# growing ADVANTAGE
## The Almond Conference

# Almond Quality: Everything You Want to Know About Retaining Almond Crunch and Flavor


Brian Dunning, Blue Diamond Growers (Moderator)

Guangwei Huang, ABC (Moderator)

Fanbin Kong, University of Georgia

Alyson Mitchell, UC Davis

Ellie King, National Food Laboratory

Dawn Chapman, National Food Laboratory

Ron Pegg, University of Georgia

# Almond Quality: Everything You Want to Know About Retaining Almond Crunch and Flavor

12:30 –2:30pm, December 9, 2014

Room 306-307, Sacramento Convention Center

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# ABC Almond Quality and Food Safety Program – Four Pillars

- Research
  - Food Safety
  - Almond Quality
- Survey and Monitor
  - Pathogen
  - Pesticide Residues
  - Aflatoxin
  - Heavy Metals:
- Education
  - Annual AQFS Symposium
  - Ongoing Industry Workshops and Seminars
  - Educational Programs
  - Tools and Factsheets
- Program Development + Compliance
  - Annual AQFS Symposium
  - Ongoing Industry Workshops and Seminars
  - Educational Programs
  - Tools and Factsheets

Revised AQFS Mission: To ensure the quality and safety of California Almonds, through science, research, leadership and industry-wide education

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# Everything You Want to Know About Retaining Almond Crunch and Flavor

- Dr. Fanbin Kong, University of Georgia 12:30 --1:00pm
  - Impact of storage conditions on physical properties of almonds
- Dr. Alyson Mitchell, University of California, Davis 1:00 – 1:30pm
  - The Chemistry of Rancidity in Almonds
- Drs. Ellie King and Dawn Chapman, The National Food Laboratory 1:30 – 2:00pm
  - Profiling Sensory Differences in Almond Varieties
- Dr. Ron Pegg, University of Georgia 2:00 – 2:30pm
  - Shelf-life of Nonpareil Almonds: Chemical and Textural Attributes and Their Association with Consumer Rejection


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# Fanbin Kong,
# University of Georgia


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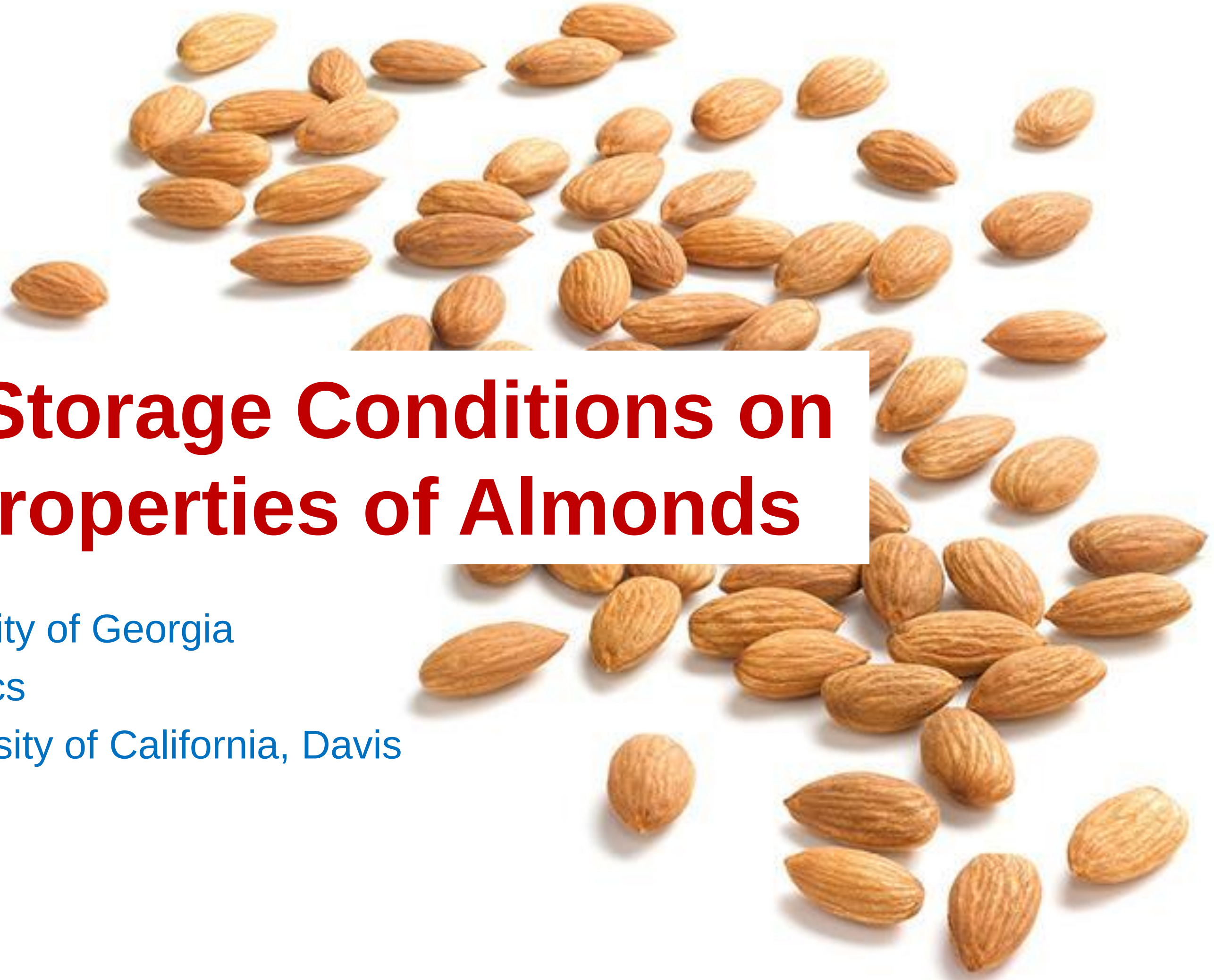
# Impact of Storage Conditions on Physical Properties of Almonds




