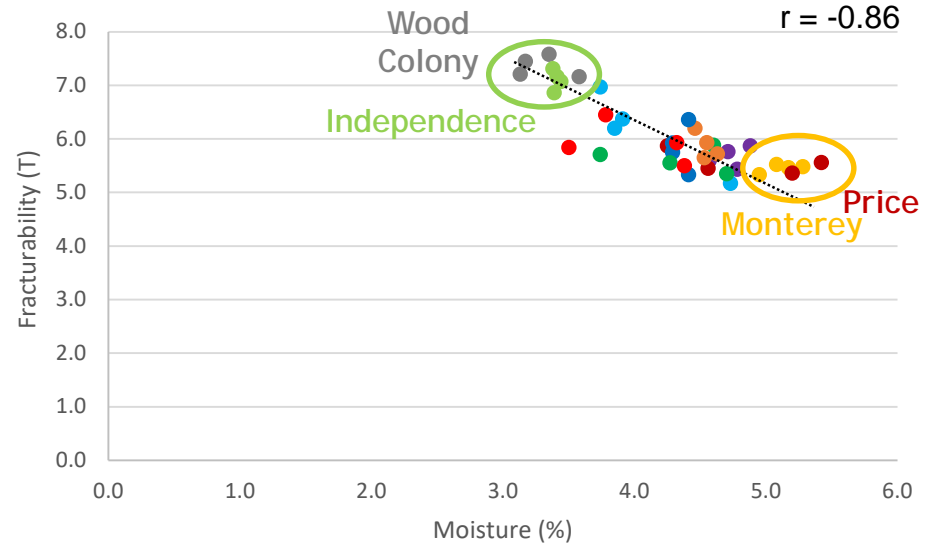
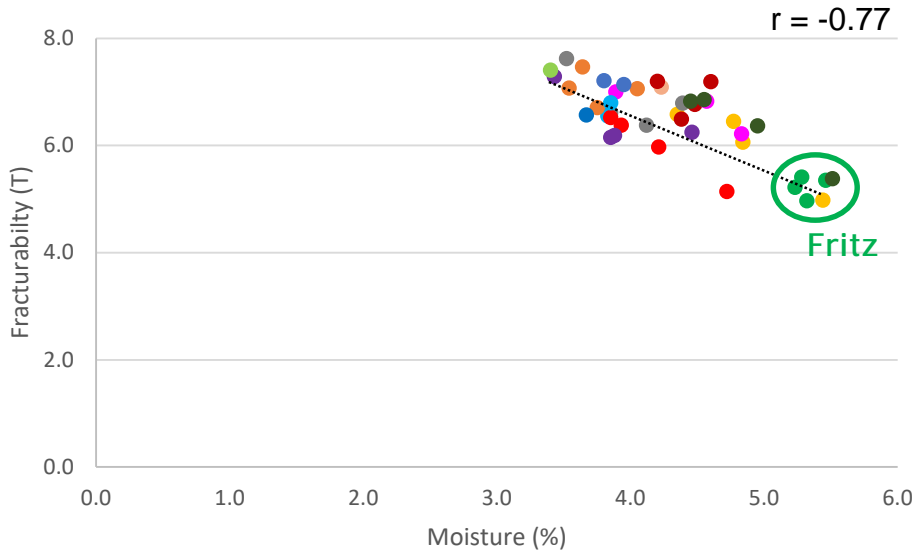


Fracturability is negatively correlated with Moisture

2015/16

Moisture (%)

2016/17



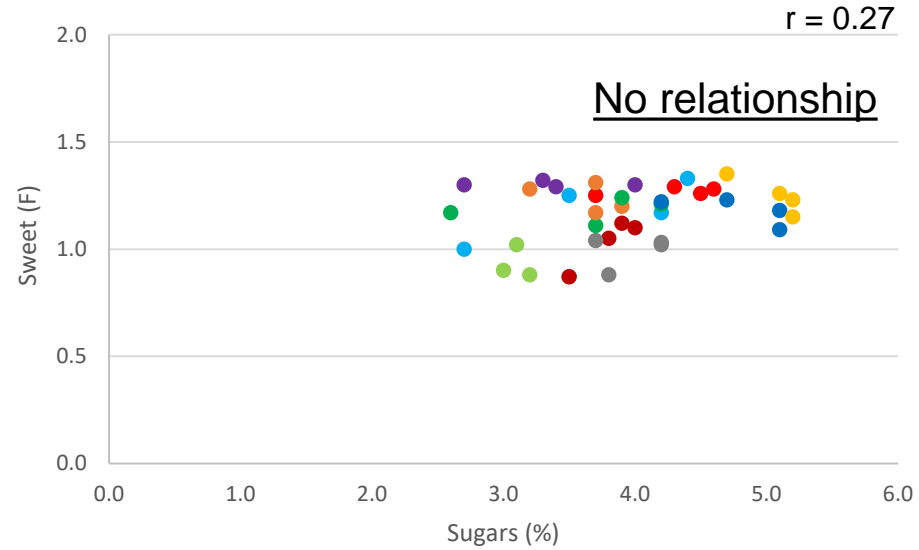
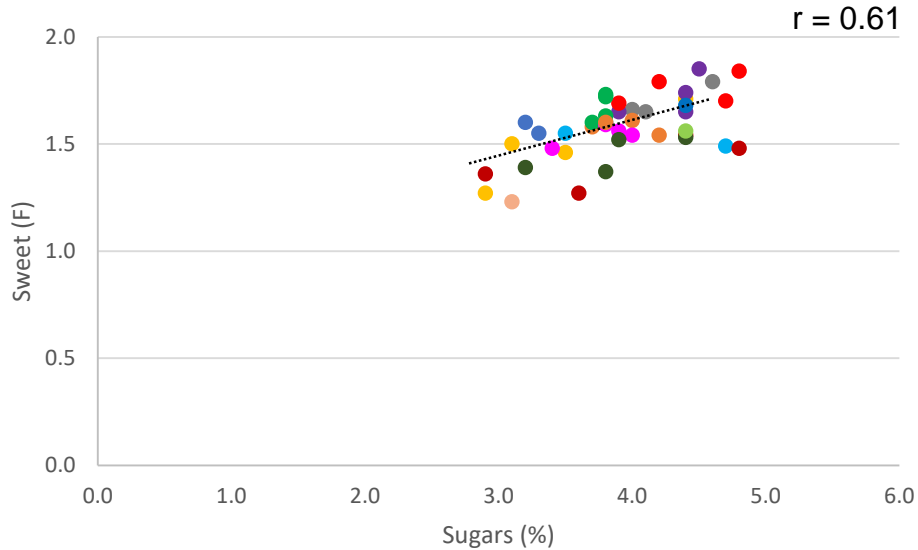
- Monterey
- Nonpareil
- Butte
- Padre
- Wood Colony
- Sonora
- Independence
- Aldrich
- Fritz
- Carmel
- Price
- Mission
- Butte/Padre

