ALMOND SENSORY

What are the sensory attributes of almonds?

How does almond variety affect sensory characteristics?

This slidedoc summarizes the latest learnings obtained from research projects funded by the Almond Board of California

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California Almonds are “sweet” varieties

In California, all almond trees growing in commercial orchards produce “sweet” varieties of almonds.

- Almonds can be characterized by 3 flavor phenotypes: **sweet** (non-bitter), **slightly bitter** (semi-bitter), and **bitter**.
- In general, a naturally occurring compound known as *amygdalin* is responsible for bitterness in almonds. Amygdalin is found in almond kernels and in the seeds of stone fruits like apricots.
- Bitter almonds contain high levels of amygdalin (3–5%), whereas only trace levels are found in sweet almond varieties (<0.05% amygdalin) and in slightly bitter varieties (<0.2% amygdalin). Bitter almonds are used mainly in the production of almond pastes and almond-flavored extracts.
- Amygdalin breaks down to release hydrogen cyanide as well as sugars (glucose) and **benzaldehyde**.

Almond characteristics are described by distinctive sensory attributes

Aroma–flavor attributes:

- Includes total intensity, marzipan (benzaldehyde), fruity, sweet, nutty, woody, toasty, earthy, etc.

Texture attributes:

- Include roughness, hardness, fracturability, crunchy, crispy, chewiness, cohesiveness of mass, astringent, etc.

Almonds can be described by **appearance**, **aroma–flavor**, and **texture** attributes:

- Aroma is evaluated by smelling the almonds before chewing
- Flavor is evaluated as the in-mouth flavor impact as the nuts are chewed
- Texture is evaluated for the almond surface, the various chewing stages, and the residual attributes after chewing

A **sensory lexicon** is like a vocabulary of terms that can be used to describe and document the attributes of a product.

Source: Civille et al. (2009), J. Sensory Studies 25: 146-162.

Benzaldehyde is the dominant flavor volatile in **raw** almonds

Major Volatiles in Raw Almonds

Compounds (51)	Aroma
Benzaldehyde	sweet, marzipan
3-Methyl-butanol	alcoholic, fruity, whiskey, banana
3-Methyl-2-butenol	fruity, green, lavender
Benzyl alcohol	floral, phenolic
Hexanal	grassy, fatty, rancid

More than 50 volatile compounds have been identified in **raw** almonds:

- **Benzaldehyde** is the main odor-active volatile contributing to raw almond flavor, although it is found in relatively low levels in sweet almonds.
- Other major volatiles include methyl-butanol, methyl-butenol and benzyl alcohol.
- Some aldehydes found in raw almonds – like hexanal – are less desirable because they are products of lipid oxidation and have a negative effect on almond aroma.

Sources: Xiao et al. (2014), Food Chem. 151: 31-39; Luo et al. (2018), Acta Hortic.1219: 1-8.

Pyrazines—derived from non-enzymatic browning (Maillard reaction)—are the dominant volatiles in **roasted** almonds

Major Volatiles in Roasted Almonds

Compound (91)	Aroma
2 & 3- Methylbutanal	Fruity, chocolate, nutty, malty
2,5-dimethylpyrazine	Coffee, roasted nuts, cocoa
2-Methylpyrazine	Chocolate, roasty, nutty
Acetoin	Sweet, buttery, creamy
Hexanal	grassy, fatty, rancid

More than 90 volatiles have been identified and quantified in **roasted** almonds:

- **Methylpyrazines** are the major volatiles in freshly roasted almonds—these desirable volatiles fade away during storage.
- Aldehydes (like hexanal) are undesirable volatiles from oil oxidation, and increase over time in storage.

Franklin et al. (2017), J. Agric. Food Chem. 65: 2549 -2563.