Fanbin Kong, University of Georgia

Li Taitano, RF Biocidics

R. Paul Singh, University of California, Davis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# Quality deterioration of almonds

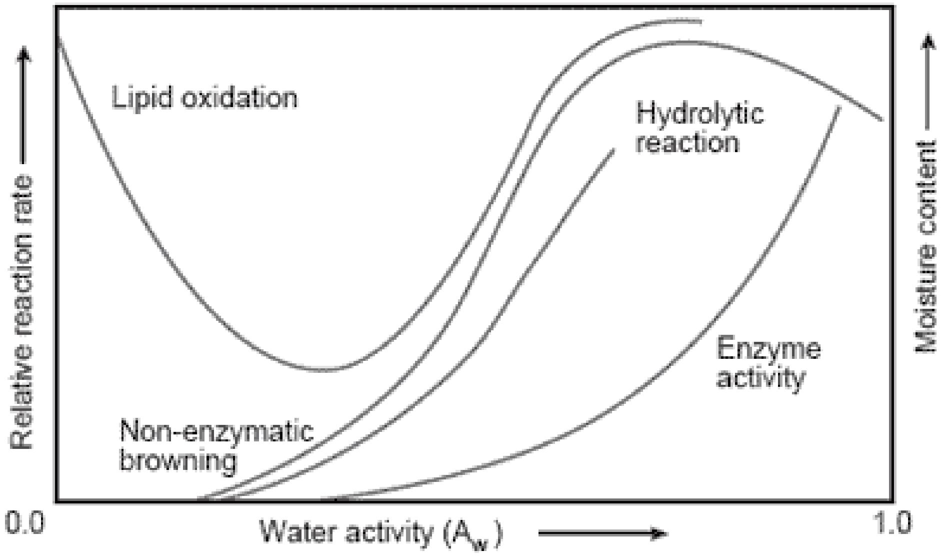
- Mode of deterioration:
  - Rancidity due to lipid oxidation
  - Loss of crispness due to moisture absorption
  - Microbial growth
- Critical environmental factors
  - Temperature
  - Relative Humidity
  - Oxygen

# Water activity

- Water activity ($a_w$) is defined as the vapor pressure of water above a sample (p) divided by that of pure water at the same temperature ($p_0$),

$$a_w = \frac{P}{P_0}$$

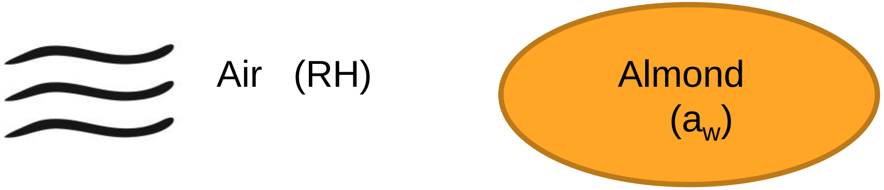
- Water activity of food affect microbial growth as well as the rate of chemical and physical deteriorative reactions.
  - microbial growth occur at $a_w > 0.6$.
  - lipid oxidation occurs below $a_w > 0.30$.
  - Maillard browning reaction accelerates as the $a_w > 0.25\text{-}0.3$.




*Reaction rates in foods as a function of water activity*

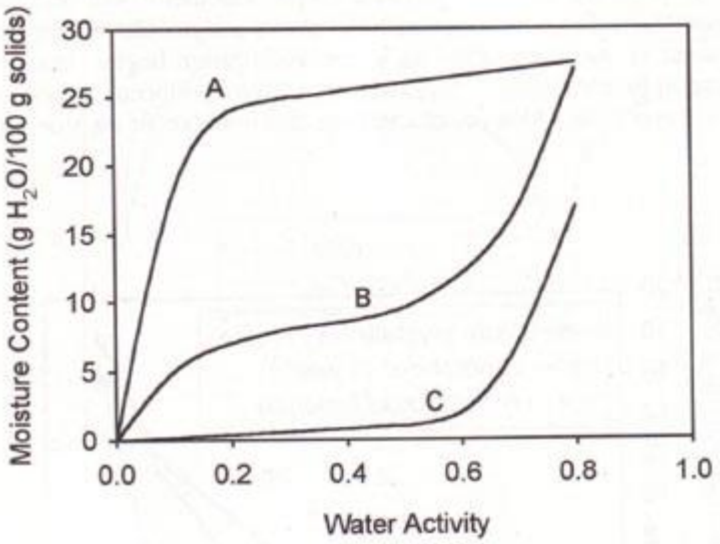
# Moisture migration

- The difference between the relative humidity (RH) of the surrounding environment and water activity ($a_w$) of the food determines whether a food gains or loses moisture during storage
  - RH> $a_w$, food will absorb moisture from air
  - RH< $a_w$, food will lose moisture
  - At equilibrium, RH= $a_w$



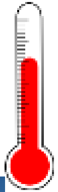
# Adsorption isotherms

- The extent of moisture migration can be described by adsorption isotherms
  - the amount of water on the food material as a function of its water activity at constant temperature.
- Various empirical mathematical models are developed to describe the sorption isotherms



# Effect of temperature

- Increasing temperature generally increases the rate of chemical reactions
  - result in faster deterioration.
- The rate of water absorption increases at high temperature
  - due to increased diffusivity coefficient
- Storage losses under fluctuating temperature condition can be significantly greater than that at the constant average temperature



