Characteristics of California Almonds

December 8, 2015

growing ADVANTAGE The Almond Conference

Speakers

Van Soetaert, Vice Chair of AQFSC
Almond Board (Moderator)

Alyson Mitchell, UC Davis

Dawn Chapman & Ellie King, The National Food Laboratory

Zata Vickers, University of Minnesota

Van Soetaert, Vice Chair of AQFSC Almond Board

Alyson Mitchell,
University of California, Davis

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The Chemistry of Almond Flavor

Alyson Mitchell PhD,
Food Science Department,
University of California Davis

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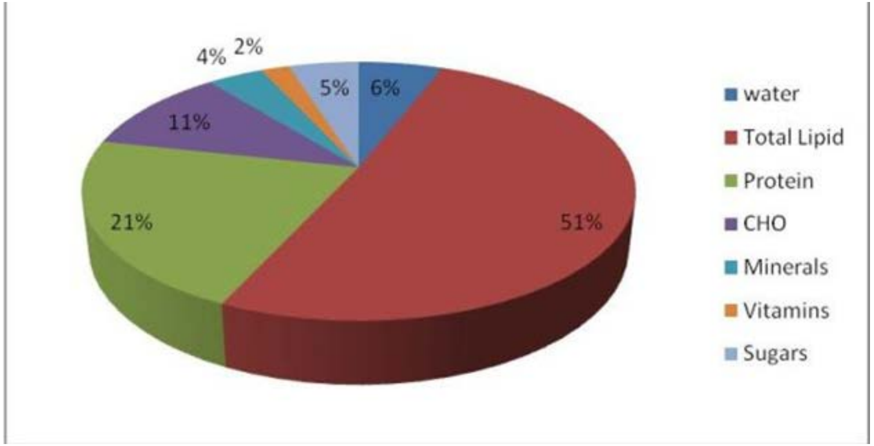
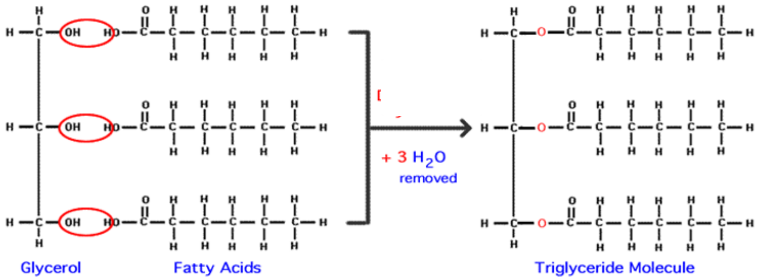
What is an Almond?

- An almond (Prunus dulcis), botanically, is the seed (fruit) of a drupe
  - Not a true nut
  - A member of the rose family and is related to peaches, plums, apricots and cherries
  - Native to the Middle East and South Asia
- Consumed since the Early Bronze Age (3000-2000 BCE)
- Convenient, dense source of energy that naturally stores well
  - Consumption is associated with a reduced risk of CVD

Almond Composition



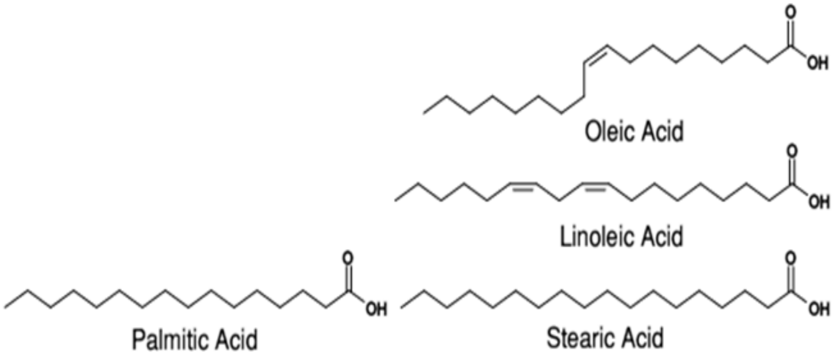
- Almonds are composed of:
  - Fat (~51-60%)
  - Protein (~21%)
  - Carbohydrate (11%)
  - Varies depending upon the cultivar
- Almond fat is composed of triglycerides
  - A triglyceride is 3 fatty acid molecules attached to a molecule of glycerol



Lipid Composition of Almonds

- Fatty acids can be saturated (no double bonds) or unsaturated (double bonds)
- The primary fatty acids in almonds are:

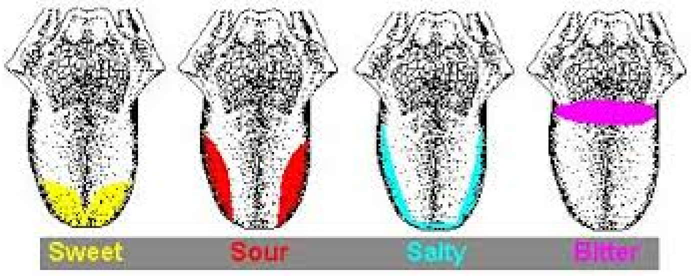
Name	Number of Carbons:Double bonds	Percent in Almond Oil
Oleic	18:1	60-75%
Linoleic	18:2	19-30%
Palmitic	16:0	0.5-8%
Stearic	18:0	1-3%

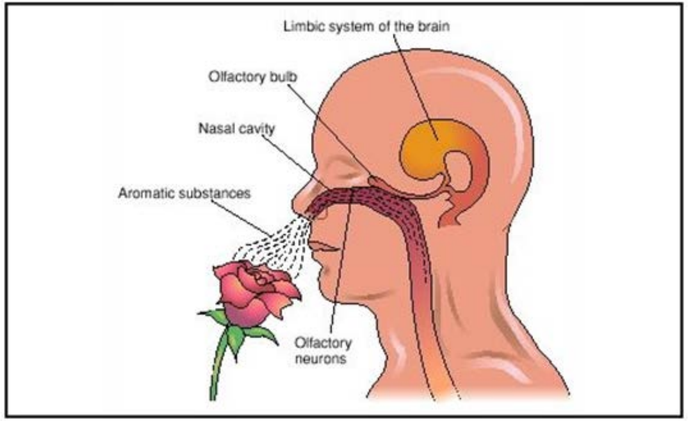


- *"Heathy fats" – primarily unsaturated*

What is Flavor?

- Flavor is a composite quality:
- A combination of sensations from taste buds in the mouth and odor receptors in the nose
  - – Taste: The human tongue can distinguish 5 basic flavors: sweet, sour, salty, bitter, and savory
  - – Aroma: hundreds of aroma molecules
- Taste is also influenced by:
  - – Chemical irritation: peppers, burning, etc.
  - – Temperature sensation



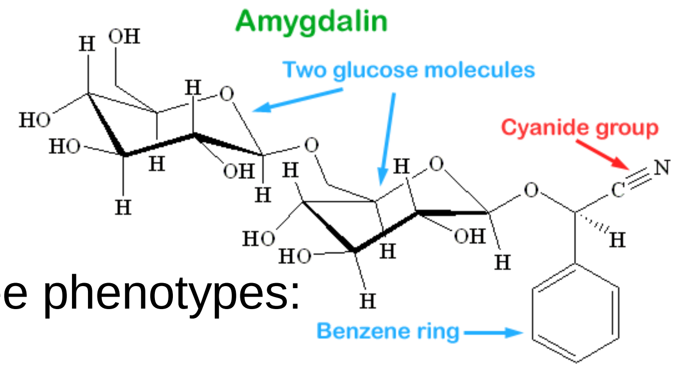


Raw Almond Taste

- Almonds are composed mainly of fat, protein, sugars and fiber
  - Primary drivers of almond *taste*
- A bitter compound called amygdalin and astringent tannins (skin)
  - Sweet almonds varieties contain very low levels of amygdalin
- Fat creates a rich taste, and lack of acid enhances sweetness of starch and sugar in almonds

Macronutrient	Range in CA-grown almonds (% g/g almond)
Lipids	35-66
Protein	16-23
Sugars	2.1-7.4
Fiber	11-14

Almond Taste & Bitterness



- Raw almonds are subjectively characterized into three phenotypes:
- Non-bitter
  - Sweet snacking almonds (nutty flavor)
- Semi-bitter
  - Often used in processing for their “marzipan-like taste”
- Bitter
  - Determined by the content of the cyanogenic glycoside amygladin
  - Bitter almonds contain 3-5% amygdalin and develop a cyanide aroma when moist

Characterizing Amygdalin Levels in California Almonds

- Non-bitter (10 commercial CA varieties)
  - 2.16-157.44 ppm
- Semi-bitter (4 varieties)
  - 523.50-1,772.75 ppm
- Bitter (6 varieties)
  - 33,006.60-53,998.30 ppm

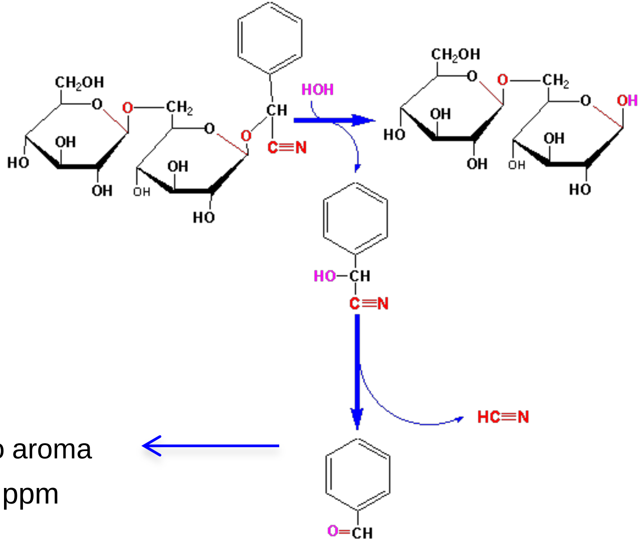
We can now use amygladin levels to distinguish almond classification

Lee et al., J. Ag. Food Chem., 2013, 61, 7754-59

Amygdalin & Benzaldehyde

- Benzaldehyde is generated by the disruption of almond tissue (e.g. chewing) which enables the amygdalin to come into contact with hydrolytic enzymes to form hydrogen cyanide and benzaldehyde

Amygladin = bitter



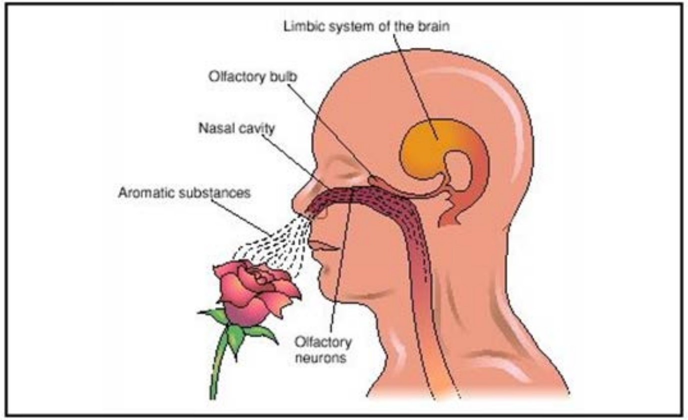
Benzaldehyde = amaretto aroma

Odor Threshold = 0.5 ppm

Bitterness = Combination of amygdalin levels and enzymatic hydrolysis rates

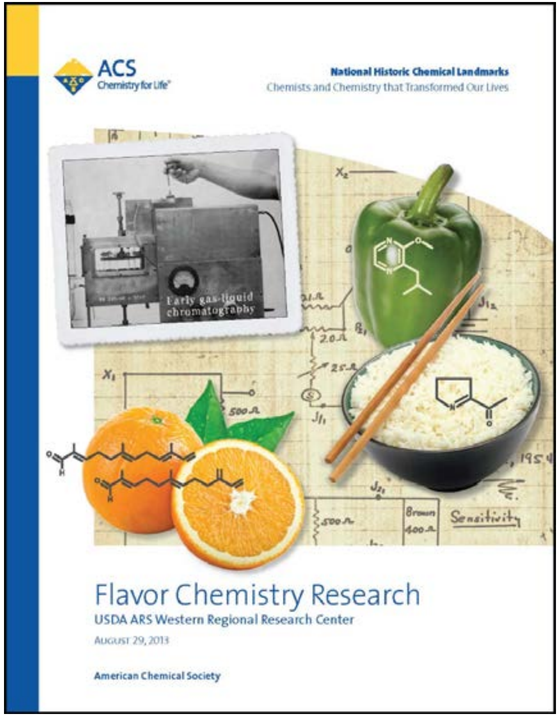
Aroma

- Aroma is based on the sense of smell
- Aroma involves chemoreception
  - the ability of the receptors in the nose to detect specific chemical compounds
- This stimulation results in the perception of aromas
- Aroma (smell) involves detection of hundreds of volatile compounds



Almond Aroma = Volatile Molecules

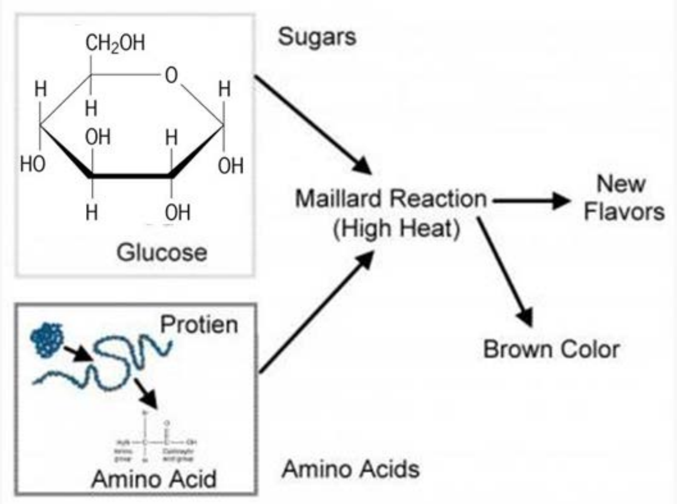
- The aroma chemicals in almonds are volatiles
- Small and uncharged molecules that can easily move through the air
- This allows them to rise with the breath into the nasal passageways
- Each with different potency or odor threshold
- Warmer temperatures increases volatile
- Roasting creates and releases news aromas



Almond Aroma

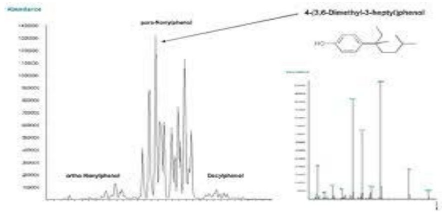
- Will depends on whether almonds are raw or roasted
- When almonds are roasted they undergo many chemical reactions that lead to the creation and release of new volatile compounds
  - Development of brown pigments
- This happens through a series of chemical reactions generated through *Maillard Browning* reactions
- A reaction between a sugar and amino acid

Louis-Camille Maillard
1912



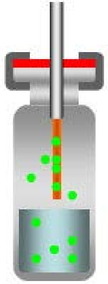
Characterizing Volatile Aroma Compounds in Almonds