Sweetness is positively correlated with Sugars in 2015/16, but shows no relationships in 2016/17

2015/16

Sugars (%)

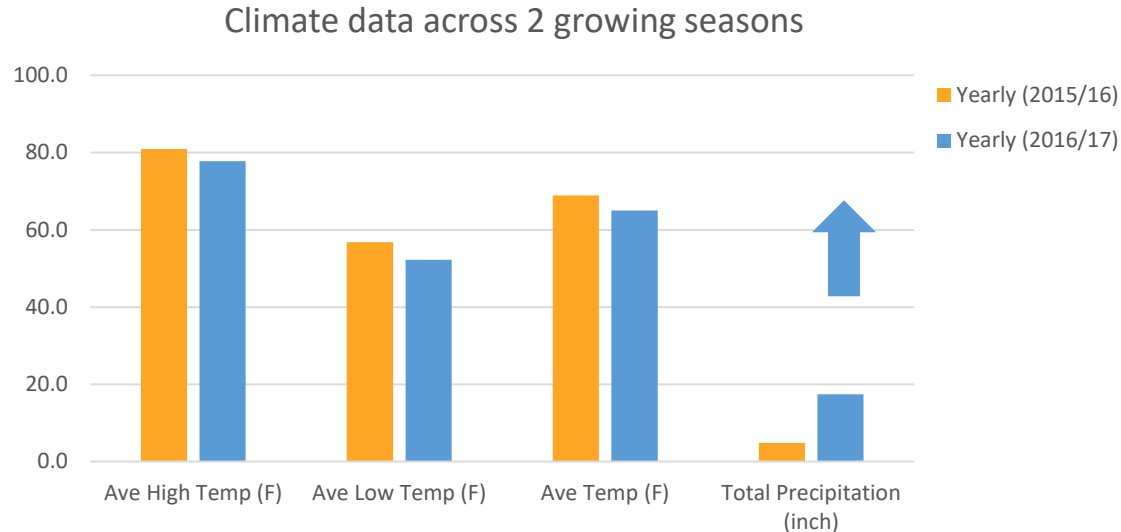
2016/17



- Monterey
- Nonpareil
- Butte
- Padre
- Wood Colony
- Sonora
- Independence
- Aldrich
- Fritz
- Carmel
- Price
- Mission
- Butte/Padre

Climate differences may account for seasonal variation among varieties

- Samples grown in Central Valley, CA
- Temperature was similar across the 2 growing seasons – 2016/17 is slightly colder than 2015/16
- 2016 growing season was much wetter than 2015/16

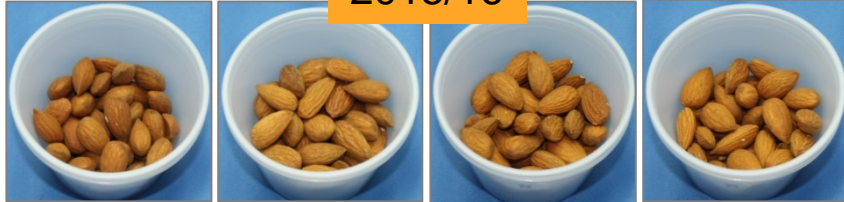




Product Descriptions

Aldrich – high in flavor & marzipan/benzaldehyde, sweeter

2015/16



Aldrich-2699

Aldrich-2703

Aldrich-2751

Aldrich-2763

2016/17



Aldrich-3014

Aldrich-3044

Aldrich-3049

Aldrich-3064

Sensory

Chemistry

2015/16

- ↑ Total Flavor Intensity (F)
- ↑ Marzipan/Benzaldehyde (F)
- ↑ Woody (O)
- ↑ Sweet Aromatic (F)
- ↓ Awareness of Skins (T)

- ↑ Amygdalin
- ↑ Benzyl alcohol
- ↑ Sugars %
- ↑ Ethyl Acetate
- ↑ Acetoin
- ↑ Prenol

2015/16

- ↓ Hexanal
- ↓ Nonanal
- ↓ Manganese
- ↓ 2-butoxy-Ethanol
- ↓ Benzeneacetaldehyde
- ↓ 5-ethylidihydro-2(3H)-Furanone (3H)-Furanon)
- ↓ 2-methoxy-Phenol

2016/17

- ↑ Total Flavor Intensity (F)
- ↑ Marzipan/Benzaldehyde (F)
- ↑ Sweet (F)
- ↓ Diversity of Shape/Size (Ap)
- ↓ Appearance of Ridges/Veins (Ap)
- ↓ Hay (F)
- ↓ Woody (F)
- ↓ Amt of Residual Particulate (T)

- ↑ Amygdalin
- ↑ Benzyl alcohol
- ↑ Toluene
- ↑ Cyclopentanol
- ↑ 2-butoxy-Ethanol
- ↑ Benzaldehyde
- ↑ 2-(methylthio)-Ethanol (methylthio)-Ethano)
- ↑ 1-Octanol
- ↑ Benzeneacetaldehyde
- ↑ 2-methoxy-Phenol
- ↑ Phenylethyl Alcohol