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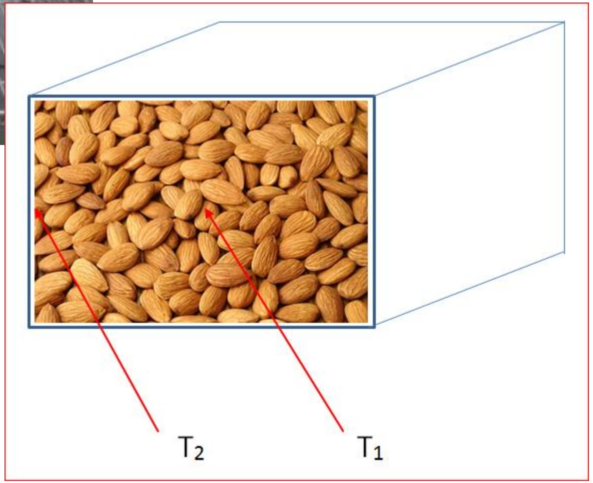
# Objectives of our research

- How change of ambient temperature affect temperature of almonds packed in a cardboard box;
- How temperature and relative humidity affect moisture migration in almonds and their texture
  - Determine moisture adsorption isotherms of almonds
  - Measure almond texture
- Develop predictive modeling to estimate the temperature changes and texture of almonds during transportation and storage.

# California grown varieties

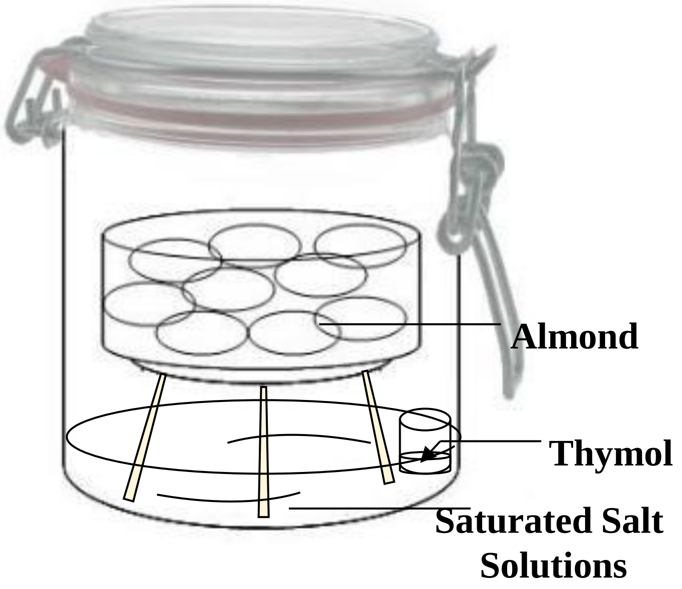
| | |
|---|---|
| Nonpareil | Np: Nonpareil Pasteurized |
| | Nup: unpasteurized |
| Monterey | Mp: Pasteurized |
| | Mup: unpasteurized |
| | Mb: blanched |
| Carmel | Cp: Pasteurized |
| | Cb: blanched |
| Butte | unpasteurized |

# Temperature measurement



# Storage device

- Storage jars holding almonds and different saturated salt solutions in the incubator
- The weight of almonds at different equilibrium relative humilities and temperatures were measured until samples reached equilibrium moisture content




*Experimental apparatus for the adsorption isotherms (Thymol used for $a_w$>0.7)*

# Storage conditions

- Temperatures: 7, 25, 35, 50 °C
- Relative humidity (RH) range: 11%~ 97% by nine different saturated salt solutions
- Corresponding water activity ($a_w$) is obtainable from the RH according to

$$a_w = \frac{RH}{100}$$

# Instruments

- Determination of almond thermal properties: density, thermal conductivity, specific heat capacity, thermal diffusivity