- With support of the ABC we developed a HS-SPME GC/MS method to measure a broad range of volatile compounds in raw and roasted almonds
  - Few studies on almonds volatiles before 2014
    - Little varietal information/incomplete characterization/solvent extraction
  - Characterize volatiles in:
  - Raw almonds
  - Roasted almonds
  - Stored almonds

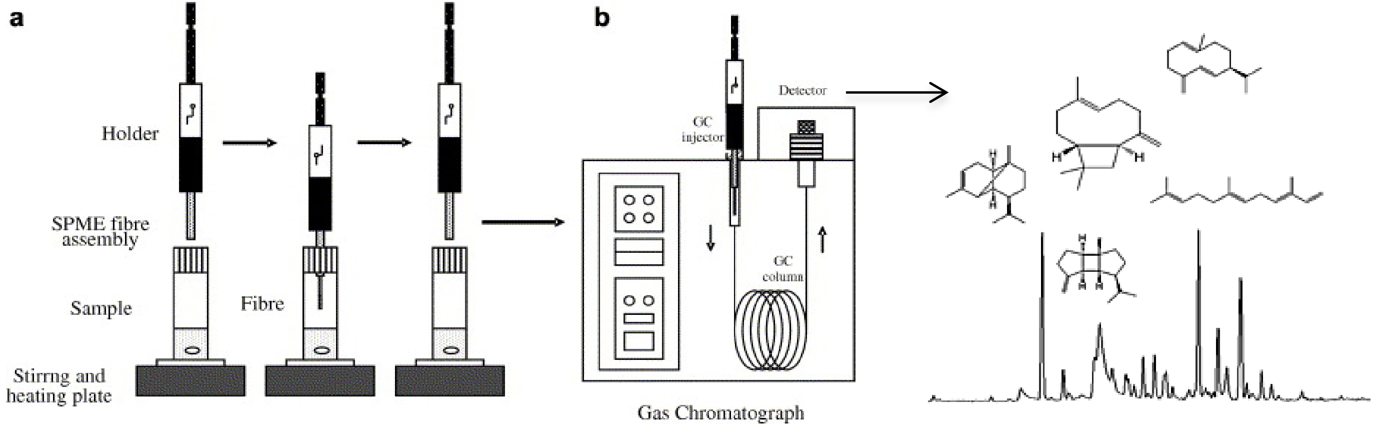


Xiao et al., 2014; Food Chemistry, 151, 31–39

HS-SPME GC/MS Analysis of Almonds

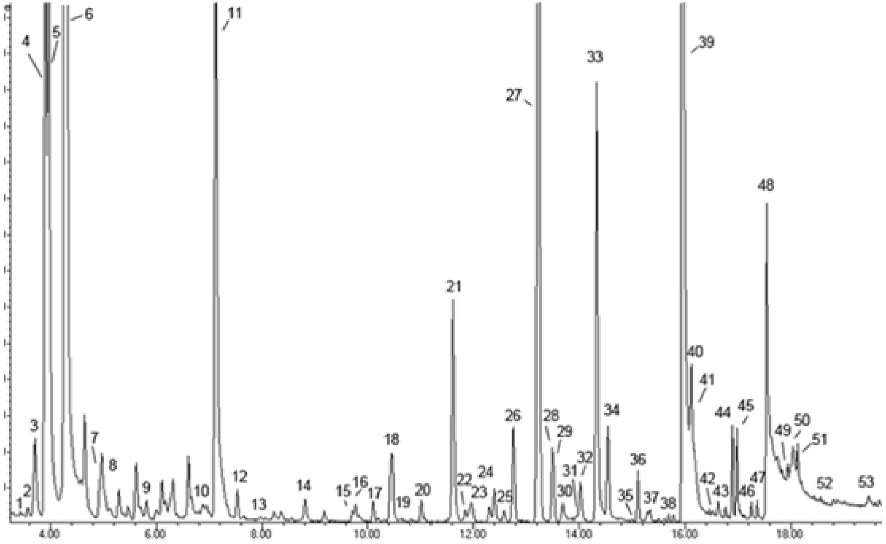


- Head Space Solid Phase Micro-Extraction (HS-SMPE)
  - Traps the volatile molecules on a fiber
- Gas Chromatography with Mass Spectrometry (GC/MS)
  - GC separates the volatiles and the MS measures their gives us a picture and mass of the compound



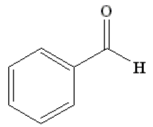
GC/MS Chromatogram

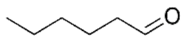
- Picture of the volatiles in the sample
- Viewed as peaks that correspond to the individual volatile compounds
- Peak Identification:
- Comparison of the t_R and mass spectra (MS) with standards
- Comparing t_R, MS and Kovats Index with NIST MS library's with 80 % cut-off (no standard)

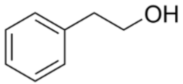


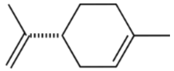
Volatiles Identified in Raw Almonds

- Identified: 13 carbonyls, 1 pyrazine, 20 alcohols, and 7 additional volatiles
- Key Compounds
  - Benzaldehyde, the breakdown product of amygladin, was the predominant volatile in raw almonds (2,934.6 ± 272.5 ppb)
    - Almond-like aroma
  - Hexanal (422.6 ± 97.9 ppb)
    - Fruity/green (cut grass)
  - 2-phenylethanol (6.2 ± 0.6 ppb)
    - Floral
  - Limonene (16.6 ± 0.5 ppb)
    - Pine/citrus



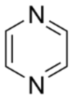


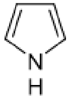




Xiao et al., J. Food Chemistry 151 (2014) 31-39

Volatiles in Roasted Almonds





- An additional 17 new volatile compounds were identified in roasted almonds and include:
  - ketones, aldehydes, pyrazines, alcohols, aromatic hydrocarbons, furans, and pyrroles
- These volatile compounds are generated through the Maillard reaction and via lipid oxidation (kernels are 48-67% oil)
- Pyrazines, furans and alcohols are key components of roasted almond flavor
  - Pyrazines: Maillard sugar-amine reactions and Strecker degradation
  - Furan-containing compounds: thermal degradation of sugars
  - Alcohols and aldehydes: lipid oxidation

Volatiles in Fresh Roasted Almonds

Acids	Acetic acid	vinegar, sour
	Butanoic acid, 3-methyl-	sweaty
Alcohols	1-Pentanol, 2-methyl-	pungent
	1-Butanol	medicine, fruit, wine
	1-Butanol, 2-methyl-	malt
	1-Pentanol, 3-methyl-	pungent
	1-Pentanol	fruit
	Acetoin	butter, cream
	2-Propanol, 1-chloro-	
	3-Pentanol	green, herbal
	1-Hexanol	resin, flower, green
	(S)-(+)-2-Chloro-1-propanol	pleasant, alcohol-like
	1-Octen-3-ol	moss, nut, mushroom
	1-Heptanol	herb
	2,3-Butanediol, [S-(R*,R*)]-	Fruity
	1-Octanol	chemical, metal, burnt
	Propylene Glycol	
	Phenylethyl Alcohol	floral, hyacinth/gardenia
Terpenes	Alpha Pinene	pine, terpentine
	D-Limonene	Fruity, citrus

Ketones	Acetone	pungent, solvent
	2-Butanone	sharp, sweet, butterscotch
	2-Pentanone	pungent, nail polish
	2,3-Pentanedione	cream, butter
	3-Penten-2-one	fruity, fish
	2-Heptanone	cheesy, banana, fruity
Esters	Acetic acid, methyl ester	glue, nail polish remover
	Ethyl acetate	fruity, glue, nail polish
	Hexanoic acid, methyl ester	Sweet
	Acetic acid, methoxy-, methyl ester	
	Formic acid, octyl ester	orange, fruity, rose
	n-Caproic acid vinyl ester	fruity
	Butanoic acid, 2-propenyl ester	pineapple
Sulfur Compounds	Methanethiol	sulfur, gasoline, garlic
	Dimethyl sulfide	cabbage, sulfur, gasoline
	Disulfide, dimethyl	onion, cabbage, putrid
	Methylthio-2-propanone	melon
	Methional	cooked potato
	Ethanol, 2-(ethylthio)-	

Volatiles in Fresh Roasted Almonds

Type of Compound	Compound Name	Descriptor
Pyrazine	2,5 Dimethyl pyrazine	Earthy, nutty, roasted nut, cocoa, roast beef
	Methyl Pyrazine	Popcorn
	Pyrazine, 2-ethyl-5-methyl-	fruity, sweet
	Pyrazine, trimethyl-	roast, potato, must
	Pyrazine, 2-ethenyl-6-methyl-	earthy
	Pyrazine, 3-ethyl-2,5-dimethyl-	Brothy, roast, potato
	Pyrazine, 2,3-dimethyl-	
	Pyrazine, 2,6-diethyl-	tobacco
	Furfural	bread, almond, sweet
	3-Furaldehyde	bread, almond, sweet
	2-Acetyl-1-pyrroline	Buttery popcorn
	Pentyl Oxirane	
	2-Pentyl Furan	green bean, butter
	Furaneol	caramel
	Pyrrole	nutty

Type of Compound	Compound Name	Descriptor
Aldehydes	Propanal	pungent, solvent
	Propanal, 2-methyl-	cooked, caramel
	Butanal	green, pungent
	Butanal, 2-methyl-	cocoa, almond
	Butanal, 3-methyl-	malt
	Pentanal	almond, malt, pungent
	Hexanal	grass, green, tallow, fat
	2-Butenal, 2-methyl-	green, fruit
	Heptanal	fat, citrut, rancid
	Octanal	Citrus-like, soapy
	Nonanal	Soapy, citrus-like
	Decanal	Soapy, citrus-like,tallow
	Benzaldehyde	almond, sweet
	Benzeneacetaldehyde	pungent, phenolic
	2-Decenal, (Z)-	tallow, fat

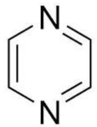
Volatiles Change with Roasting Time/Temp

possible compounds		raw	roasting time 28 min	33 min	38 min	increase[b] (%)
aldehydes and ketones						
butanal		19.6 ± 2.7	$27.6 \pm 1.5^{*}$	$29.3 \pm 0.6^{*}$	$40.8 \pm 2.1^{***}$	67
2-methylbutanal	[chocolate/nutty]	14.3 ± 0.3	$1468.6 \pm 25.7^{**}$	$5000.3 \pm 241.1^{***}$	$6573.7 \pm 275.0^{***}$	30216
3-methylbutanal	[chocolate]	32.4 ± 0.5	$911.4 \pm 50.9^{*}$	$2867.4 \pm 71.1^{***}$	$4268.9 \pm 381.8^{***}$	8167
2,3-butanedione	[sweet/butter]	8.0 ± 0.3	$100.3 \pm 0.8^{***}$	$163.7 \pm 1.3^{***}$	$226.3 \pm 13.7^{***}$	1940
pentanal		50.4 ± 5.7	$223.0 \pm 8.6^{***}$	$169.0 \pm 5.1^{***}$	$264.1 \pm 15.9^{***}$	334
hexanal		422.6 ± 97.9	$983.0 \pm 133.7^{**}$	689.0 ± 78.1	$1140.8 \pm 3.8^{**}$	122
2-heptanone		50.0 ± 4.7	$72.0 \pm 7.3^{*}$	$71.0 \pm 6.3^{*}$	$123.6 \pm 3.0^{***}$	78
heptanal		40.5 ± 8.9	$75.2 \pm 16.2^{*}$	57.1 ± 4.0	$114.8 \pm 3.0^{**}$	103
2-hexenal	[almond/green leaf]	ND[c]	$14.6 \pm 2.7^{**}$	$11.3 \pm 2.2^{*}$	$14.1 \pm 2.7^{**}$	New
2-methyloxolan-3-one	[rummy/nut]	ND	15.4 ± 1.3	$86.3 \pm 4.2^{***}$	$128.1 \pm 11.0^{***}$	New
3-hydroxybutan-2-one	[buttery]	ND	$2.2 \pm 0.2^{**}$	$3.0 \pm 0.1^{***}$	$3.8 \pm 0.6^{***}$	New
octanal		25.2 ± 4.7	31.1 ± 7.3	18.5 ± 6.3	42.0 ± 3.0	21
1-hydroxypropan-2-one		1.3 ± 0.0	$9.0 \pm 0.9^{*}$	$11.0 \pm 0.0^{**}$	$13.7 \pm 3.0^{**}$	771
(Z)-2-heptenal		19.1 ± 0.9	$65.6 \pm 13.2^{**}$	36.5 ± 4.6	$61.9 \pm 1.6^{**}$	186
nonanal		36.6 ± 4.9	55.9 ± 13.3	34.6 ± 4.0	70.5 ± 18.9	47
(E)-2-octenal		7.3 ± 0.9	12.5 ± 2.1	8.3 ± 0.1	$15.9 \pm 2.0^{*}$	67
furfural	[brown/caramel]	ND	$103.2 \pm 8.7^{**}$	$366.1 \pm 13.2^{***}$	$460.0 \pm 21.4^{***}$	New
decanal	[aldehydic]	ND	$6.9 \pm 2.3^{*}$	5.0 ± 1.6	4.6 ± 1.0	New
benzaldehyde	[almond/marzipan]	2934.6 ± 272.5	$368.8 \pm 41.2^{***}$	$246.7 \pm 53.0^{***}$	$331.9 \pm 65.4^{***}$	-89
(Z)-2-nonenal	[green]	ND	ND	ND	$5.3 \pm 1.7^{**}$	New
2-phenylacetaldehyde	[honey/floral]	ND	$107.5 \pm 20.3^{*}$	$284.0 \pm 22^{***}$	$491.3 \pm 45.4^{***}$	New

- Generated through lipid oxidation and the Maillard reaction
- Most compounds increase with roasting (exception is benzadehyde)

Volatiles Change with Roasting Time/Temp

Roasted Nutty Flavors

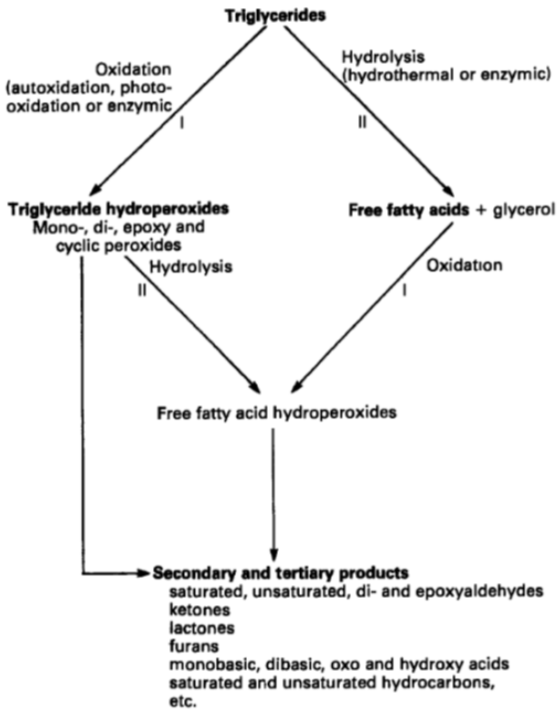


Compound	roasting time				increase[b]
	raw	28 min	33 min	38 min	(%)
Pyrazine					
2-methylpyrazine	ND	4.1 ± 0.3*	21.5 ± 0.6***	26.5 ± 1.8***	New
2,5-dimethylpyrazine	11.4 ± 0.5	16.2 ± 0.6***	53.3 ± 0.3***	66.5 ± 0.4***	298
2,6-dimethylpyrazine	ND	ND	2.8 ± 0.4**	4.2 ± 0.6***	New
2-ethylpyrazine	ND	ND	2.6 ± 0.1***	3.2 ± 0.1***	New
2,3-dimethylpyrazine	ND	ND	1.0 ± 0.1***	1.4 ± 0.1***	New
2-ethyl-6-methylpyrazine	ND	ND	1.7 ± 0.1***	2.2 ± 0.0***	New
trimethylpyrazine	ND	ND	4.5 ± 0.3***	6.1 ± 0.2***	New