2016/17

- ↓ Hexanal
- ↓ Nonanal
- ↓ Soluble Fiber %
- ↓ Sugars %
- ↓ Potassium
- ↓ 2-Butanone
- ↓ 2-methyl-Butanal
- ↓ Isopropyl Alcohol
- ↓ Ethanol
- ↓ Pentanal
- ↓ 1-Heptanol
- ↓ Furfural
- ↓ [R-(R*, R*), -2,3-Butanediol (R*, R*)]-2,3-Butanediol)

Significant at 95% within each growing season:

- ↑ Has more
- ↓ Has less

Nonpareil – uniform with lighter color and ridges/veins, sweeter

2015/16



Nonpareil-2727 Nonpareil-2731 Nonpareil-2735 Nonpareil-2739

2016/17



Nonpareil-3035 Nonpareil-3099 Nonpareil-3101 Nonpareil-3104

Sensory

- ↑ Appearance of Ridges/ Veins (Ap)
- ↑ Diversity of Color (Ap)
- ↑ Sweet (F)
- ↑ Fruity/Sour (O)
- ↑ Hay (O)
- ↑ Unripe/Beany (O)
- ↓ Average Darkness of Color (Ap)
- ↓ Roughness (T)
- ↓ Astringent (T)

- ↑ Appearance of Ridges/ Veins (Ap)
- ↑ Diversity of Color (Ap)
- ↑ Sweet (F)
- ↑ Cohesiveness of Mass (T)

2015/16

2016/17

Significant at 95% within each growing season:

↑ Has more
↓ Has less

Chemistry

- ↑ Sugars %
- ↑ MUFA %
- ↑ 2-butoxy-Ethanol

2015/16

- ↓ Phosphorus
- ↓ 3-methyl-2-Butenal
- ↓ Dietary Fiber %
- ↓ Insoluble Fiber %
- ↓ Ash %
- ↓ Manganese
- ↓ Toluene
- ↓ Nonanal
- ↓ 1-Octanol
- ↓ Benzeneacetaldehyde
- ↓ 5-ethylidihydro-2(3H)-Furanone (3H)-Furanon

- ↑ Dietary Fiber %
- ↑ 2-methyl-3-Pentanol
- ↑ cis-Linaloloxide

2016/17

- ↓ Phosphorus
- ↓ 3-methyl-2-Butenal
- ↓ Isopropyl Alcohol
- ↓ 2-Butanol
- ↓ 1-Butanol
- ↓ Benzyl alcohol



Key Findings

Key Findings – Varietal Sensory Profiles

More consistent sensory profiles across seasons:

- **Aldrich** – high in flavor & marzipan/benzaldehyde, sweeter
- **Fritz** – darker, moist, chewy & marzipan/benzaldehyde
- **Wood Colony** – hard, fracturable, crunchy & astringent
- **Independence** – ridges/veins, hard, rough & fracturable
- **Sonora** – larger & lighter-colored, sweet & hay aromas, crunchy
- **Butte** (2015/16) – low aroma & flavor
- **Price** – intermediate sensory profile
- **Mission** (2015/16) – intermediate sensory profile

Higher variability in sensory profiles among samples/ across seasons:

- **Monterey** – high in moistness, roughness, & chewiness
- **Carmel** – woody & marzipan/benzaldehyde flavors, toothpacking
- **Butte/Padre** – smaller with fruity/sour aroma
- **Nonpareil** – uniform with lighter color and ridges/veins, sweeter
- **Padre** (2015/16) – intermediate sensory profile



- Sensory & chemical differences between almond **varieties are greater than** variation among **replicates/ samples**
- There is **high seasonal variation** within variety, seen both in the chemical and sensory data
 - **Flavors** tend to be **more variable** across seasons, whereas **textures** are **more consistent**
 - Climate differences may account for seasonal variation among varieties – **2016/17 was a wetter season than 2015/16**
- Key differences in the sensory profile of the 13 raw almond varieties are found in **texture – hardness/fracturability/crunchy vs. moistness of mass/chewiness/cohesiveness of mass**
 - Appears to be driven by **moisture content**
 - Almond samples are further differentiated by flavor – **hay/woody vs. marzipan/benzaldehyde**
 - The perception of marzipan/benzaldehyde is highly correlated to **amygdalin** and **benzaldehyde**

Contributors



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Thank you!



Understanding the Chemistry and Aroma of California Almonds

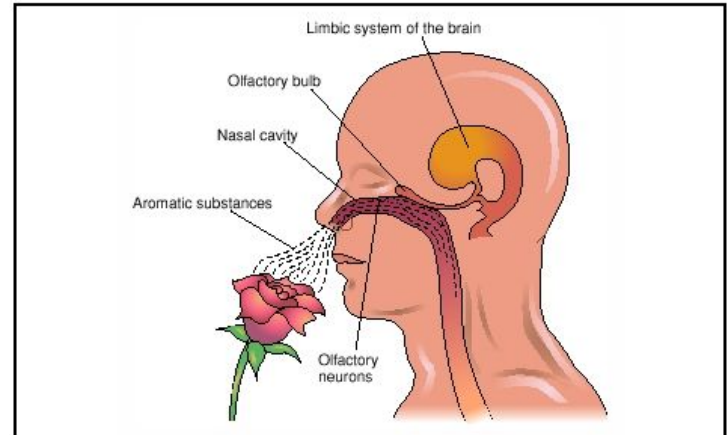
Alyson Mitchell PhD
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University of California Davis
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The Almond Conference
Sacramento CA Dec 5-7th

Flavor

- Flavor is the sensory impression of a food
- Composite quality involving the sensations of aroma, taste, chemical irritation, as well as temperature, texture and sound
- Taste: Humans can distinguish 5 basic flavors
 - Sweet, sour, salty, bitter, and savory (umami)
 - Reactions with taste receptors on the tongue
- Aroma: Involves the interaction of **volatile molecules** with olfactory receptor neurons located in the nasal passageways