*Kd2 Pro Thermal Properties Analyzer*

*Mettler-Toledo Differential Scanning Calorimeter(DSC)*

# Instruments

Low-Temperature
Incubator Model 815

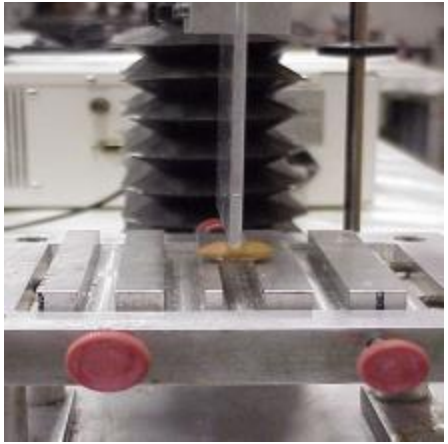

Aqualab CX-2
Water Activity Meter

TA.XT2 Texture analyzer

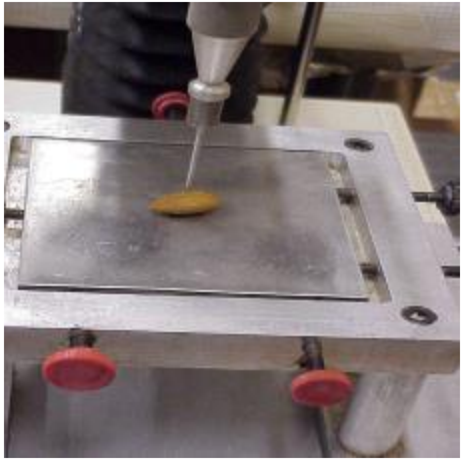
# Measurement of textural properties

I. Compression test

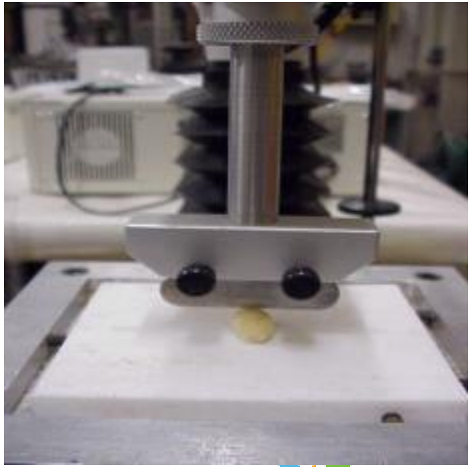
II. Three-point bending test



III. Penetration test

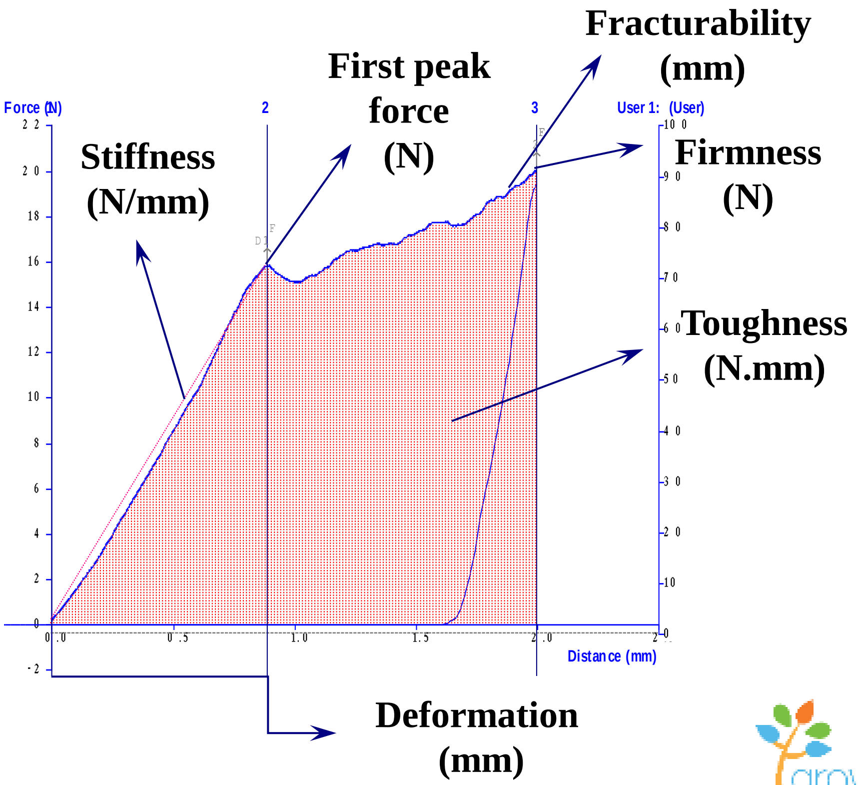


IV. Cutting test by using a craft knife



# Penetration test

- Firmness (N): The maximum force in the curve was used to indicate the hardness of the almond;
- Fracturability (mm):  The linear distance of the curve;
- Toughness (N.mm): The area under the curve;
- Stiffness (N/mm): The gradient of the first force peak;
- Deformation (mm): The distance at the first peak.



# Mathematical models

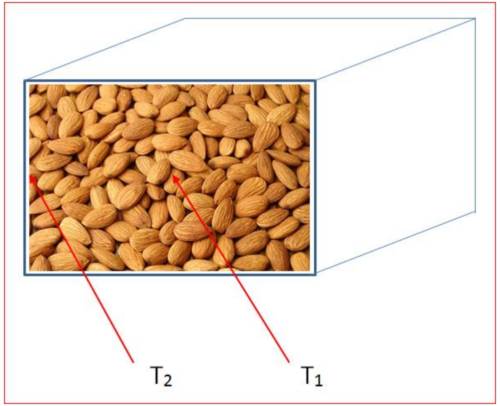
- Kinetic model (Fick's second law)
  - to predict moisture changes of almonds with time at different temperatures and water activities
- Sorption isotherm model (GAB model)
  - to correlate the data of equilibrium moisture of almonds and the water activity
- Textural Model (Fermi's distribution)
  - to describe textural changes of almonds at different water activities and temperatures

# Predictive modeling

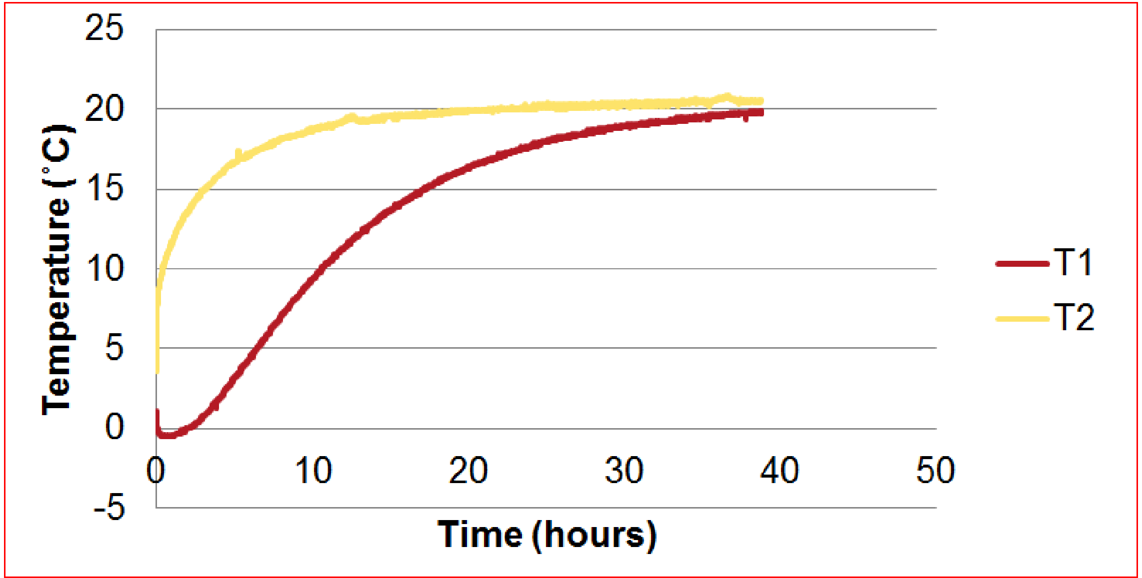
- Develop a model to predict temperature changes in packaged almonds in response to ambient temperature
- Develop a model to predict textural changes in almonds under constant and dynamic storage conditions