30 attributes can be used to describe and compare the sensory properties of almond varieties

- **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

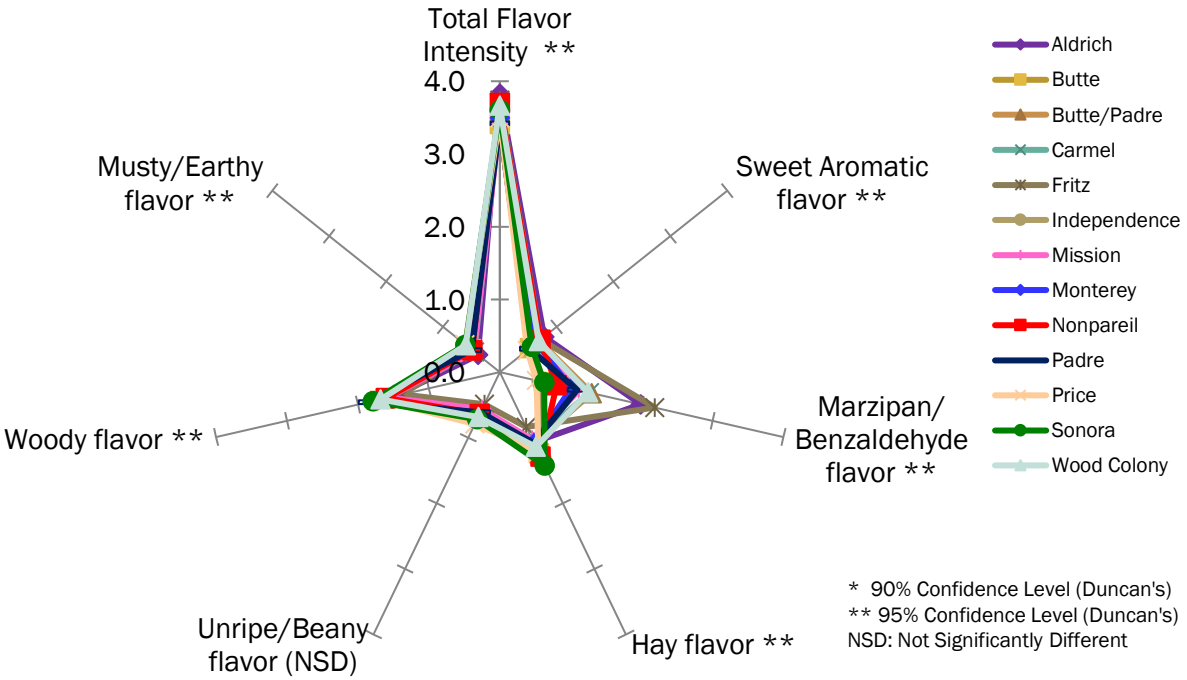
- **Texture – Residual**
  - Amount of Residual Particulate
  - Residual Toothpack
  - Astringent

* Flavor only

A 15-point scale, from “None” to “Extreme” is used in descriptive sensory analysis by trained panelists to assess almonds:

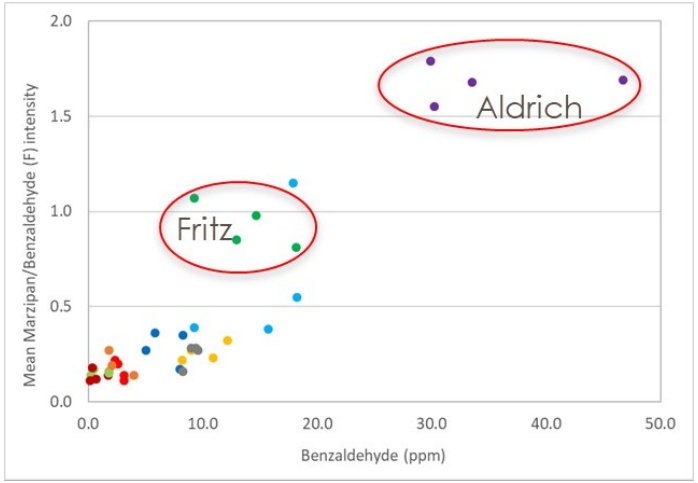
Source: King and Heymann, 2014. Almond Sensory Attribute Training

Benzaldehyde shows greater variation than other **flavor** attributes among California almond varieties



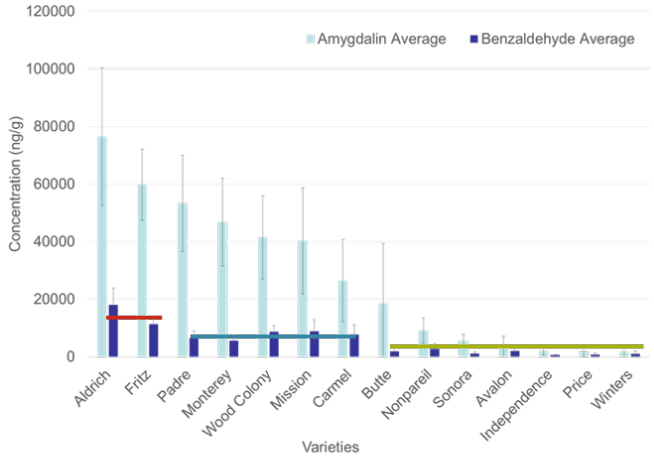
Adapted from COVANCE 2017 report to ABC, Descriptive Analysis of Almonds.