Raw Almond Flavor

- Taste
- Aroma



Raw Almond Taste

Fat, protein, sugars and starch

- Fat creates a rich taste, and lack of acid enhances sweetness of the sugar in raw almonds
- Fats, protein and sugars are similar in CA almond varieties
- Contribution to taste will be similar in all varieties

Bitterness

- Bitterness is derived from **amygdalin**
- Almonds can be classified based upon their level of bitterness

Astringency

Derived from tannins located in the skin

- 2.1 mg/g skin
- isorhamnetin-3-O-rutinoside, catechin, epicatechin, kaempferol-3-O-rutinoside etc.,
 - Bolling et al., J. Food Science 2009



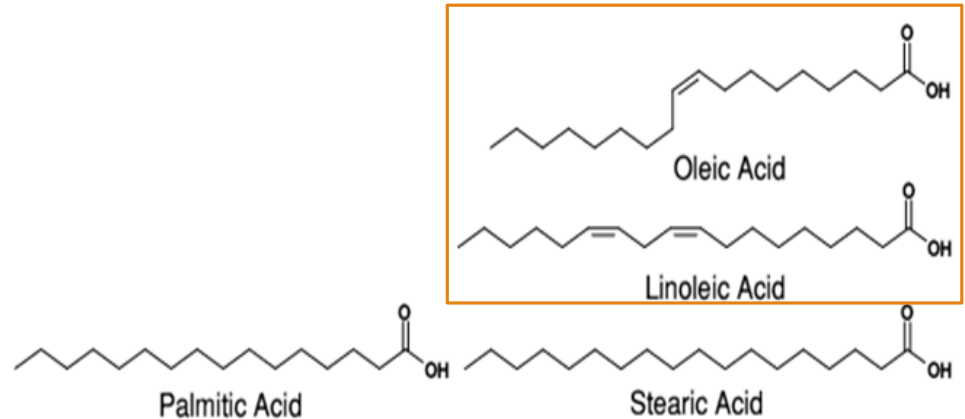
Macronutrient	Range in CA-grown almonds (% g/g almond)
Lipids	44.7-54.1
Protein	18.5-24.0
Sugars	7.9-16.0
Fiber	9.4-15.1

Lipid Composition of Almonds

- The primary fatty acids in almonds are “*Heathy fats*”
 - Unsaturated fats
- Oleic (18:1, 62–80%) and linoleic acid (18:2, 10–18%)
- Create a rich taste in almonds, carry volatile aroma compounds
- When oxidized create off odors



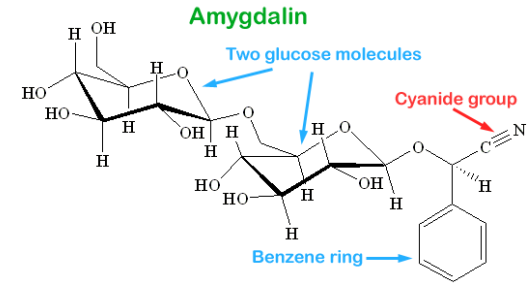
Name	Number of Carbons:Double bonds	Percent in Almond Oil
Oleic	18:1	60-80%
Linoleic	18:2	10-18%
Palmitic	16:0	0.5-8%
Stearic	18:0	1-3%



Almond Bitterness (Phenotypes)

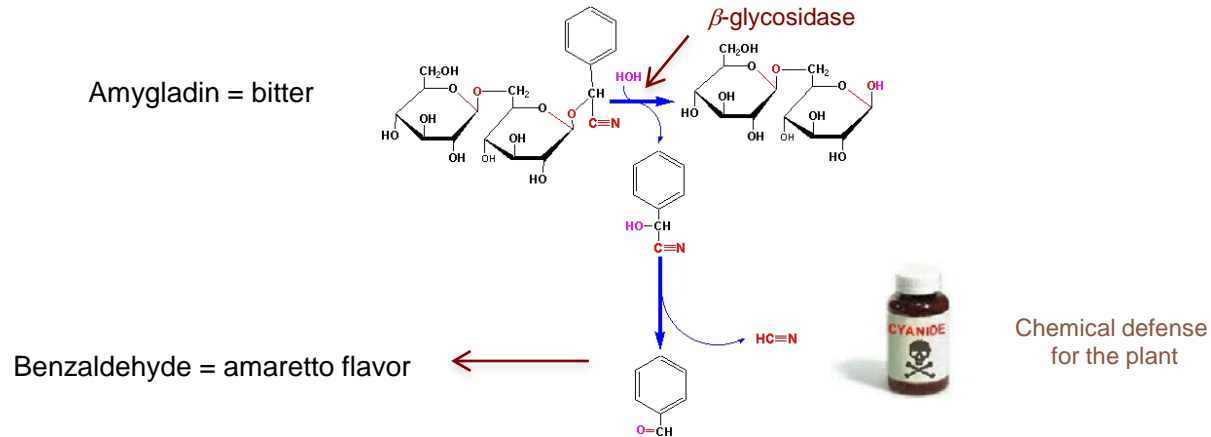


- Non-bitter (Sweet)
 - Sweet snacking almonds (creamy nutty flavor)
- Semi-bitter
 - Often used in processing for their “marzipan-like taste”
- Bitter
 - Middle East and Asia
 - Oils and flavorings
 - Contain amygdalin (3-5%) and develop a cyanide aroma when moistened (chewed)
 - Can be toxic



Amygdalin

- A diglycoside (2 sugars attached)
- The disruption of almond tissue (e.g. chewing) enables amygdalin to come into contact with enzymes (*β*-glycosidase) and form benzaldehyde and trace levels of HCN



Amygdalin in California Almonds

- Developed a sensitive method (UHPLC (ESI)-MS/MS) to measure amygdalin in almonds
 - Understand levels in CA varieties and breeding stocks
- Commercial non-bitter (sweet) varieties
 - Average amygdalin content 63.13 ± 57.54 mg/kg
- Semi-bitter (UCD)
 - Average amygdalin 992.24 ± 513.04 mg/Kg
- Bitter (UCD)
 - Average amygdalin $40,060.34 \pm 7,855.26$ mg/kg
- *Additional applications alcoholic bitters*
- *USDA recall of almonds*