- Six new pyrazines were identified in roasted almonds
  - 2-methylpyrazine likely occurred nonenzymatic browning during drying
- Generated through the Maillard reaction
- Most have low odor thresholds and increased with the degree of roast

Rancidity Another Source of Volatiles

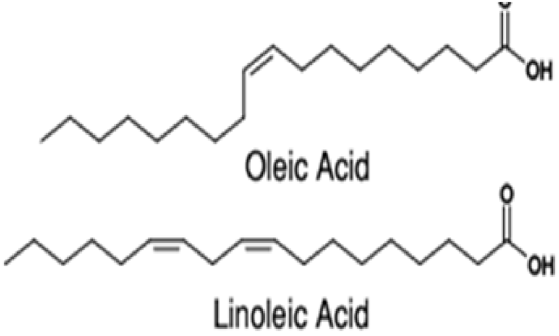
- Rancidity is the unpalatable odor and flavor of deteriorating edible fats and oils in foods
- Problem that can develop with storage of almonds
- Rancidity occurs via two chemical reactions:
- Oxidation
  - Oxygen attack of the triglycerides at double bonds
- Hydrolysis
  - Addition of *water* across triglycerides and release of Fatty acids (FFAs)



california almonds
Almond Board of California

Rancidity in Almonds

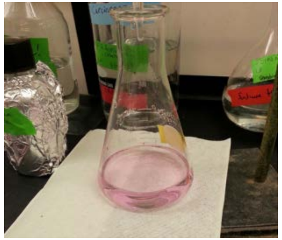
- Rancidity in almonds occurs primarily via the oxidation of oleic [18:1] and linoleic [18:2] acids
  - – Double bonds
  - – Initiated by exposure to heat (e.g. pasteurization, blanching, roasting, etc.,), or oxygen exposure (e.g. during storage)
- Primary lipid oxidation products include:
  - – Lipid hydroperoxides and conjugated dienes
- Secondary lipid breakdown products include:
  - – Volatile compounds
    - Aldehydes (hexanal), ketones, off-odors



Accelerated Shelf-life Storage & Rancidity

- Nonpareil almonds were roasted at 60 min (240˚F) light roast or 20 min at 315˚F dark roast
- Almonds were stored at 39 + 2ºC and RH Humidity of15 + 3%
- Almonds were stored in open bags to maximize oxidation during storage
- On-going

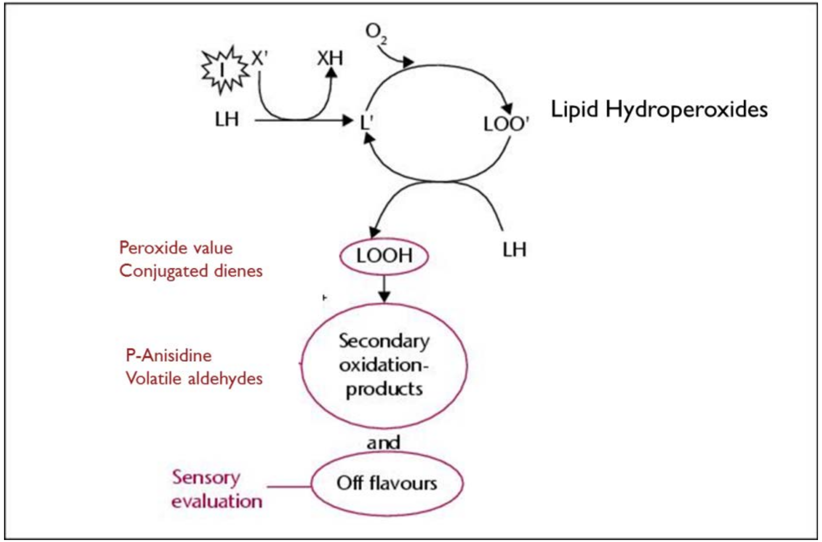
Monitoring Rancidity



- Goal of the Study:

- Primary Oxidation Products
  - Peroxide Value
- Secondary Oxidation Products
  - Volatiles by GC-MS
- Hydrolytic Rancidity
  - Free Fatty Acids

- Sensory Measures
  - Consumer Acceptance
  - Descriptive Analysis

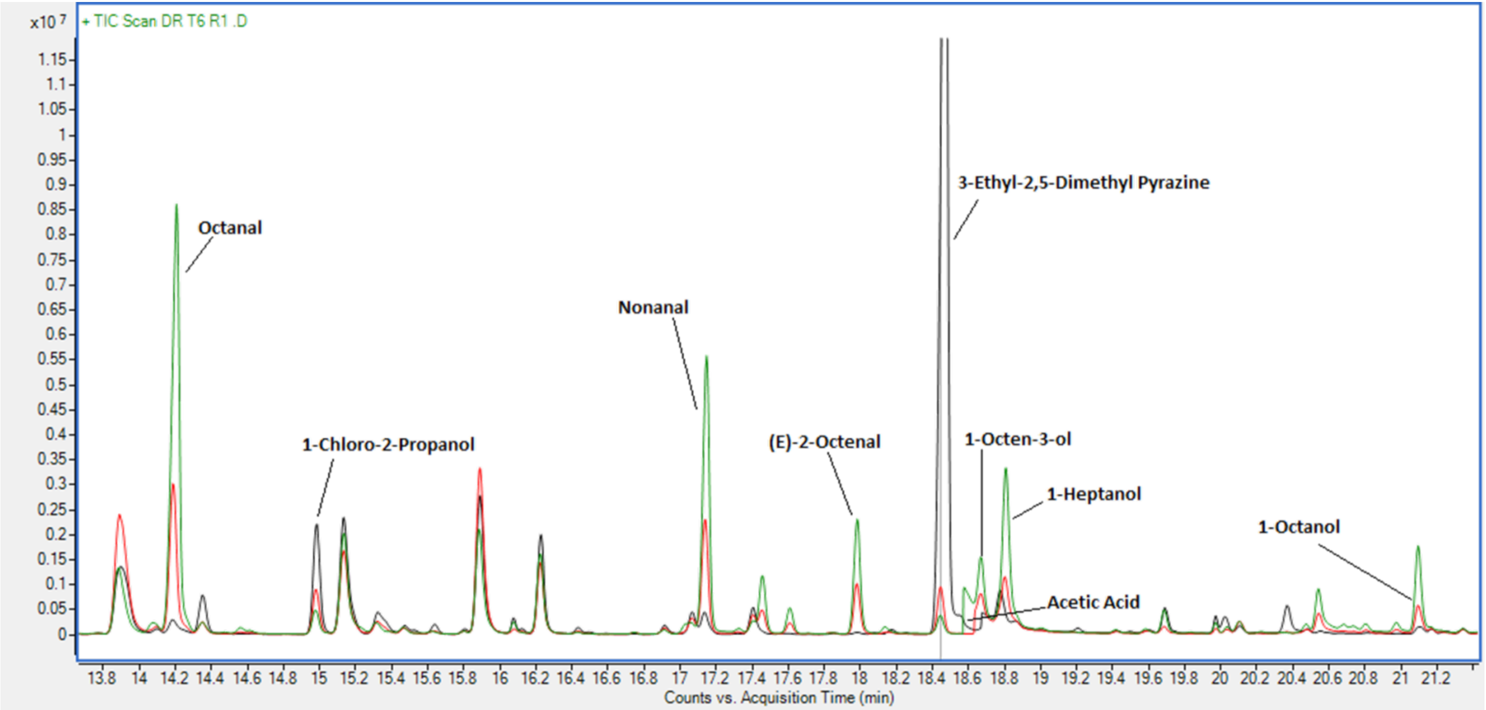


Volatiles Associated with Lipid Oxidation in Almonds

Type of Compound	Name of Compound	Descriptor
Aldehydes	Pentanal	almond, malt, pungent
	Hexanal	grass, green, tallow
	4-Pentenal	strawberry, fruit, tomato
	Heptanal	fat, citrust, rancid
	Octanal	Citrus-like, soapy
	Nonanal	Soapy, citrus-like
	2-Octenal, (E)-	fruity, soap, fatty
	Decanal	Soapy, citrus-like,tallow
	2-Decenal, (Z)-	tallow, fat
	2-Heptenal, (Z)-	soap, fat, almond
Ketones	2,3-Pentanedione	cream, butter
	2-Heptanone	cheesy, banana, fruity
	2-Octanone	herb, butter, resin
	1-Hepten-3-one	mushroom
	3-Octen-2-one	nut, crushed bug
	2-Propanone, 1-(acetyloxy)-	
	3-Heptanone, 2-methyl-	fruity
	trans-3-Nonen-2-one	fruity, brandy, mushroom
Esters	Acetic acid, octyl ester	fruity

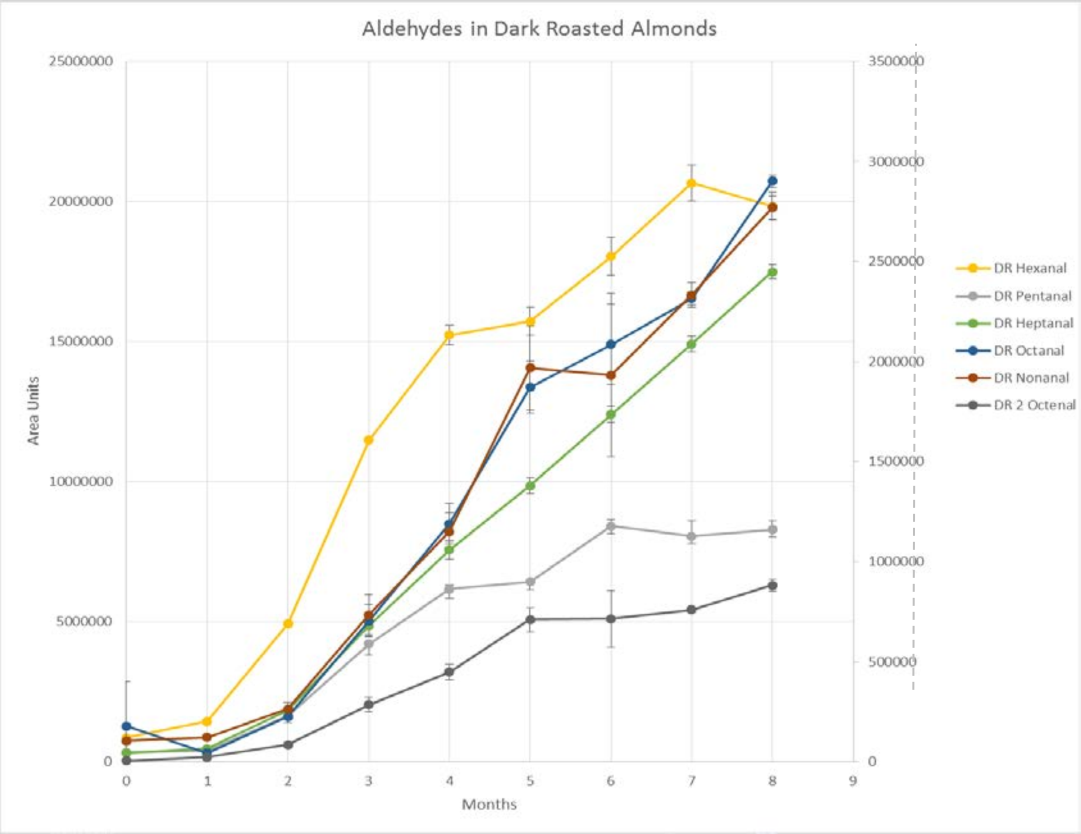
Type of Compound	Name of Compound	Descriptor
Oxiranes/Heterocycles	2-n-Butyl furan	spicy
	Oxirane, pentyl-	
	Oxirane, hexyl-	
	2(3H)-Furanone, 5-ethyldihydro-	spice
	2H-Pyran-2-one, tetrahydro-6-methyl-	coconut, cream, chocolate
	2(3H)-Furanone, dihydro-5-propyl-	nut, fat, fruit
Alcohols	1-Butanol	medicine, fruit, wine
	1-Butanol, 2-methyl-	malt
	1-Pentanol	fruit
	3-Octen-1-ol, (E)-	melon, earthy
	1-Octen-3-ol	moss, nut, mushroom
	1-Heptanol	herb
	1-Octanol	chemical, metal, burnt
Acids	Acetic acid	vinegar, sour
	Pentanoic acid	sweaty, pungent, putrid
	Hexanoic acid	sweaty, pungent
	Butanoic acid, 3-methyl-	sweaty

Comparison of Volatiles in Stored Almonds



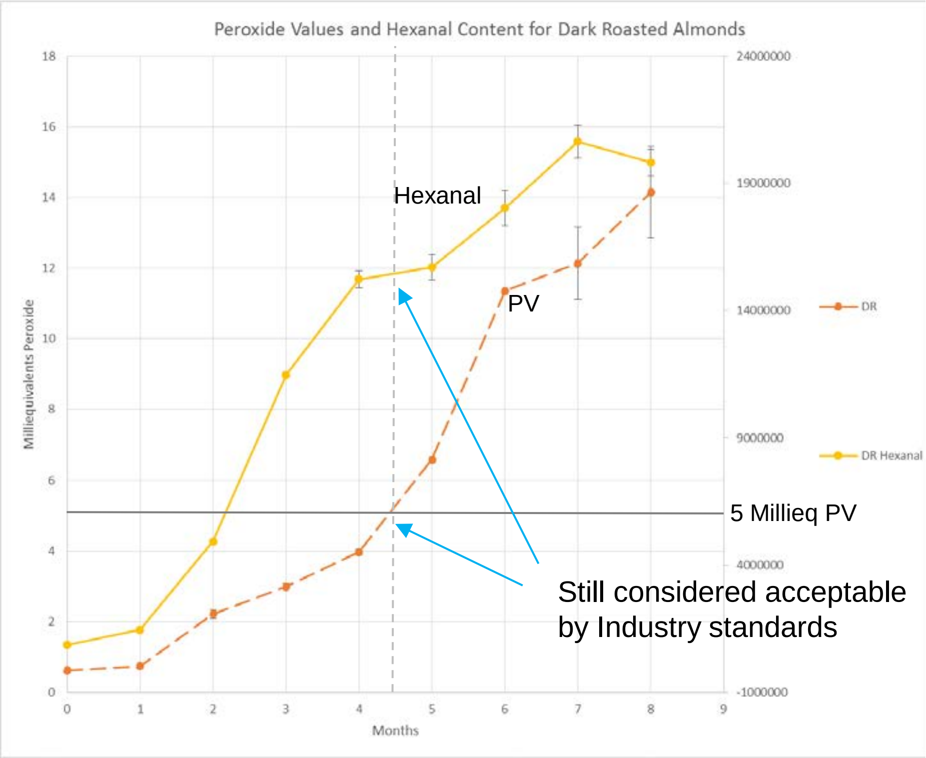
. (▪ Just roasted ▪3 months storage ▪ 6 months storage)