# Results

# 25 lbs cardboard box with plastic liner



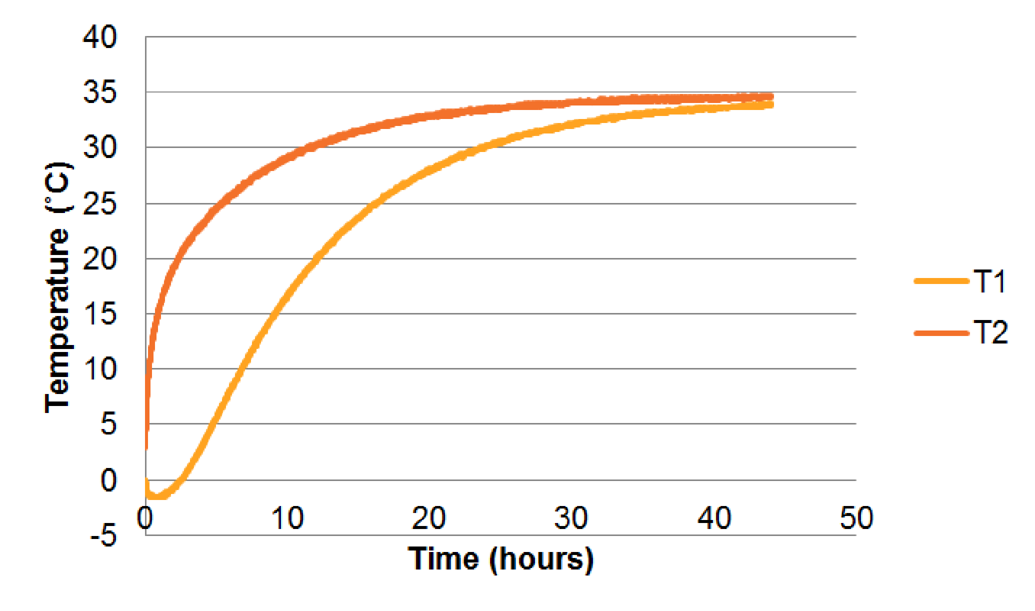

## Ambient temperature from 3 ˚C to 21 ˚C

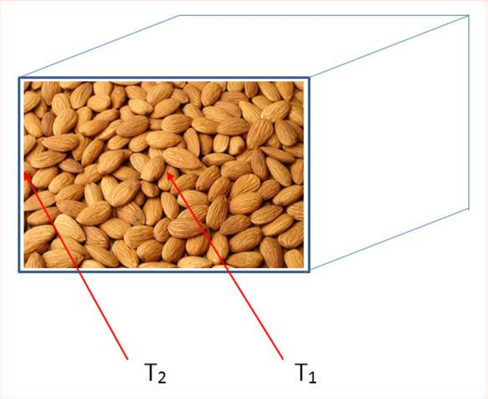



- T1 reached 10, and 15 ˚C after 11 and 17 hours
- T2 reached 10 and 15 ˚C after 20 min, and 3 hours