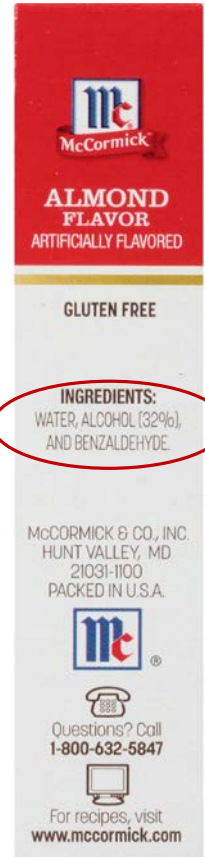
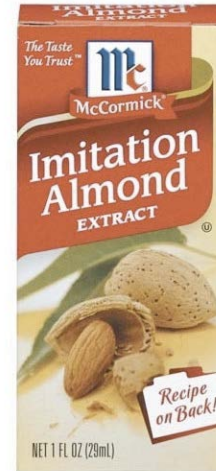
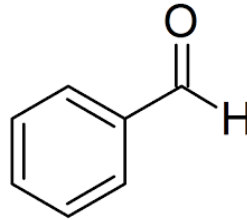
Amygdalin in California Almond Varieties



Flavor	Variety	Amygdalin (mg/kg)				Mean Concentration
		Growing Region				
Non-bitter		Colusa	Fresno	Kern	Stanislaus	
	Butte	3.47 ± 0.17*	0.85 ± 0.65			2.16 ± 1.25
	Price	7.49 ± 0.06 d	2.49 ± 0.30 b	1.43 ± 0.05 a	5.85 ± 0.38 c	4.32 ± 2.45
	Sonora	1.83 ± 0.18 a	7.08 ± 1.26 b	5.17 ± 0.51 b	16.95 ± 0.37 c	7.76 ± 6.04
	Nonpareil	7.05 ± 0.56 a	12.92 ± 0.57 b		16.72 ± 1.26 c	12.23 ± 4.41
	Monterey	108.75 ± 1.20 c	44.87 ± 1.12 a	62.17 ± 6.55 b	34.08 ± 10.13 a	62.47 ± 27.19
	Wood Colony	78.25 ± 8.70 c	81.20 ± 3.71 c	63.68 ± 1.22 a	76.99 ± 1.46 ab	75.03 ± 8.07
	Carmel	75.04 ± 5.89 ab	94.72 ± 5.32 b	74.19 ± 19.52 ab	63.94 ± 5.06 a	76.97 ± 15.22
	Mission	72.47 ± 8.84 a	138.11 ± 6.06 b	68.75 ± 26.97 a	79.07 ± 6.11 a	89.60 ± 32.34
	Fritz	133.62 ± 8.37 a	130.05 ± 3.38 a	114.91 ± 16.67 a	200.90 ± 28.82 b	144.87 ± 36.44
	Aldrich	90.06 ± 5.01 a	214.87 ± 11.65 c	194.49 ± 1.55 c	130.34 ± 19.25 b	157.44 ± 54.01
All Varieties						63.13 ± 57.54

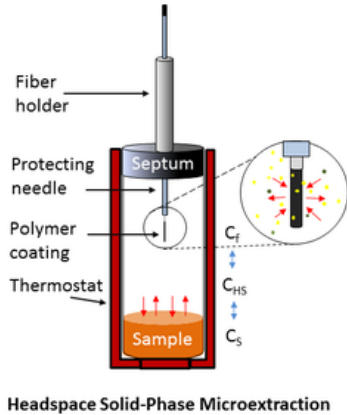
Raw Almond Aroma

- Volatile molecules are responsible for the aroma of almonds
- The predominant almond aroma compound is **benzaldehyde**
 - Cherry, almond flavor
 - Artificial almond aroma
- Comes from the breakdown of **amygdalin**