Increases in Aldehydes During Storage (39°C)

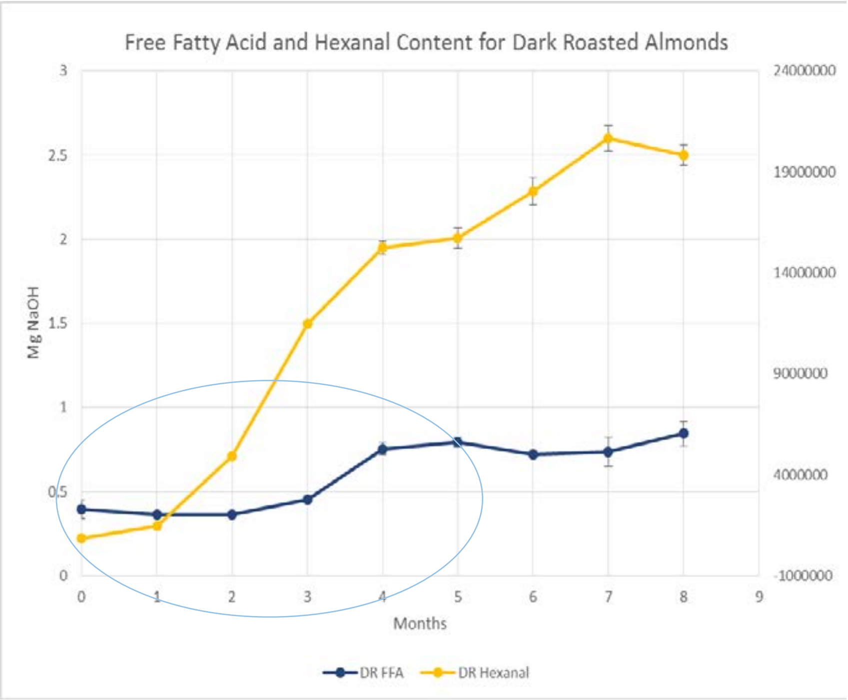


Tallow, fat, rancid, soapy, green, citrus

Effectivity of PV as an Indicator of Rancidity



Effectivity of FFA as an Indicator of Rancidity



- Slower to indicate significant changes
- does not follow hexanal
- May not be very useful

Conclusions

- Almond flavor is a composite quality that involves taste (fat, sugar, proteins, amygdalin, tannins) and volatiles (especially benzaldehyde)
- Flavor is influenced by roasting (development of pyrazines) and storage (lipid oxidation products)
- Changes in volatile aroma compounds may be the earliest indicators of quality losses, shelf life limits, and abuse
- HOWEVER
  - Quantifying volatiles does not necessarily indicate the actual flavor of the almonds
    - Sensory thresholds
    - Concentration dependency of the various flavor attributes
    - Suppression/enhancement due to compounding effects of multiple molecules in the profile
    - Furthermore, knowing how the flavor is described does not indicate *consumer ACCEPTANCE* of products
- There is a need for a comprehensive analysis to connect chemical measures with sensory data
  - Poster #32
- This research is underway in conjunction with the National Foods Lab

Acknowledgements

Advancing Knowledge a Team Effort

- UC Davis
  - Cristian Rogel Castillo, PhD candidate
  - Arunwong Opastpongkarn, BS student
  - Tom Gradziel, PhD
- Food Safety and Measurement Facility
- Almond Board of California
  - Guangwei Huang, PhD
  - Karen Lapsley, PhD
- Agilent Technologies
- Phil Wilie, PhD
- John Kinsella Endowment

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Dawn Chapman & Ellie King
The National Food Laboratory

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Profiling Sensory Differences in Almond Varieties

Dr Dawn Chapman & Dr Ellie King

The National Food Lab, Livermore CA

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Content

- Capabilities of The NFL
- Methodology – Descriptive Analysis
- Results
- Key Findings

The NFL Overview

What We Do

The NFL is a food and beverage consulting and testing firm providing creative, practical and science-based solutions for the following areas:

Product and Process Development

Safety and Quality

Sensory and Consumer Research

Who We Are

- Privately held company; over 35 years in operation
  - Technology & Product Design Centers located in the San Francisco Bay Area
  - Heritage in food safety, process validation and commercialization across product development continuum
- ≈ 150 employees
  - Highly experienced subject matter experts
  - 80+% of staff have BA/BS – 1/3 with Masters/PhD

Sensory Evaluation

Our Approach:

- Tap into our pool of 45 highly trained panelists with an average of 5 years of experience.
  - These are not Consumers and they do not provide their liking or opinions.
  - Skilled at describing sensory characteristics and intensity ratings of a wide variety of products.
  - Screened for olfactory & gustatory acuity and ability to describe flavor nuances.
  - Extensively screened and provided with 3+ months of training before qualification.
- Overseen by experienced panel leaders
  - Advanced degrees (Master’s or Ph.D. in Sensory Science)

Previous Almond Sensory Work

- **2006 – Sensory Spectrum – Almond Lexicon**
  - 36 samples representing 20 almond varieties used to develop lexicon
  - 86 attributes:
    - 15 appearance terms
    - 9 aroma terms
    - 36 flavor terms
    - 3 basic taste terms
    - 4 chemical-feeling factor terms
    - 19 textural terms
  - A large number of attributes used (entire overview of almond sensory profiles)
  - Limited examples of reference standards to use for translation and training
  - Extensive sample preparation
  - No statistics or mapping
- **2013 – UC Davis, Hildegarde Heymann – develop a simple sensory analysis procedure**
  - 14 varieties – raw, pasteurized and roasted; shelled or unshelled; whole, sliced & diced
  - 31 attributes:
    - 4 appearance terms
    - 13 aroma/flavor terms
    - 3 basic taste terms
    - 11 texture terms

Profiling Sensory Differences in 13 Almond Varieties

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Background & Objectives

Background:

- The Almond Board of California was interested in understanding the variability in different almond varieties.
- The NFL conducted sensory descriptive analysis on 13 almond varieties from various Californian growing counties (43 almond samples in total).

Objectives:

- To describe the appearance, aroma, flavor and texture of 43 almond samples using trained sensory panelists.
- To create a sensory map to differentiate almond varieties based on their sensory profiles.

Product Descriptions

- **13 varieties (43 samples total)**
- Raw and unpasteurized – Samples were sorted and dusted before evaluation.

Variety	Number of samples
Aldrich	4
Butte	4
Butte Padre	3
Carmel	2
Fritz	4
Indendence	1
Mission	4
Monterey	4
Nonpareil	4
Padre	1
Price	4
Sonora	4
Wood Colony	4
TOTAL	**43**

Methodology – Descriptive Analysis

- Descriptive testing was conducted by The National Food Lab using trained panelists.
- 10 panelists, 2 replications.
- Panelists participated in three 2-hour orientation sessions to discuss the samples and review the references.
- Samples were identified by 3-digit codes and were served in a randomized and balanced order.
- Panelists rated attribute intensities on 15-point line scales.

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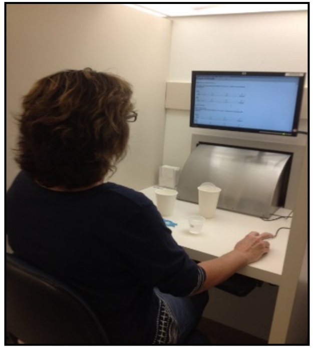
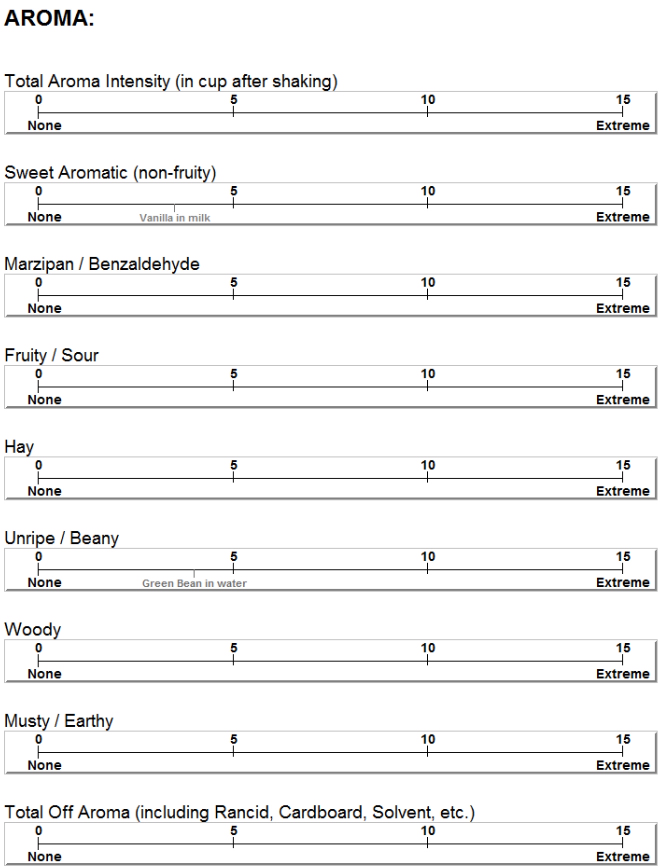


Key Sensory Attributes

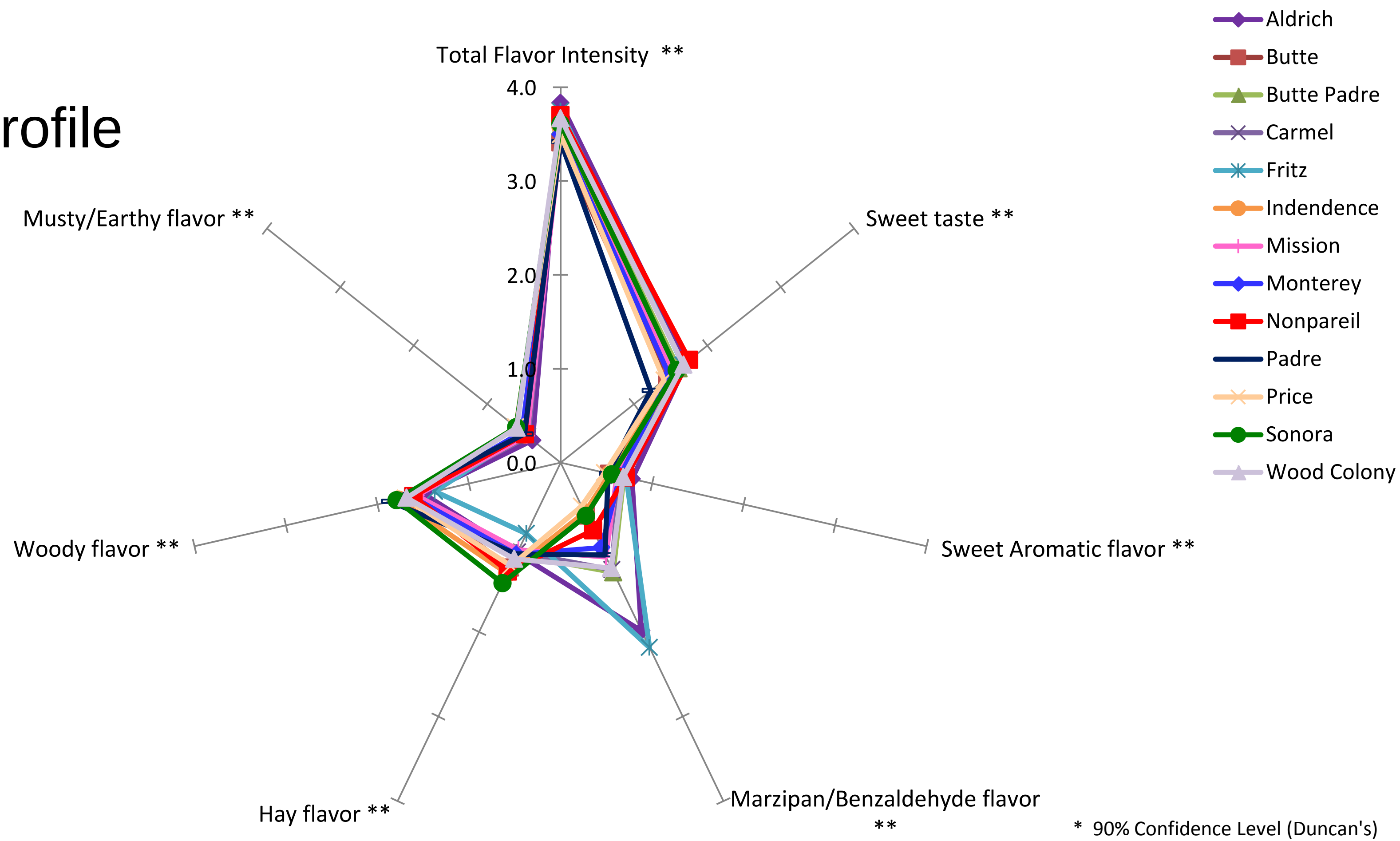
- **Aroma and Flavor**
  - Total Aroma/Flavor Intensity
  - Sweet *
  - Bitter *
  - Sweet Aromatic (non-fruity)
  - Marzipan/Benzaldehyde
  - Fruity/Sour
  - Hay
  - Unripe/Beany
  - Woody
  - Musty/Earthy
  - Total Off Aroma/Flavor
    - Rubber/Medicinal
- **Appearance**
  - Average Darkness of Color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