# 25 lbs cardboard box with plastic liner

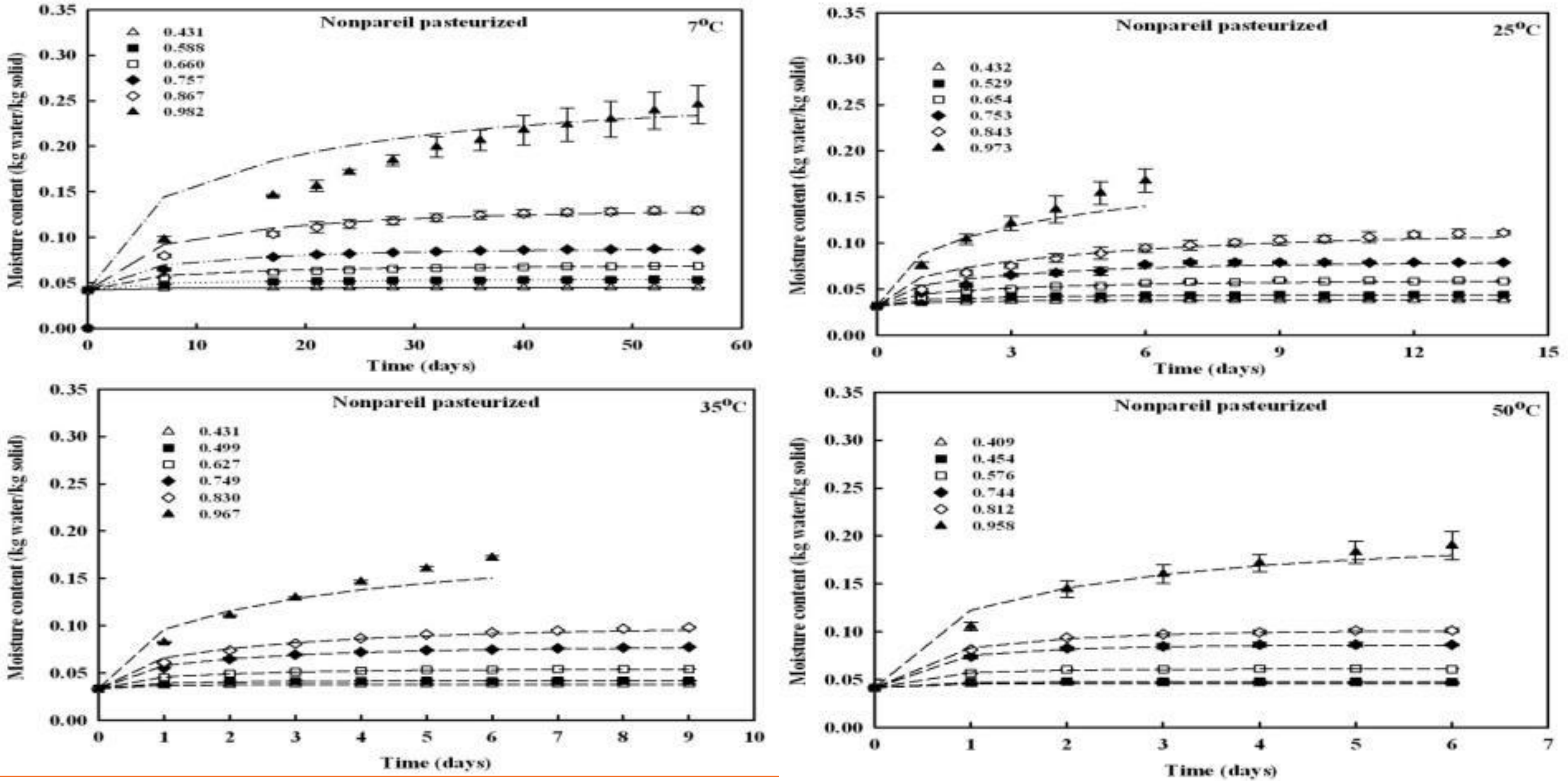
## Ambient temperature from 3 ˚C to 35 ˚C



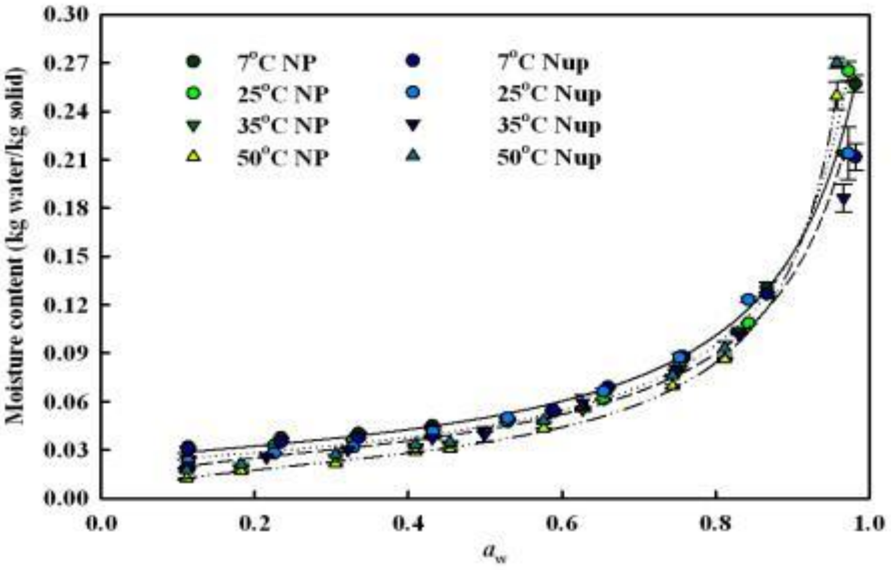



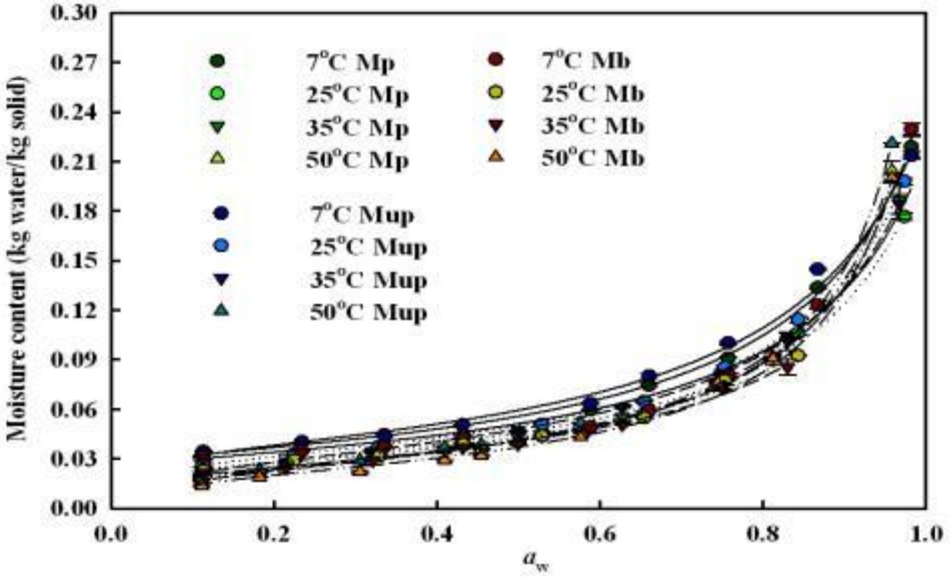

- $T_1$ increased to 10, 20 and 30 ˚C after 7, 12, and 24 hours
- $T_2$ increased to 10, 20 and 30 ˚C after 20 min, 2 hour, and 12 hours