Measuring Volatile Aroma Compounds in Almonds

HS-SPME GC/MS

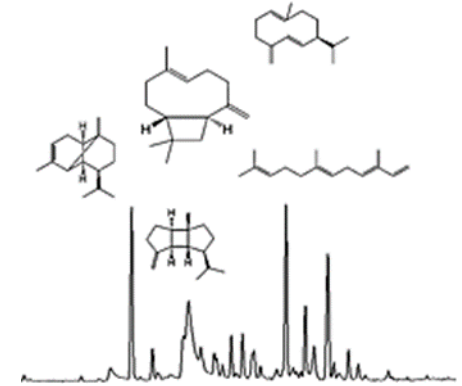


5 g sample is placed in a 20-mL SPME vial



Gas Chromatography

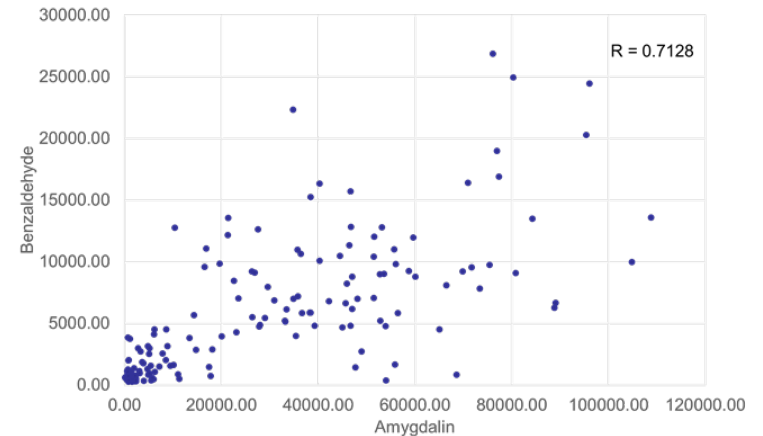
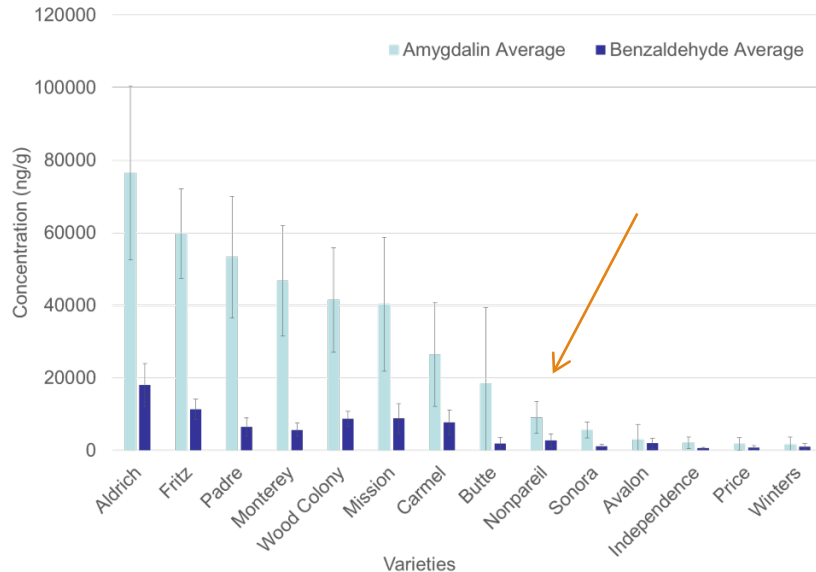
Samples are agitated at 500 rpm and pre-equilibrated at 40°C for 45 min, after which they were extracted with a 1 cm 30/50um StableFlex DVB/CAR/PDMS fiber exposed for 45 mins at 250 RPM



Chromatogram

Amygdalin and Benzaldehyde in California Almonds

- Strong correlation between amygdalin levels and benzaldehyde levels



Benzaldehyde Flavor and Variety

- Benzaldehyde ranges between 0.587-17.995 mg/kg in commercial almonds

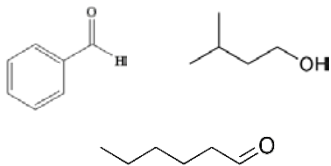
Variety	Classification type	Average amygdalin (mg/kg)	Average benzaldehyde (mg/kg)
Aldrich	California	76.50 ± 23.99 a	17.995 ± 5886.7 a
Fritz	California, Mission	59.71 ± 12.37 ab	11.315 ± 2795.5 b
Padre	California, Mission	53.24 ± 16.74 bc	8.806.8 ± 4101.5 bc
Monterey	California	46.76 ± 15.21 bc	8.654.3 ± 2137.3 bc
Wood Colony	California	41.49 ± 14.41 bcd	7.703.4 ± 3394.5 bc
Mission	Mission	40.24 ± 18.40 cd	6.489 ± 2503.4 cd
Carmel	California	26.42 ± 14.30 de	5.656.9 ± 1845.3 cde
Butte	California	18.56 ± 20.77 ef	2.768.3 ± 1783.2 def
Nonpareil	Nonpareil	9.11 ± 4.42 ef	1.939.5 ± 1318.9 ef
Sonora	California	5.56 ± 2.20 f	1.936.4 ± 1602.1 ef
Avalon		3.00 ± 4.17 f	1.179.6 ± 488.1 f
Independence		2.07 ± 1.66 f	1.062 ± 871.4 f
Winters	California	1.62 ± 2.10 f	0.730.6 ± 633.3 f
Price	California	1.77 ± 1.74 f	0.587.7 ± 272.9 f

Raw Almond Aroma

Literature review

- Volatile compounds identified in raw almonds and reported in 2+ studies
- Benzaldehyde, benzyl alcohol and **hexanal** are the most widely detected volatiles in raw almonds
- Other key volatiles include: pentanol, hexanol, 2-phenylethanol, 3-methyl-1-butanol, 3-methyl-2-buten-1-ol, and **nonenal**

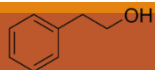
Type	Compound	Aroma ^a	Source ^b
Alcohol	1,2-propanediol	nd	2, 3
	1-butanol	medicine, fruit, wine	2, 3, 4
	1-heptanol	herb	2, 7
	1-hexanol	resin, flower, green	1, 2, 3, 7, 4
	1-Nonanol	aldehydic, waxy, citrus	7, 3
	1-octanol	chemical, metal, burnt	2, 3, 7, 4
	1-pentanol	fruity	1, 2, 3, 5, 6
	2-ethyl-1-hexanol	sweet, floral, oily	1, 3,
	2-heptanone	cheesy, banana, fruity	1, 2
	2-methyl-1-propanol	wine, whisky	2, 3, 7
	Benzyl alcohol	floral, phenolic	1, 3, 4, 5, 6, 7
	2-phenylethanol	floral, hyacinth/gardenia	5, 7, 6, 1, 3
	3-methyl-butanol	malt	2, 3, 7
	3-methyl-2-Butenol	fruity, alcoholic, green	5, 7, 6, 3
3-Methyl-3-Butenol	nd	3, 5, 6	
Pyrazine	2-Methylpyrazine	roasted	1, 4
Acids	Acetic acid	sour	8, 3
	hexanoic acid	sweaty, rancid	2, 3
Terpenes	alpha-pinene	piny	7, 2
	limonene	orange peel	2, 7
Aldehydes	Benzaldehyde	sweet, marzipan	1, 3, 2, 7, 5, 6, 4
	heptanal	ranid, pungent	1, 2, 7, 4
	Hexanal	green fatty aldehydic grass	1, 8, 2, 3, 5, 7, 6
	Nonanal	soapy, fatty, rancid	8, 2, 3, 7, 4
	Octanal	soapy, fatty, rancid	8, 2, 7
	pentanal	almond, malt, pungent	1, 2
Lactone	butyrolactonec	creamy, oily, fatty	2, 3
Alkane	Toluene	painty	4, 7, 5, 6
Sulfur-containing	Methional	cooked potato	8, 4