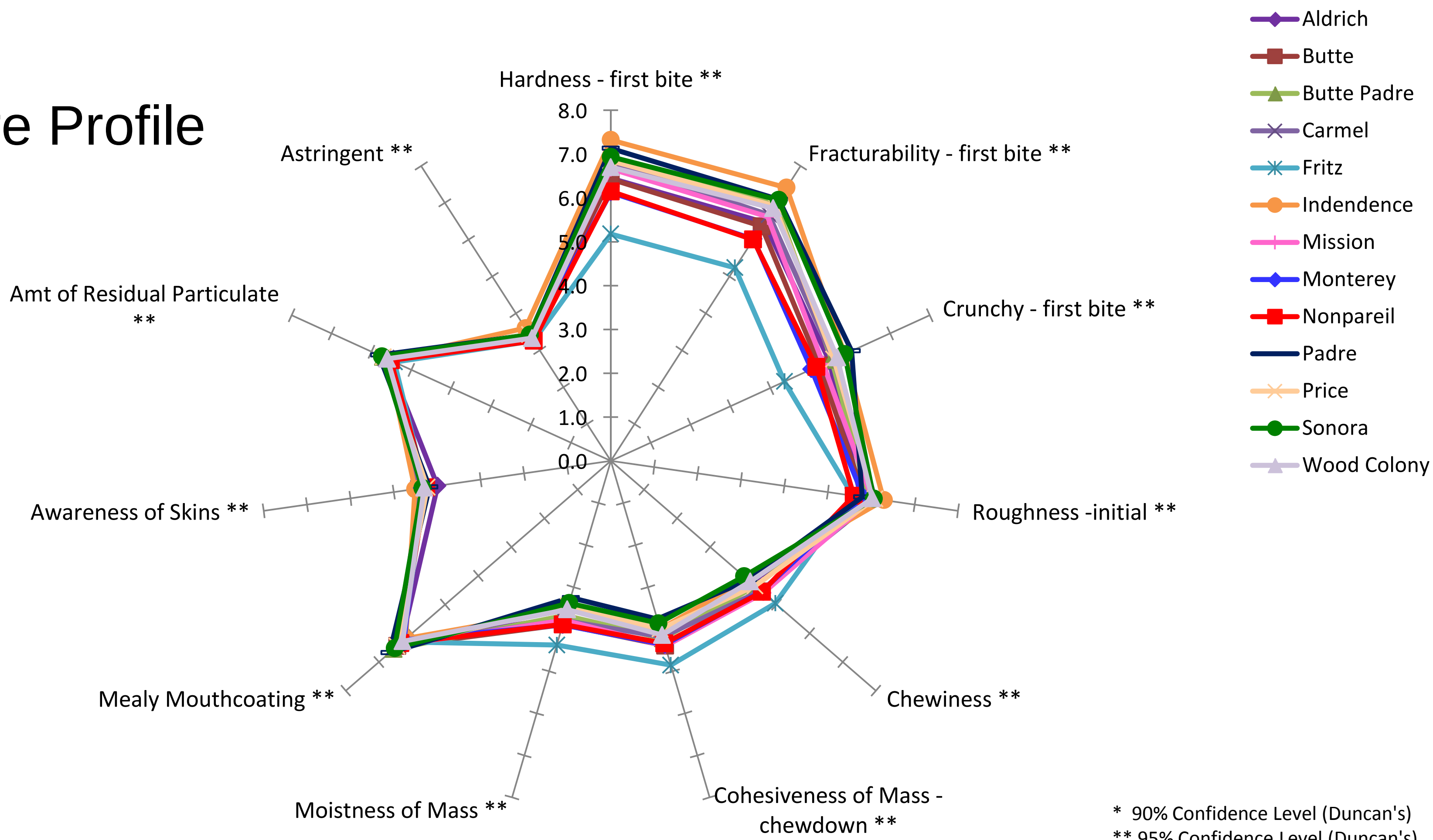


Flavor Profile



* 90% Confidence Level (Duncan's)
** 95% Confidence Level (Duncan's)
NSD: Not Significantly Different

Texture Profile



* 90% Confidence Level (Duncan's)
** 95% Confidence Level (Duncan's)
NSD: Not Significantly Different

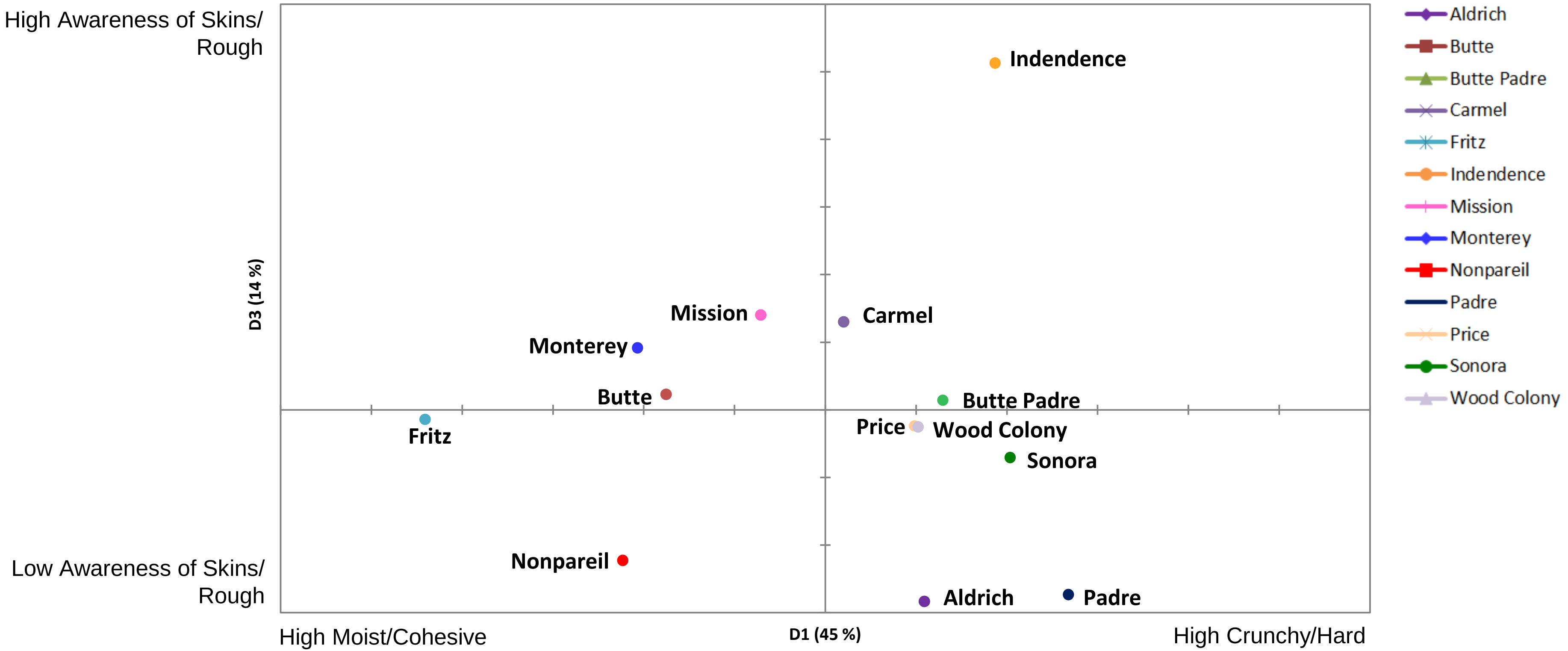
Four Sensory Dimensions* Define the Perceptual Space for Raw Almonds

- Although appearance was a key differentiator of the samples, it was removed from further data analysis.

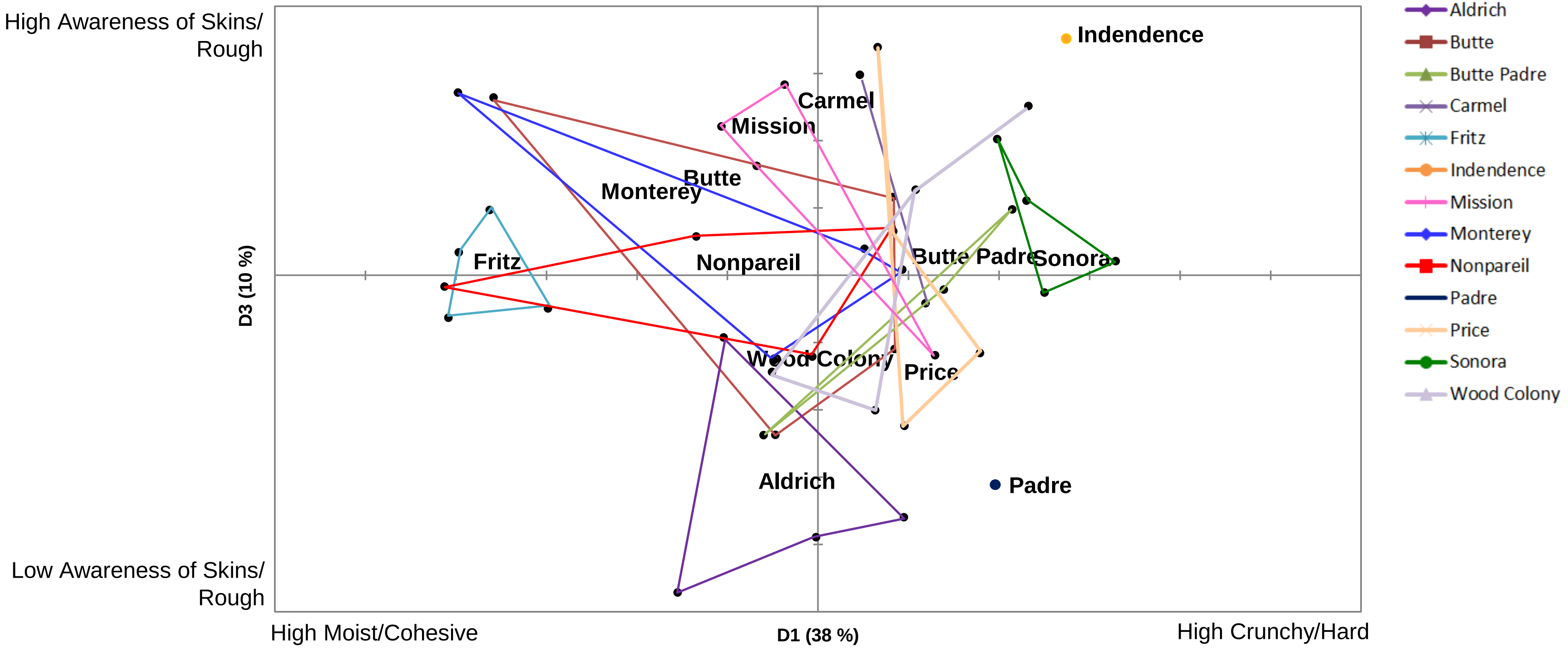
Moist/Cohesive to Crunchy/Hard	Total Flavor	Awareness of Skins/ Rough	Marzipan/ Benzaldehyde to Hay flavor
• Crunchy • Fracturability • Hardness *Opposing:* • Moistness of Mass • Cohesiveness of Mass	• Hay aroma • Total Flavor intensity • Sweet taste	• Awareness of Skins • Roughness	• Hay flavor *Opposing:* • Marzipan/ Benzaldehyde flavor
45%	18%	14%	13%

* A sensory dimension consists of sensory attributes that are related statistically, and tend to rise and fall together. They are determined by Principal Component Analysis, a data reduction technique that identifies key dimensions to describe the sensory differences among samples. The above 4 dimensions reflect 90% of the sensory variability within this sample set.

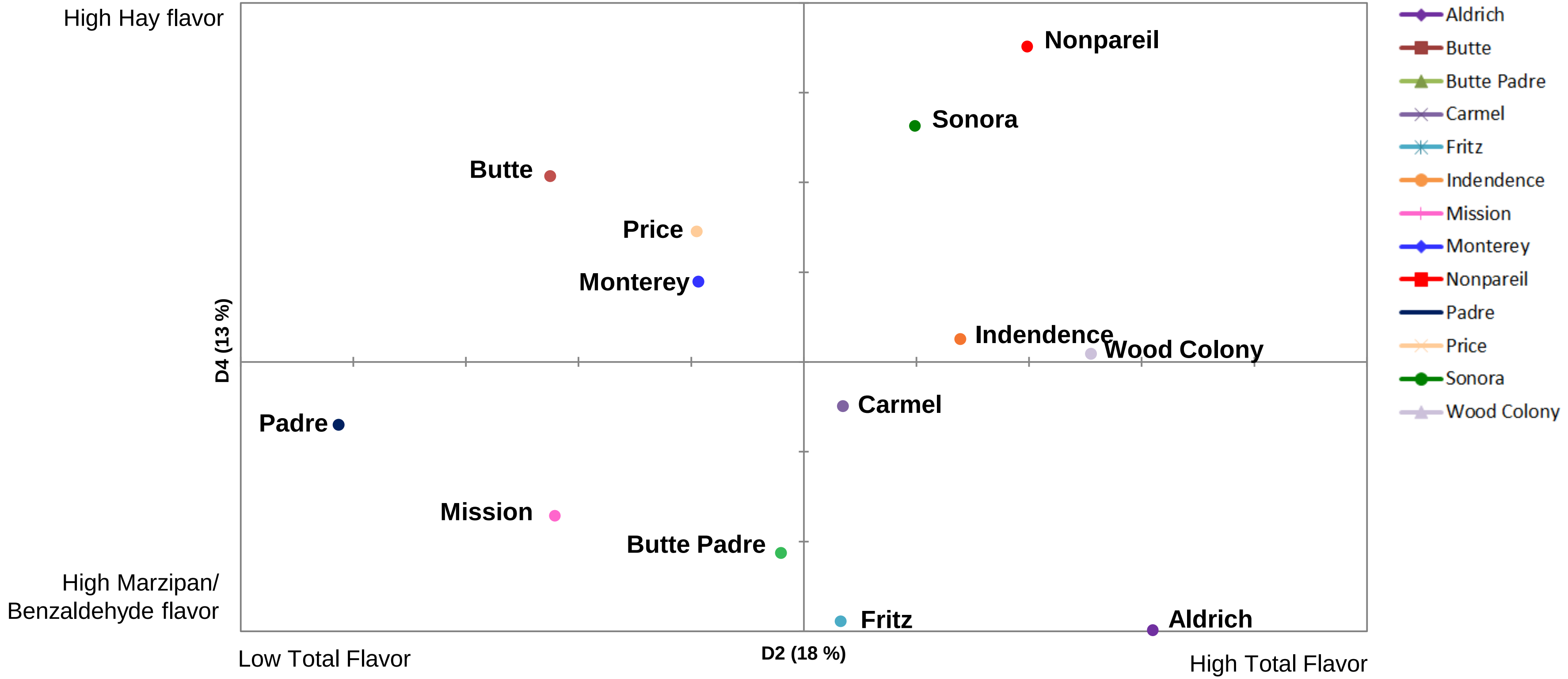
Perceptual Map of Dimensions 1 and 3 (Texture)



Perceptual Map of Dimensions 1 and 3 (Texture)



Perceptual Map of Dimensions 2 and 4 (Flavor)