# Experimental and Predicted Moisture Content in Almonds during storage.



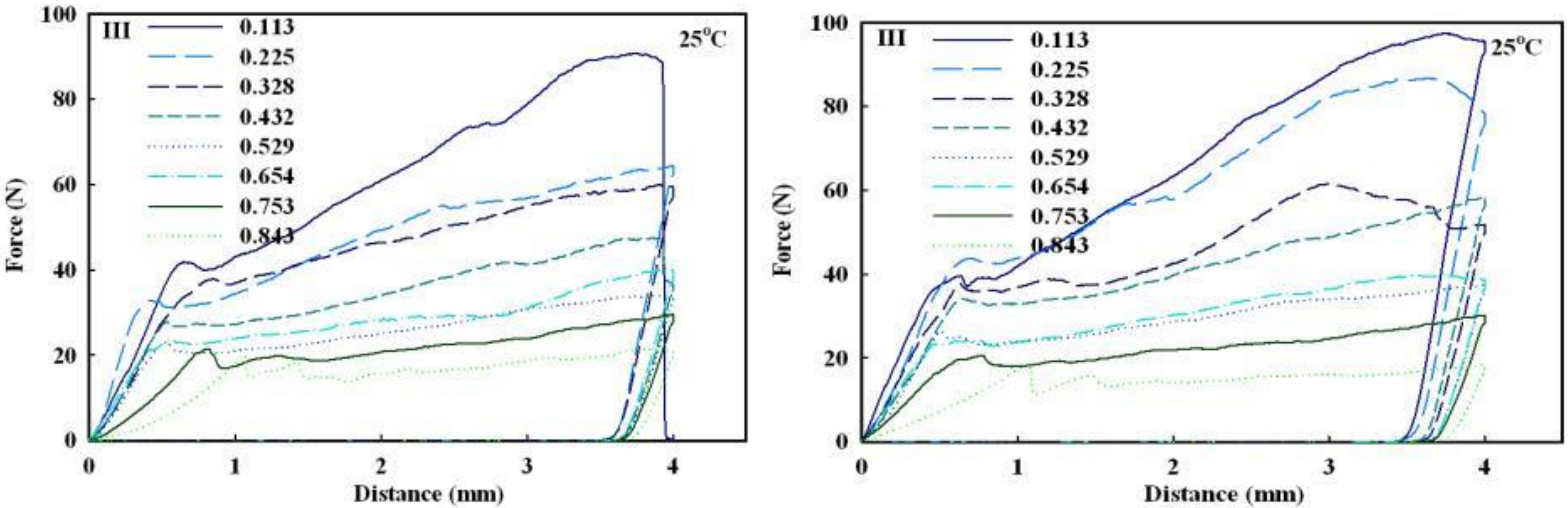
# Moisture adsorption isotherm of almond




*Experimental and predicted data of equilibrium moisture content (EMC) of Nonpareil almonds (lines correspond to the GAB model)*

# Texture analysis




*Representative Force-Distance curves obtained from penetration test of Monterey almonds stored at 25˚C*

# Predictive modeling of almond texture

http://rpaulsingh.com/abc/index.html

Select the variety and type of almonds

Input values: Temperature, $a_w$, time (t) and initial moisture content ($m_0$)

Calculate $m_e$ from GAB equation at certain temperature and $a_w$

Calculate moisture content at time (t) from mass transfer equation

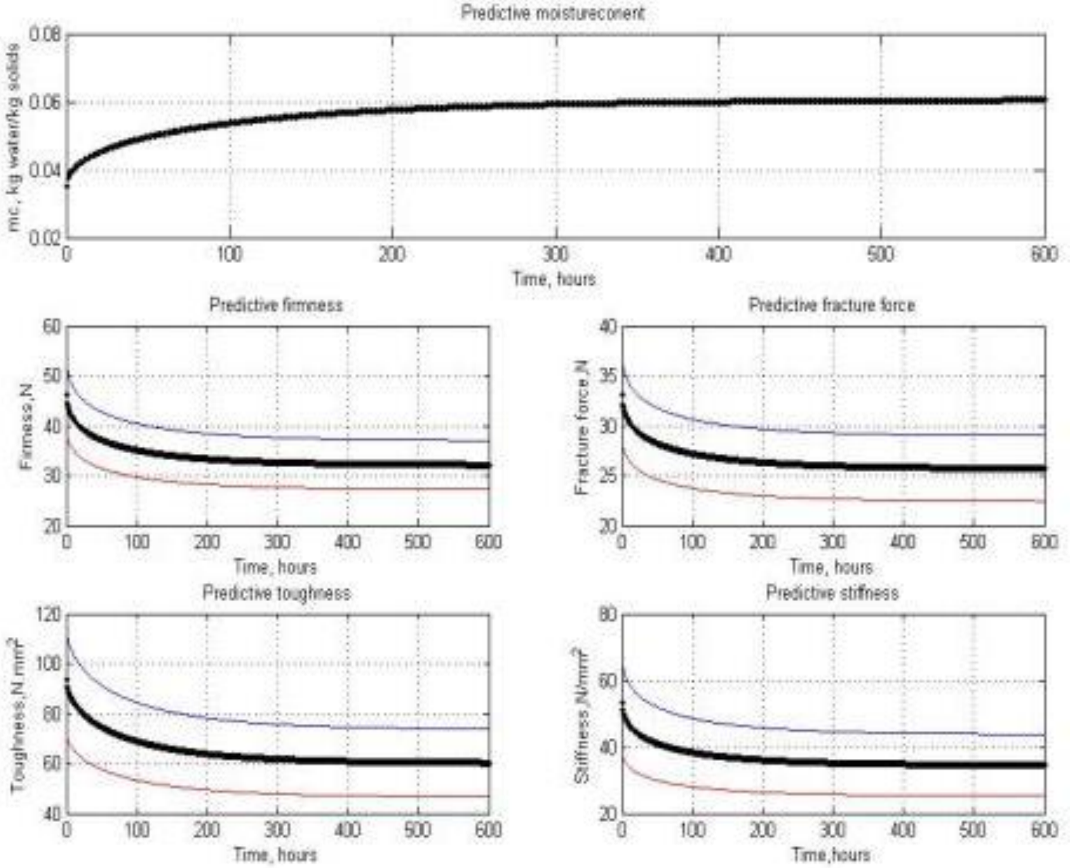
Predict texture parameters from texture empirical models