Among California almond varieties, Aldrich and Fritz offer strongest benzaldehyde flavor



Positive correlation of marzipan/benzaldehyde-flavor intensity with benzaldehyde concentration of 40 almond samples in 2016 growing season

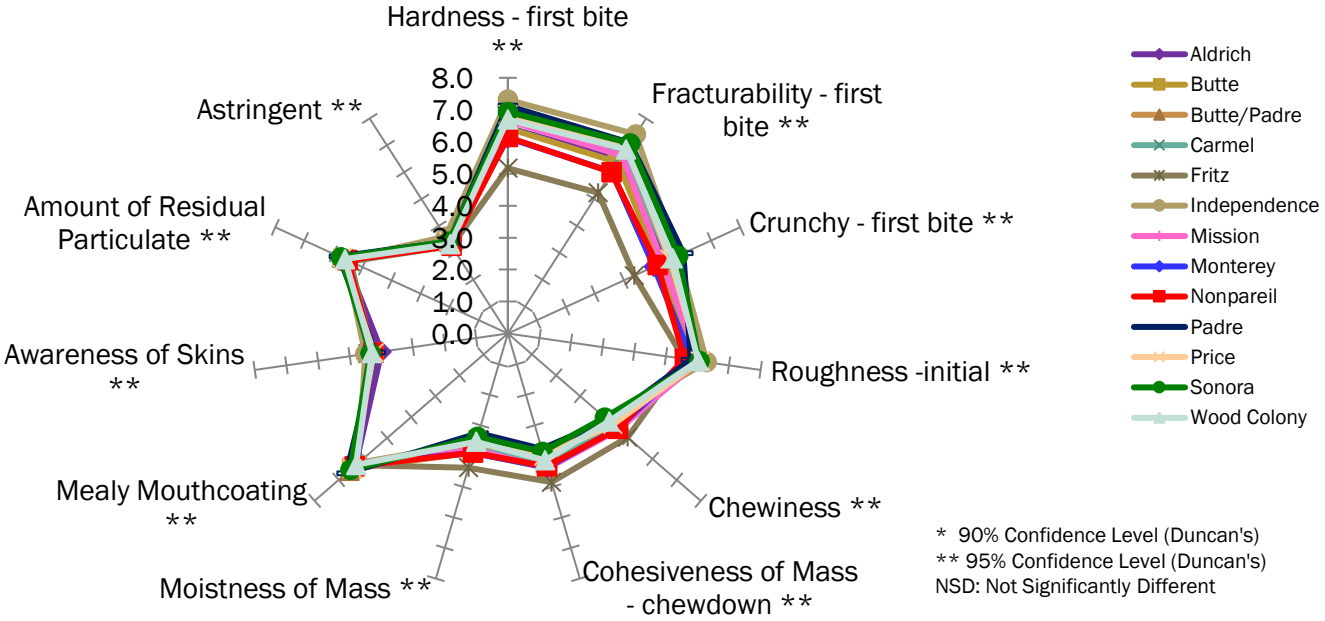
Chemical and sensory analyses link benzaldehyde to marzipan flavor in almonds — benzaldehyde content varies in California almond varieties:



- Amygdalin ranges between 76.50 ± 23.99 - 1.77 ± 1.74 mg/Kg
- Benzaldehyde ranges between 17,995 ± 5,887 - 587.7 ± 272.9 ng/g