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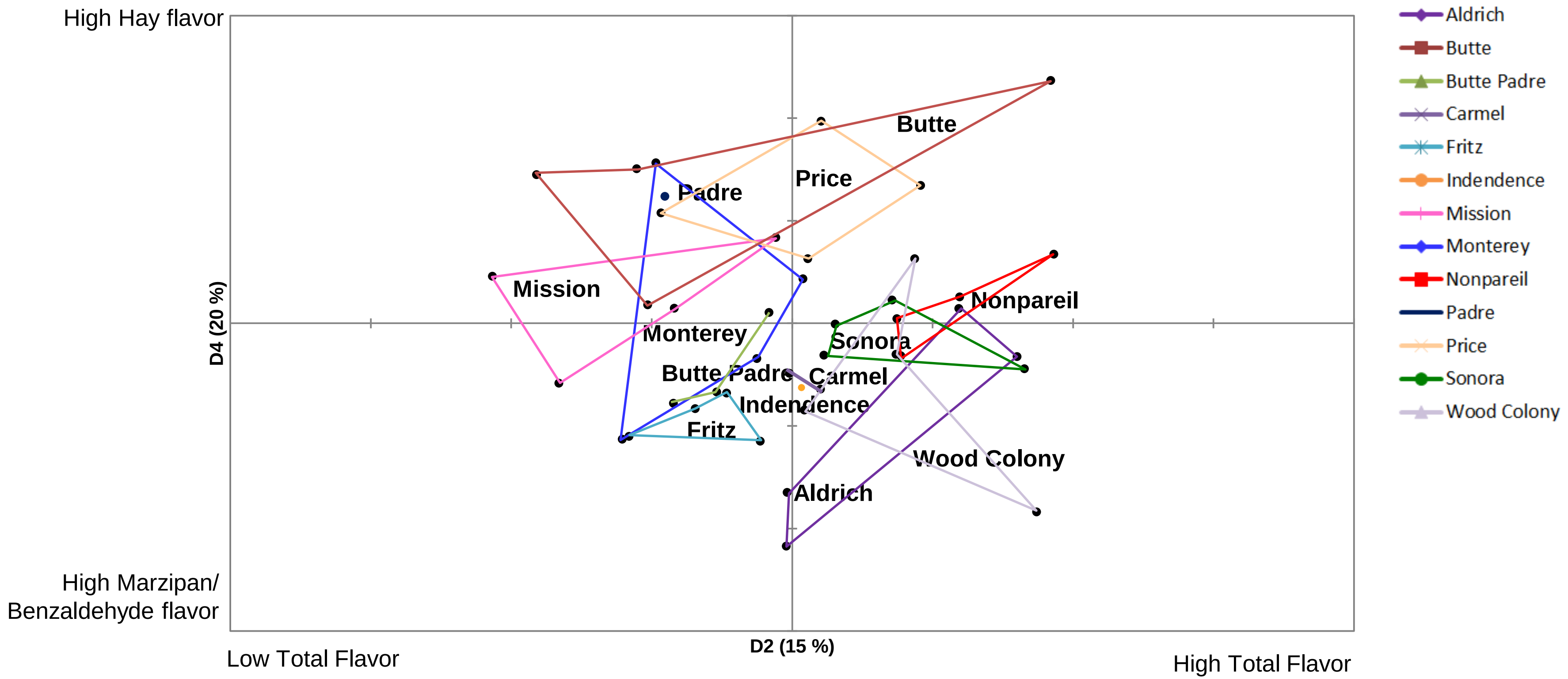
Perceptual Map of Dimensions 2 and 4 (Flavor)



Sensory Dimensions by Liking Segment & Product

Almond Varieties	"Moist/ Cohesive"	"Crunchy/ Hard"	"Total Flavor"	"Awareness of Skins/Rough"	"Marzipan/ Benzaldehyde flavor"	"Hay flavor"
Aldrich	Mid	Mid	High	Low	High	Low
Butte	Mid-High	Low-Mid	Low-Mid	Mid	Low-Mid	Mid-High
Butte Padre	Mid	Mid	Mid	Mid	Mid-High	Low-Mid
Carmel	Mid	Mid	Mid	Mid	Mid	Mid
Fritz	High	Low	Mid	Mid	High	Low
Indendence (n=1)	Low-Mid	Mid-High	Mid	High	Mid	Mid
Mission	Mid	Mid	Low-Mid	Mid	Mid-High	Low-Mid
Monterey	Mid-High	Low-Mid	Mid	Mid	Mid	Mid
Nonpareil	Mid-High	Low-Mid	Mid-High	Low	Low	High
Padre (n=1)	Low	High	Low	Low	Mid	Mid
Price	Mid	Mid	Mid	Mid	Mid	Mid
Sonora	Low-Mid	Mid-High	Mid	Mid	Low	High
Wood Colony	Mid	Mid	High	Mid	Mid	Mid

High intensity

Low intensity

High variability

Key Findings

- We found differences in the sensory profiles of 13 almond varieties.
  - **Fritz** had a different sensory profile to the other almond varieties and high consistency lot-to-lot. It was the most moist and cohesive sample, and was high in Marzipan/Benzaldehyde flavor.
  - **Butte** & **Monterey** had similar sensory profiles, however, they both had a high level of lot-to-lot variation.
  - **Butte Padre**, **Price**, **Sonora** and **Wood Colony** were similar in texture profile, but had flavor profile differences.
  - **Independence** was very high in Awareness of Skins/Rough, but only one sample was assessed for this variety.
- Lot-to-lot variability exists to a larger extent for some varieties than others, in particular **Aldrich**, **Butte**, **Monterey** and **Wood Colony**.

Next Steps

- Relate the sensory profiles to the analytical measures conducted in Alyson Mitchell's laboratory at UC Davis.
- Collect consumer findings to understand which dimensions are most important to focus on for consumer liking of raw almonds.
- Are these findings stable over years?
- These sensory differences can then be translated and presented to Food Manufacturers and Retailers, to aid discussions around which almond products would best serve the purposes of the end-product.

Contributors

Guangwei Huang
Associate Director, Food Research & Technology
Almond Board of California

Ellie King, Ph.D.
Project Leader, Sensory Science
The National Food Lab
KingE@TheNFL.com, 925-551-4289

Dawn Chapman, Ph.D.
Technical Director, Sensory & Consumer Science
The National Food Lab
ChapmanD@TheNFL.com, 925-551-4243

Zata Vickers,
University of Minnesota

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Descriptive Analysis and Consumer Testing of Almond Texture

Presented by Zata Vickers
Professor
Department of Food Science and Nutrition
University of Minnesota

California almonds
Almond Board of California

Objectives

- to measure sensory texture attributes of five types of almonds conditioned at 4 different moisture levels
- to measure liking of a subset of these products
- to compare the sensory texture measurements with consumer liking ratings and with moisture.

Descriptive Analysis

- 13 panelists
- Trained
  - Selected appropriate texture attributes
  - Established appropriate eating techniques
  - Practiced rating -- with feedback

Descriptive Analysis

- Almonds tested:
  - 5 almonds
    - Raw whole
    - Dry Roasted whole
    - Blanched whole
    - Blanched sliver
    - Sliced
  - 4 moistures
    - Very low (LL)
    - Low
    - Normal (Norm)
    - Adjusted Higher (High)

Descriptive Analysis

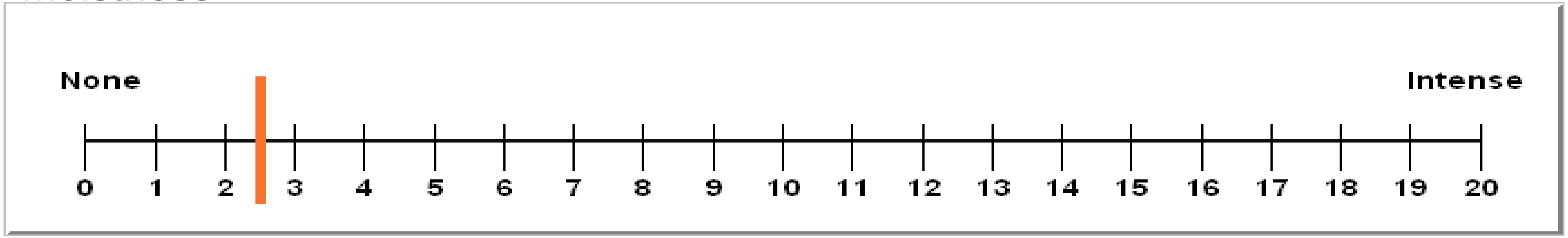
- Sensory procedure
  - Rated 20 samples twice over 5 sessions
  - Balanced for position and carryover
  - Rated each sample for 17 texture attributes

Lexicon

- <u>Surface</u>
  - Powdery/Fuzzy
  - Macro-roughness
  - Loose particles
  - Oiliness
- <u>First bite (with Molars)</u>
  - Hardness to split/crack
  - Crispness
  - Number of Pieces
  - Hardness to grind pieces
- <u>Chewdown</u>
  - Number of chews to bolus
  - Moistness of Mass (5 chews)
  - Cohesiveness of mass
  - Particulate mass (at swallowing)
  - Fibers between teeth
  - Crunchiness
  - Persistence of crunch
  - Number of swallows
- <u>Residual</u>
  - Toothpack
  - Loose particles
  - Fatty/oily film

Each attribute was rated on a 20-point scale

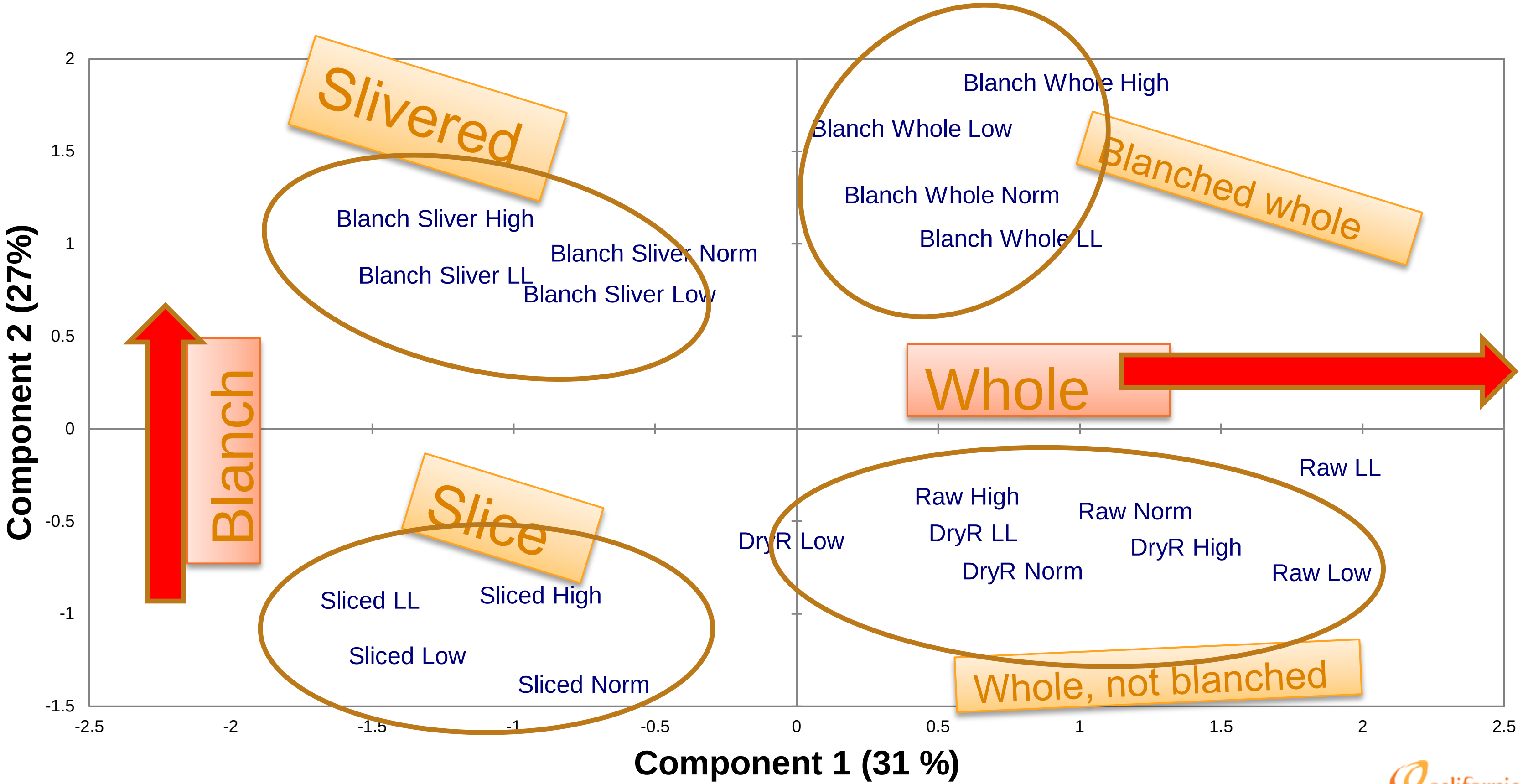
Moistness



Descriptive Analysis Results

- Used Principal Components Analysis (PCA) to make summary **plots**
  - Similar products are positioned close to each other
  - Axes represent latent (more basic, summary) variables

PCA plot of all almonds



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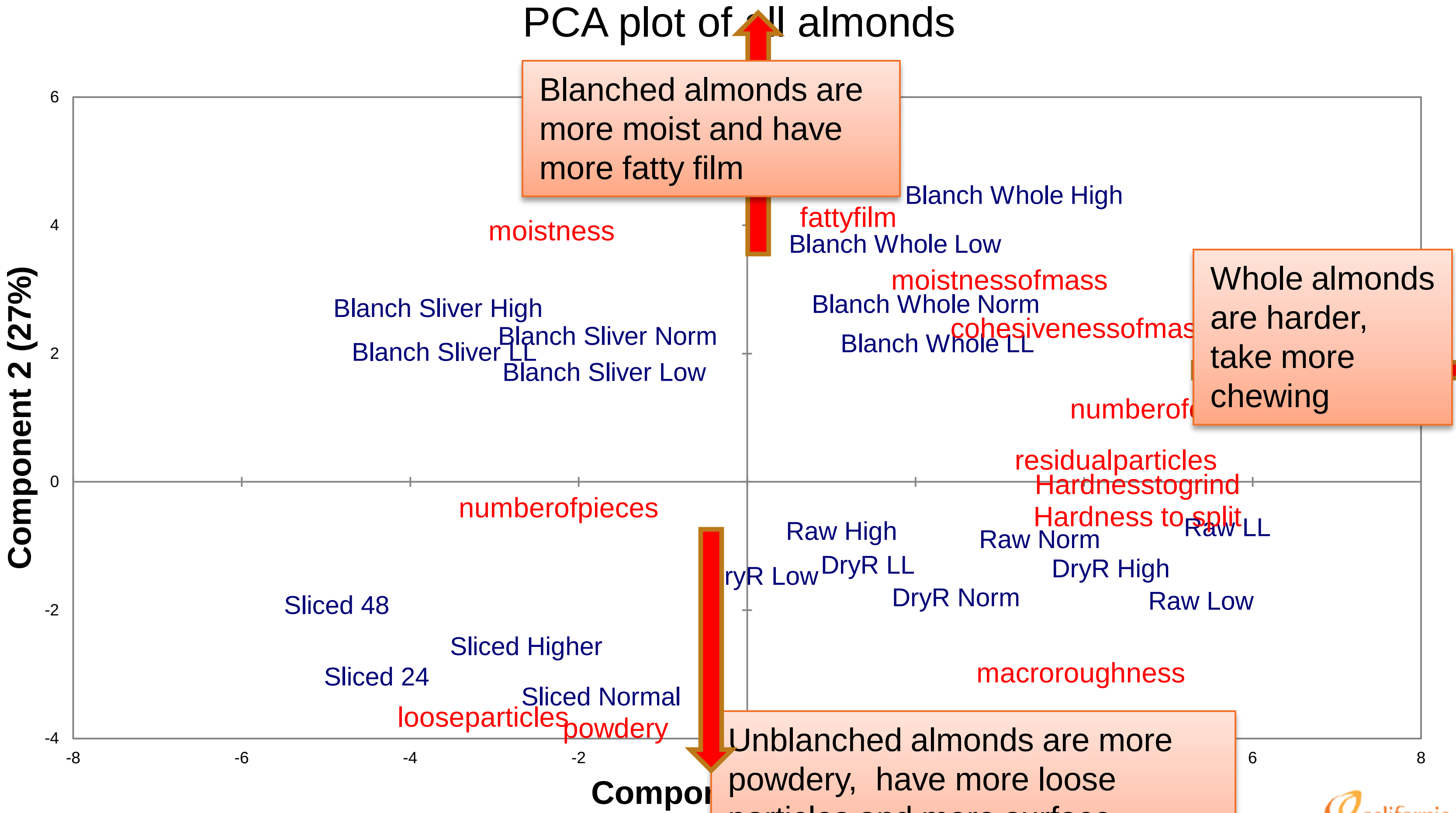