Raw Almond Aroma & Variety 2017

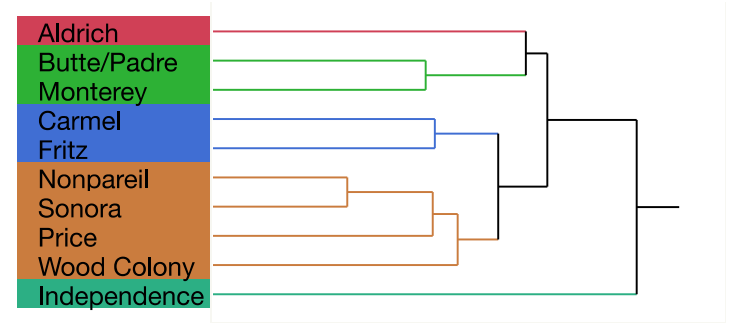
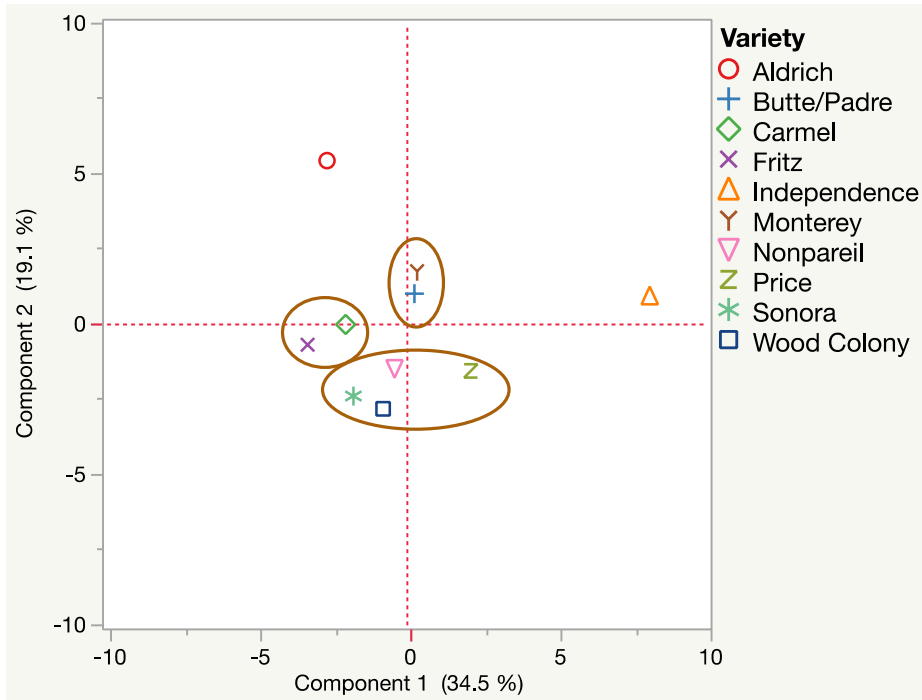


Volatile Aroma	Characteristics	Aldrich	Fritz	Carmel	Monterey	Butte/Padre	Wood Colony	Nonpareil	Sonora	Price	Independence
		ug/kg									
2-methyl-2-butenal	Pungent green ethereal sharp nutty	163.2 ± 73.91	155.19 ± 83.44	70.27 ± 22.82	118.7 ± 26.03	145.67 ± 57.79	84.05 ± 8.7	88.76 ± 31.6	105.87 ± 10.57	114.74 ± 19.35	64.08 ± 8.73
3-methyl-2-butenal	Sweet fruity pungent brown nutty almond cherry	93.54 ± 61.85	166.48 ± 86.96	81.2 ± 24.67	118.67 ± 25.92	152.52 ± 59.24	85.87 ± 9.31	88.77 ± 31.6	105.91 ± 10.63	113.7 ± 18.81	81.03 ± 9.74
3-methylbutanal	Alcoholic, fruity, whiskey, banana	20.72 ± 2.62	21.57 ± 4.29	22.29 ± 3.48	26.91 ± 4.09	48.28 ± 6.89	27.94 ± 2.4	36.57 ± 8.68	28.49 ± 4.83	31.1 ± 5.27	29.82 ± 8.82
Acetoin	buttery, creamy-fatty	199.87 ± 30.02	67.4 ± 10.51	69.25 ± 11.35	132.21 ± 43.39	97.59 ± 24.59	381.83 ± 109.72	163.66 ± 47.27	197.94 ± 85.08	120.21 ± 16.94	270.29 ± 101.38
Benzaldehyde	Almond, sweet, marzipan	34506.1 ± 8774.15	16427.9 ± 2412.43	14376.16 ± 3690.11	9193.43 ± 1000.88	6656.89 ± 1520.41	8575.98 ± 837.29	2847.85 ± 340.79	2265.31 ± 979.56	720.66 ± 720.37	714.19 ± 736.06
Benzeneacetaldehyde	Green sweet floral hyacinth clover honey cocoa	65.29 ± 12.38	36.63 ± 5.67	26.82 ± 5.26	42.81 ± 7.07	57.29 ± 8.42	27.27 ± 3.67	36.84 ± 6.22	20.93 ± 0.61	32.39 ± 5.14	43.57 ± 3.8
Ethyl Acetate	Ethereal fruity sweet	31.47 ± 6.96	31.76 ± 12.15	28.56 ± 13.67	62.66 ± 36.31	34.28 ± 9.06	85.62 ± 27.25	43.1 ± 14.02	22.52 ± 7.39	47.84 ± 26.45	125.31 ± 67.42
Furfural	Sweet woody almond fragrant baked bread	36.26 ± 17.61	54.59 ± 31.01	40.46 ± 12.82	71.58 ± 22.61	134.93 ± 46	30.91 ± 14.32	67.15 ± 27.04	86.75 ± 9	39.74 ± 33.22	55.45 ± 4.83
Hexanal	Fresh green fatty aldehydic grass leafy fruity sweaty	37.21 ± 3.56	40.21 ± 6.48	45.67 ± 8.5	52.51 ± 2.59	74.08 ± 9.27	60.77 ± 2.19	71.66 ± 5.86	68.48 ± 15.18	106.32 ± 14.54	103.33 ± 11.86
2,3-Butanediol	Fruity creamy buttery	618.11 ± 104.18	779.46 ± 65.2	409.68 ± 105.82	651.49 ± 138.11	777.91 ± 151.21	635.17 ± 42.41	712.27 ± 167.41	536.06 ± 79.92	807 ± 49.74	2508.47 ± 340.93
1-butanol	Sweet apricot	39.22 ± 5.53	47.48 ± 6.07	49.24 ± 8.03	32.43 ± 6.78	42.69 ± 3.78	60.23 ± 11.09	37.14 ± 7.66	37.93 ± 8.07	42.15 ± 10.06	53.17 ± 3.11
2,3-Butanediol	Fruity creamy buttery	173.18 ± 23.89	255.23 ± 24.3	95.57 ± 22.48	216.02 ± 34.42	182.9 ± 30.59		202.73 ± 44.41	147.19 ± 19.47	245 ± 17.37	803.65 ± 67.64
3-methyl-1-butanol	Fusel oil alcoholic whiskey fruity banana	601.04 ± 140.64	1135.28 ± 154.66	505.52 ± 136.05	2799.3 ± 506.02	711.6 ± 118.24	328.05 ± 11.41	914.48 ± 358.21	518.6 ± 43.56	848.02 ± 136.02	2221.38 ± 763.22
Benzyl alcohol	Floral rose phenolic balsamic	676.91 ± 101.07	231.59 ± 139.95	260.91 ± 151.55	215.97 ± 82.24	143.94 ± 35.63	146.69 ± 86.51	68.27 ± 33.19	24.71 ± 5.63	44.83 ± 17.39	134.27 ± 5.16