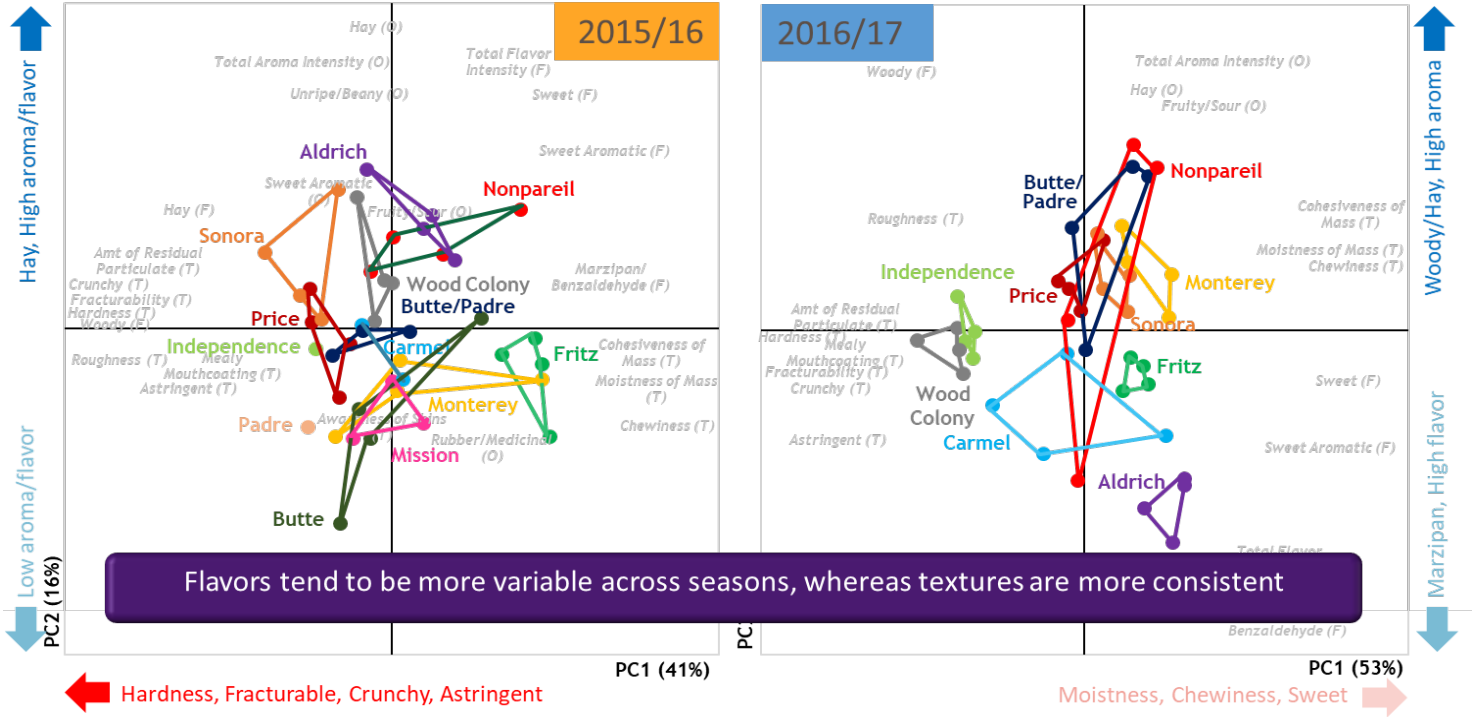
Sources: Luo et al. (2018), Acta Hortic. 1219: 1-8; King et al. (2019), J. Agric. Food Chem. 67: 3229-3241.

Hardness, fracturability, crunchy, cohesiveness and moistness of mass show greater variation than other **texture** attributes among almond varieties



Adapted from COVANCE 2017 report to ABC, Descriptive Analysis of Almonds

Sensory profiles of almond varieties show some variability across seasons



Source: King et al. (2019), J. Agric. Food Chem. 67: 3229-3241.

Sensory profiles of major California almond varieties

Varieties with more consistent sensory profiles across seasons include:

- **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

Varieties with higher variability in sensory profiles among samples and across seasons:

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

Source: King et al. (2019), J. Agric. Food Chem. 67: 3229-3241.

In **raw** almonds: moisture content drives texture properties; benzaldehyde drives flavor properties

Moisture content is positively associated with moistness, chewiness and cohesiveness of mass; and negatively associated with fracturability, hardness and crunchiness.

- High humidity affects almond texture, resulting in increased moistness of mass and cohesiveness of mass, and decreased hardness, crispness, crunchiness, fracturability, persistence of crunch and particulate mass.
- Fracturability is positively associated with volatile compounds: acetoin, 1-butanol, 2-butanone, ethyl acetate.
- Flavor differentiates the samples less than texture, and was found to be less consistent across the growing seasons—indicates that flavor is influenced more by external factors, such as orchard practices or environmental factors, than varietal composition.