Blanched almonds are more moist and have more fatty film

Whole almonds are harder, take more chewing

Unblanched almonds are more powdery, have more loose particles and more surface roughness

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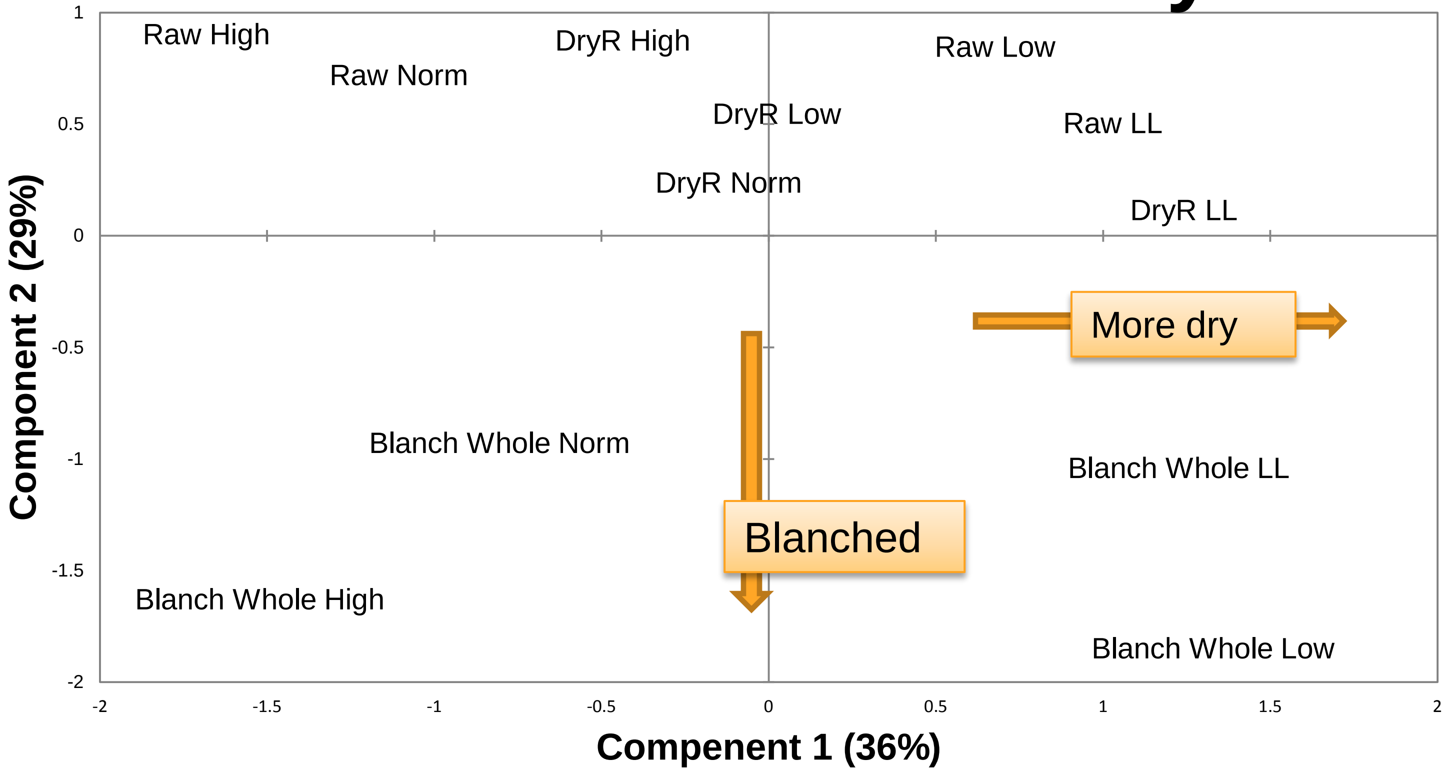
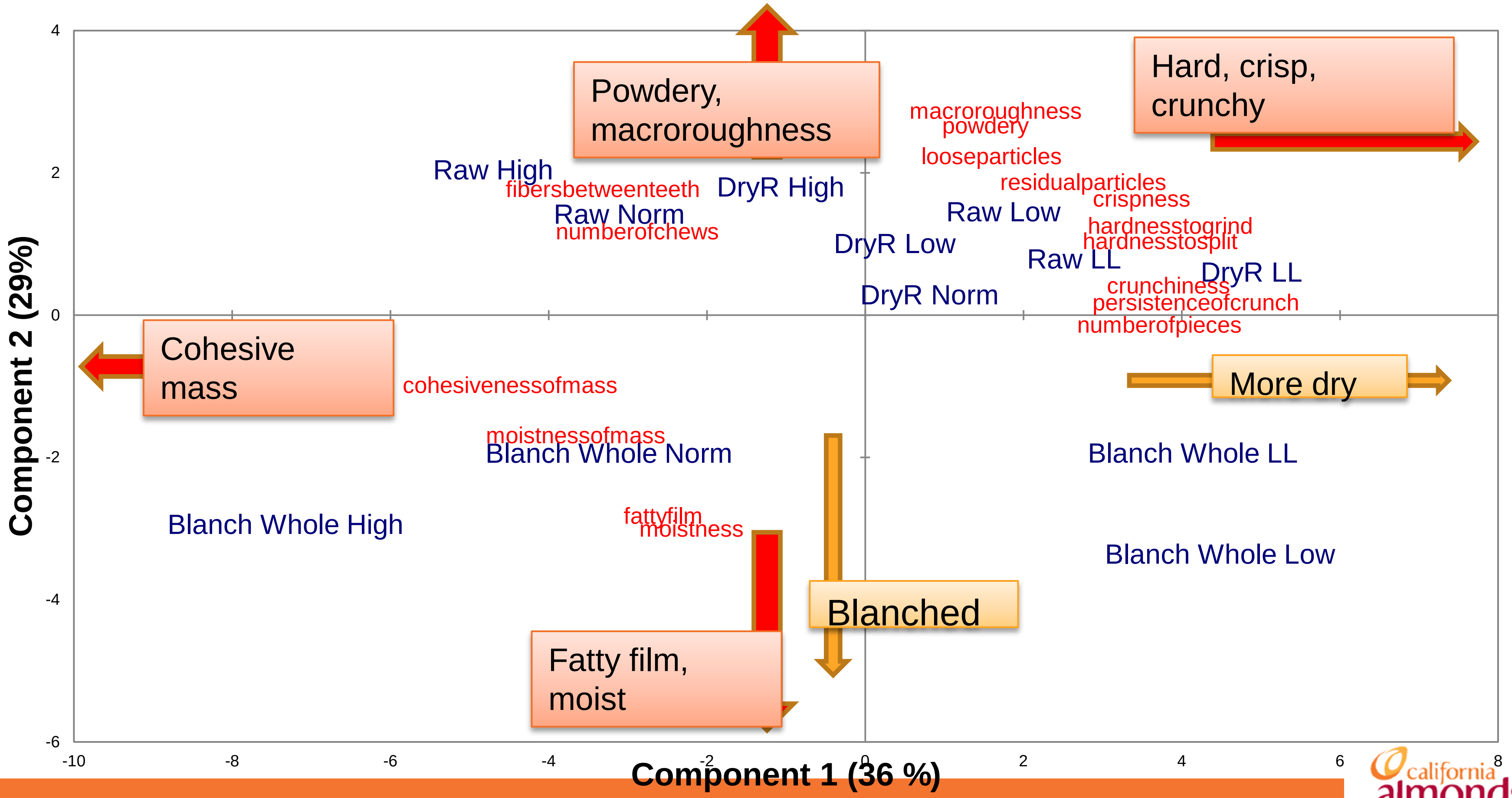
Whole almonds only



PCA plot whole almonds only



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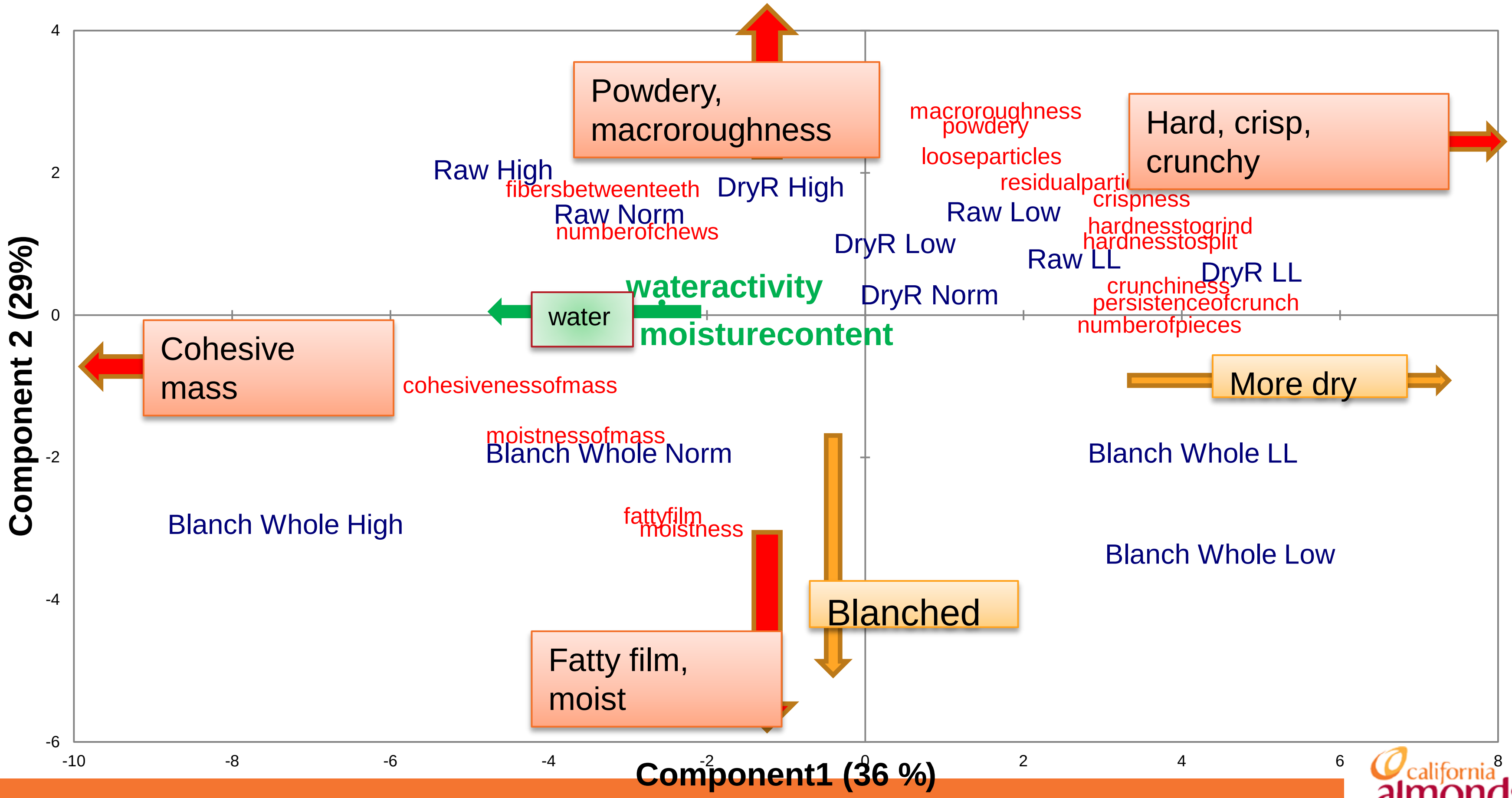
PCA plot whole almonds only PCs 1 & 2



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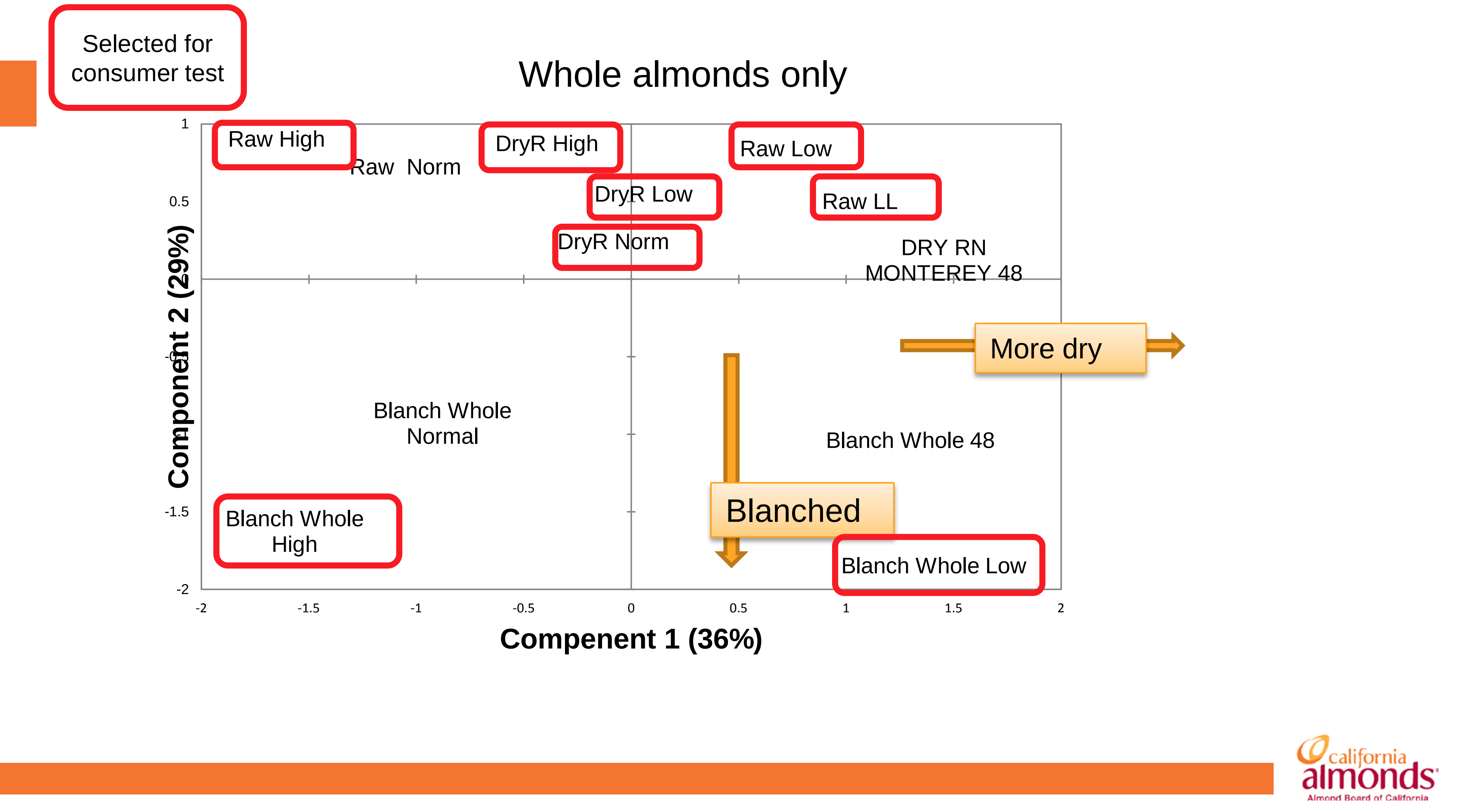
Consumer test