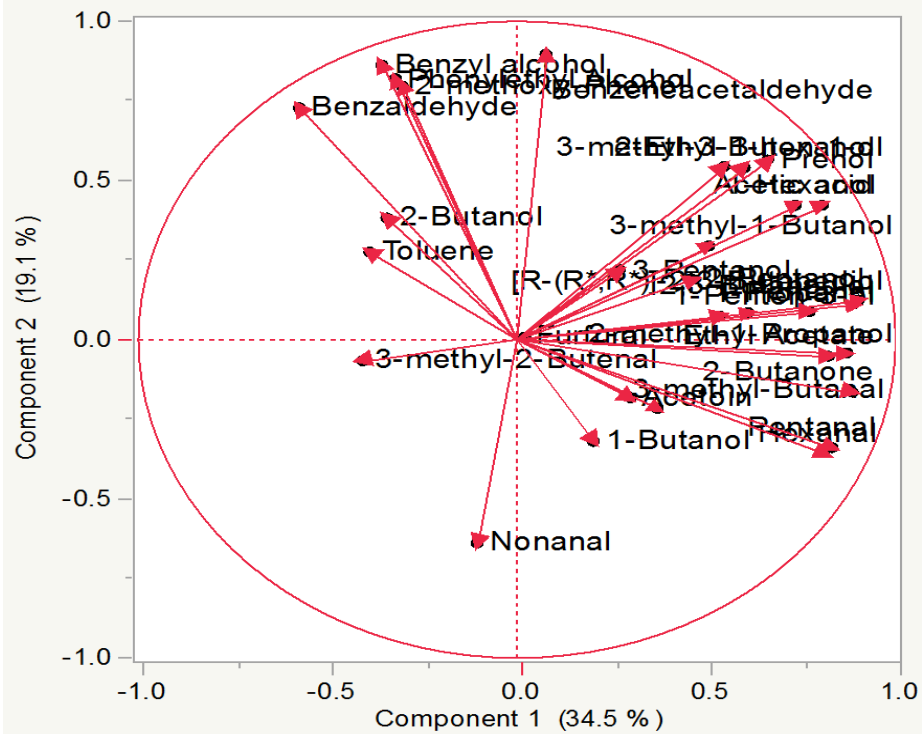
Principal Component Analysis (PCA)

Scores Plot



- *Based upon the PCA analysis of 52 volatiles in CA almond samples*

Benzaldehyde
 Benzyl alcohol
 Benzene acetaldehyde



3-methyl- 1-butanol
 Butanol
 3—methyl- butanal

Conclusions



- Amygdalin levels correlate with benzaldehyde and are highest in Aldrich and Fritz and lowest in Independence (2016)
- Analysis of volatiles in 3 month old Aldrich, Butte/Padre, Carmel, Independence, Monterey, Nonpareil, Price, Sonora, Wood Colony, Fritz
 - Aldrich has significantly higher levels of levels of benzaldehyde than other varieties and that and Independence has the lowest
- PCA Analysis:
 - Aldrich have the highest levels of volatiles related to almond flavor whereas Independence has more compounds related to creamy, buttery, fruit flavor
 - Cluster analysis indicate that Butte/Padre and Fritz/Carmel are more similar to each other than other varieties and that Nonpareil, Price, Sonora, Wood Colony are similar to each other
 - **Posters: Wednesday 3:00-5:00 PM**
 - Larry Lerno: Volatile Profiling of Raw Almonds #29
 - Kathleen Luo: Chemical Markers Measuring Quality of Moisture Exposed Almonds, #26
 - Kara Nguyen: Nondestructive Classification of Bitterness in Almonds, #28
 - Sean McKeown: In-hull Moisture Content using Microwaves. #27

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- Blue Diamond Almonds
 - W. Scott Moore
 - Brian Dunning
- Agilent Technologies
 - Phil Wylie, PhD



Thank you!



What's Next

Thursday, December 7 at 1:50 p.m.

- Maximizing Shelf Life – Room 314
- European's Appetite for Almonds Endures and Grows – Room 306-307
- What's New in Almond Tree Nutrition and Regulation? – Room 308-309
- Research Update: Irrigation and Harvest – Room 312-313

What's Next

Wednesday, December 6 at 12:00 p.m.

- Luncheon Presentation – Hall C

The Future of Agriculture: Innovation, Ingenuity, Perseverance

Speaker: Steve Forbes

Luncheon is ticketed and is sponsored by Yosemite Farm Credit