Marzipan/benzaldehyde flavor is positively associated with amygdalin, benzaldehyde, phenylethyl alcohol and benzyl alcohol; and negatively associated with hexanal and pentanal (when chemical analyses overlaid).

- Aldrich and Fritz higher in total flavor intensity and marzipan/benzaldehyde flavor, associated with higher concentrations of amygdalin, benzaldehyde, phenylethyl alcohol and benzyl alcohol.

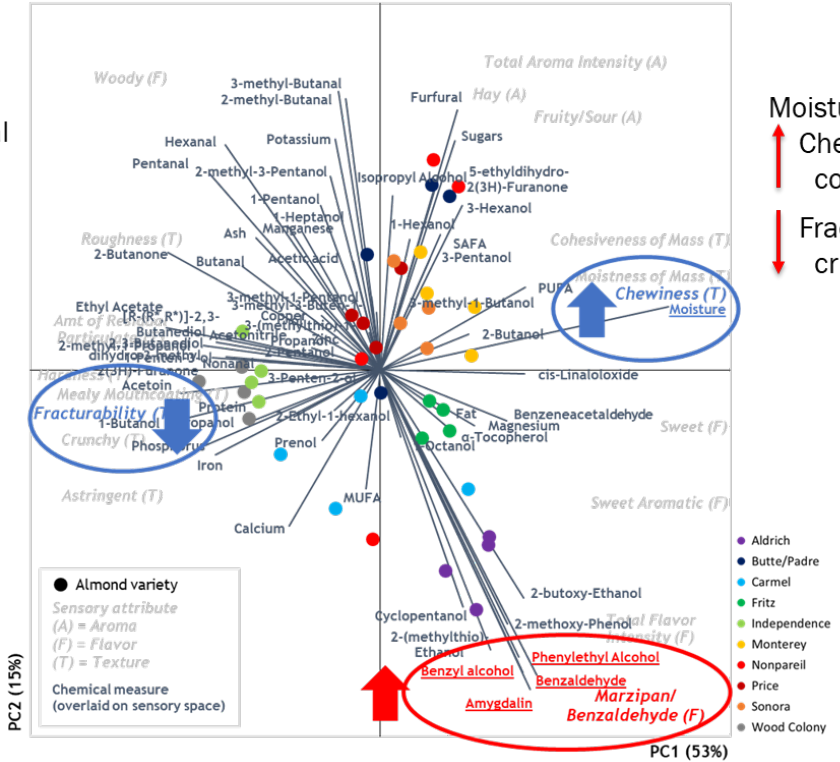
Source: King et al. (2019), J. Agric. Food Chem. 67: 3229-3241.

Sensory drivers in **raw** almonds: moisture content and benzaldehyde

Hexanal, pentanal

↓

Marzipan/ benzaldehyde flavor



Moisture:

↑ Chewiness, mass moistness and cohesiveness

↓ Fracturability, hardness, crunchiness

Marzipan/benzaldehyde flavor

↑

Benzaldehyde, amygdalin, benzyl alcohol, phenylethyl alcohol

Source: King et al. (2019), J. Agric. Food Chem. 67: 3229-3241.

In **roasted** almonds: fresh roasted flavor drives consumer liking; oxidized volatiles lead to consumer rejection