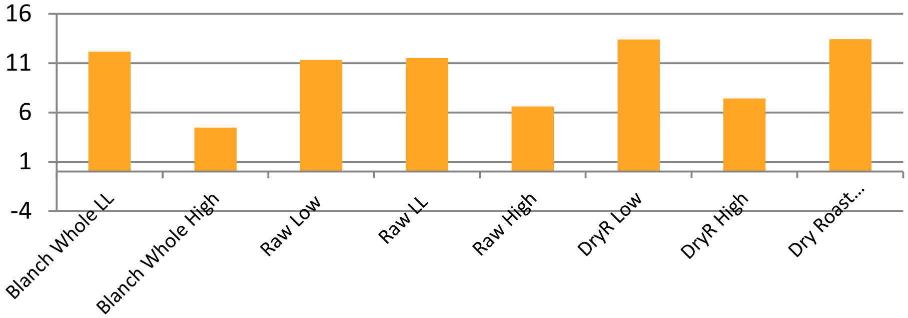
- 113 panelists
  - that had consumed almonds in the last month
  - no food allergies
- Whole almonds that spanned the range of the PCA space


Selected for consumer test
Whole almonds only
Raw High
Raw Norm
DryR High
DryR Low
DryR Norm
Raw Low
Raw LL
DRY RN MONTEREY 48
More dry
Blanch Whole Normal
Blanch Whole 48
Blanched
Blanch Whole High
Blanch Whole Low
1
0.5
-1.5
-2
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Component 2 (29%)
Compenent 1 (36%)

Consumer test

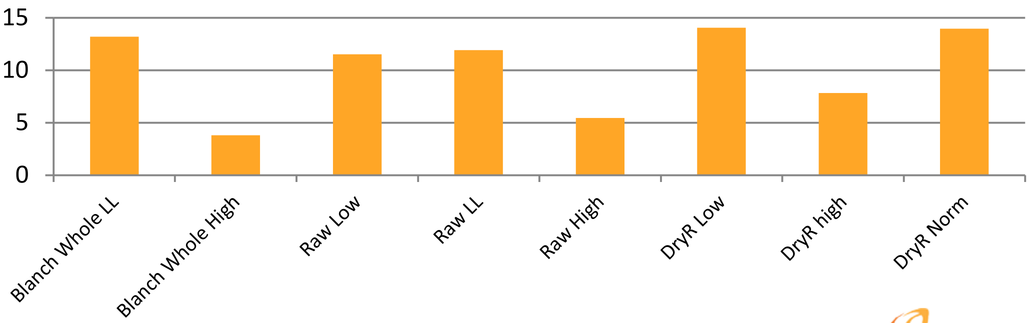
- 113 panelists
  - that had consumed almonds in the last month
  - no food allergies
- 8 whole almonds that spanned the range of the PCA space
- Place the sample in their mouth, bite down and chew with their molars
  - Rated
    - Liking (overall, flavor, texture)
    - Hardness, crispness, crunchiness, toothpacking

Overall Liking

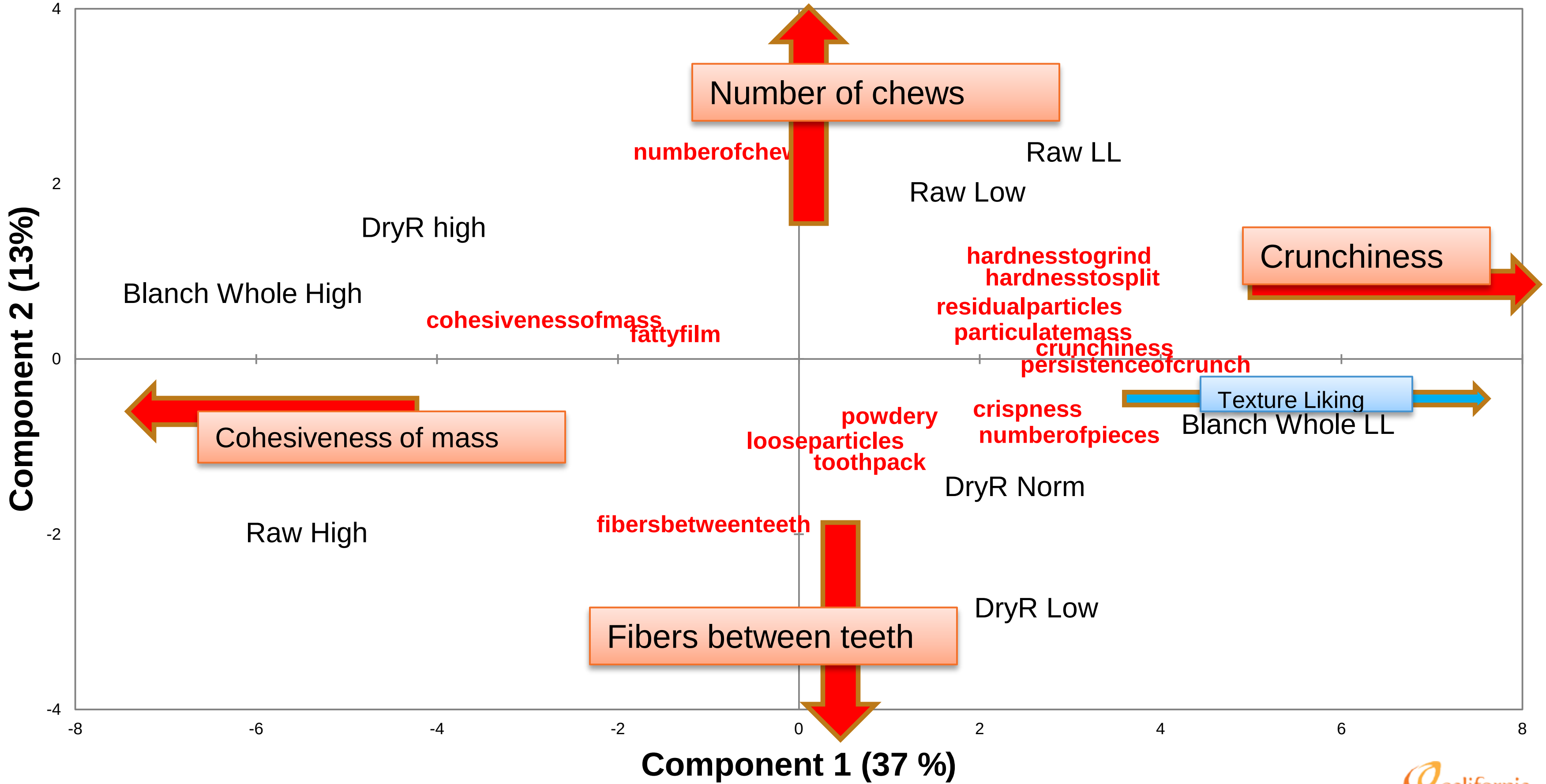


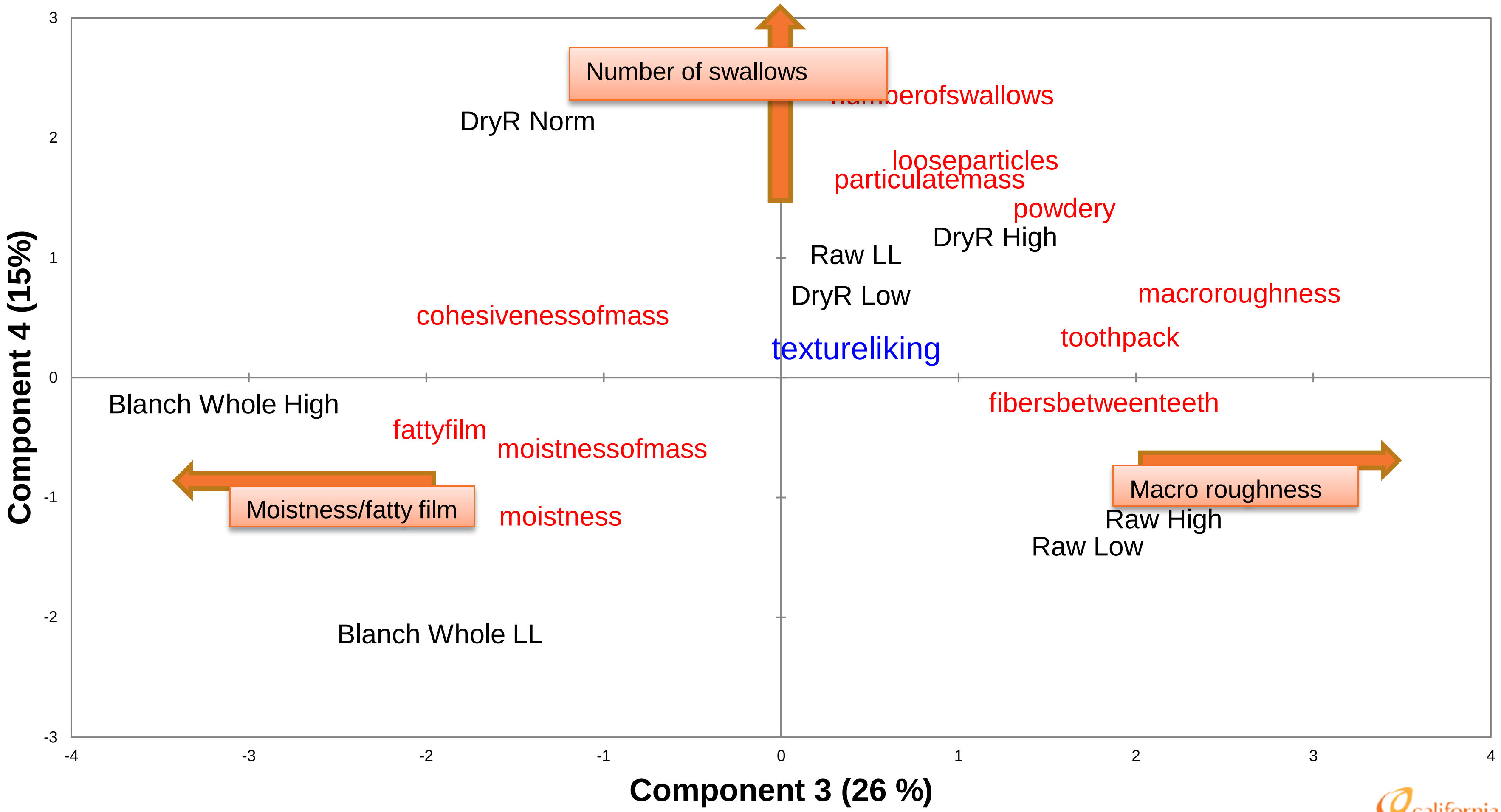
Texture Liking matches overall liking

Texture Liking

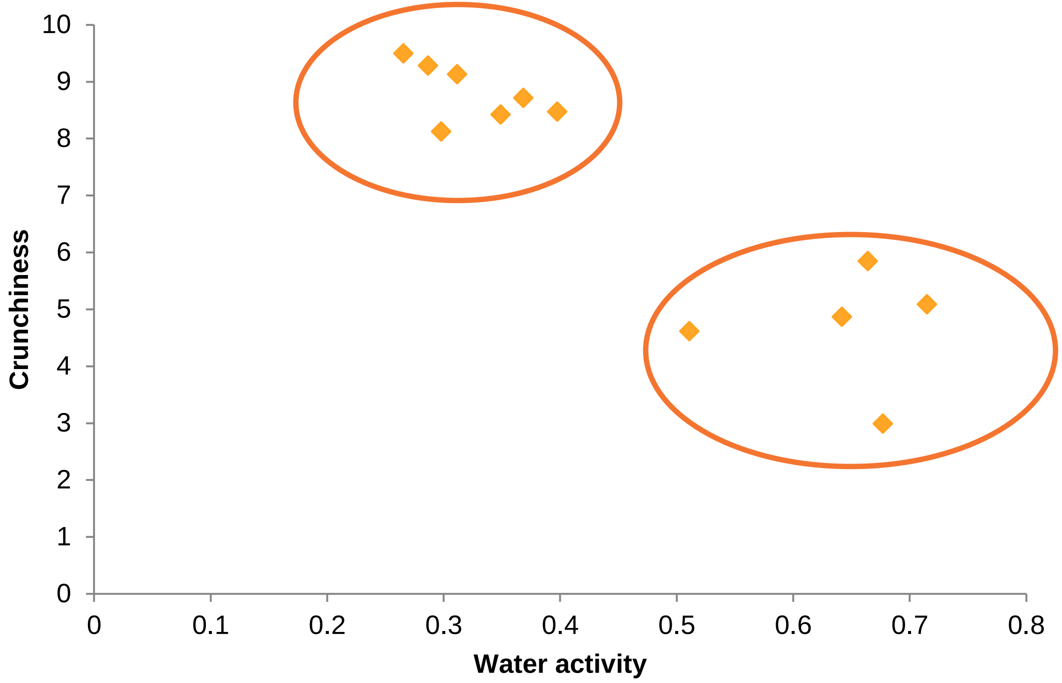


PCA for 8 whole almonds in the consumer test Components 1 & 2




Number of swallows
numberofswallows
DryR Norm
looseparticles
particulatemass
powdery
DryR High
Raw LL
DryR Low
macroroughness
cohesivenessofmass
toothpack
textureliking
Blanch Whole High
fibersbetweenteeth
fattyfilm
moistnessofmass
Macro roughness
Moistness/fatty film
moistness
Raw High
Raw Low
Blanch Whole LL
Component 4 (15%)
Component 3 (26 %)
3
2
1
0
-1
-2
-3
-4
-3
-2
-1
0
1
2
3
4

Water activity vs. crunchiness



Summary

- sliced and slivered almonds had less hardness and less crunchiness than whole almonds
- Crispness, hardness, crunchiness, and persistence of crunch decreased with increasing moisture content
- Consumer texture liking ratings were highly positively correlated with crispness, crunchiness, and persistence of crunch.

Closing Thoughts

- **Continuing Education Credits** are available for many of today's symposiums. To receive CCA credit, you must sign in before and after each individual symposium at the back of each room.



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