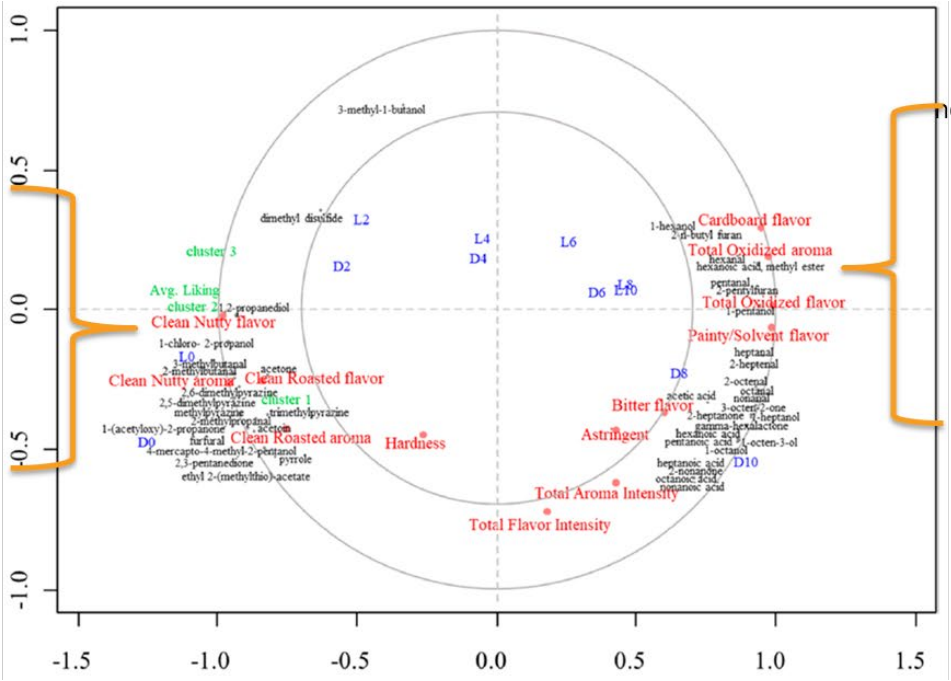
Consumer liking

↑

Clean nutty or roasted flavor or aroma

↑

2- & 3-methylbutananal
2,5-dimethylpyrazine



Hexanal, pentanal, nonanal, octanal, acetic acid, etc.

↓

Painty or cardboard flavor, total oxidized flavor or aroma

↓

Consumer rejection

Source: Franklin et al. (2018), J. Agric. Food Chem. 66: 1222 -1232.

In **raw**, **blanched** & **roasted** almond forms: crispness, crunchiness, hardness and particulate mass decrease with increasing moisture content

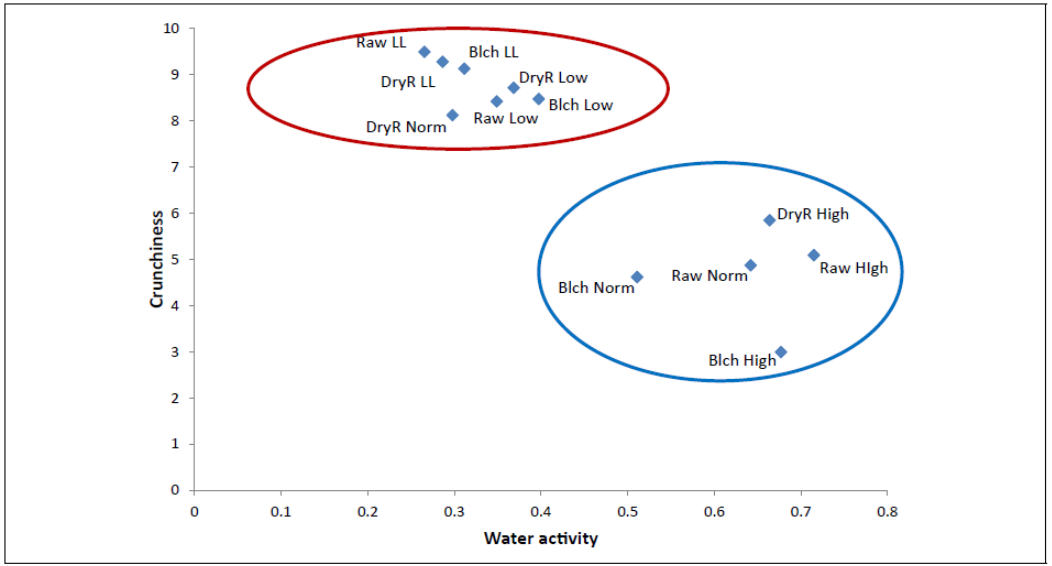


Figure 5–Water activity compared with crunchiness. Points represent the mean sensory scores for crunchiness of whole almonds at specific water activities. Crunchiness ratings were made on a 20 point scale where 0 = none and 20 = intense. Abbreviations by each point note the almond and treatment that point represents. The red oval encompasses the products with similarly high levels of crunchiness; the blue oval encompasses the products with "similarly" low levels of crunchiness.

Further decreasing moisture level below 4% (or a_w <0.4) does not appear to increase crunchiness

- Water activities above 0.3–0.4 can be negative to crispness/crunchiness

Source: Vickers et al. (2014), J. Food Sci. 79: 1399-1406.

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