# Input

Variety: Nonpareil
Type: pasteurized
Temperature: 25° C
$a_w$: 0.65
Storage period: 25 day
Initial $m_c$: 0.035 kg water/kg solid

# Output

After storage 25 days, the predictive moisture content is 0.0605 kg water/kg solid;
Predictive firmness is 32.2 N, range from 27.3 N to 37.1 N;
Predictive fracture force is 25.7 N, range from 22.5 N to 29.0 N;
Predictive toughness is 60.3 $N.mm^2$, range from 46.7 $N.mm^2$ to 73.9 $N.mm^2$;
Predictive stiffness is 34.5 $N/mm^2$, range from 25.7 $N/mm^2$ to 43.8 $N/mm^2$.




http://rpaulsingh.com/abc/index.html

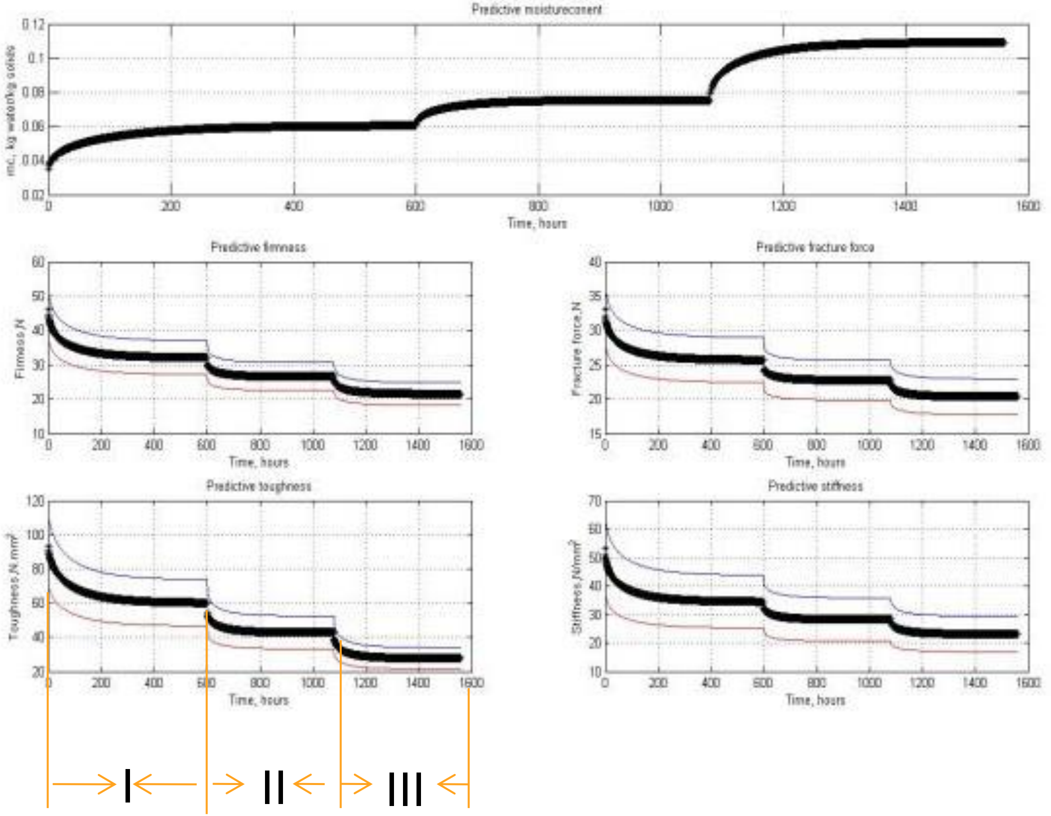
# Input

Variety: Nonpareil
Type: pasteurized

I . Temperature: 25° C; $a_w$: 0.65; Storage period: 25 day; Initial $m_c$: 0.0350 kg water/kg solid.

II. Temperature: 35° C; $a_w$: 0.75; Storage period: 20 day; Initial $m_c$: 0.0605 kg water/kg solid.

III. Temperature: 40° C; $a_w$: 0.85; Storage period: 20 day; Initial $m_c$: 0.0755 kg water/kg solid.




http://rpaulsingh.com/abc/index.html

# Conclusion

- Moisture sorption isotherms were developed for major California almond varieties
- Texture of almonds at different EMC were determined
- Temperature changes of packaged almonds were measured as affected by ambient temperature and packaging dimensions
- An online Adobe Flush model was developed
  - predict how storage humidity and temperature could affect almond moisture and texture
- Ongoing studies
  - developing computational modeling to predict temperature changes in packaged almonds

## Thank you for your attention!

*Questions?*

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# Alyson Mitchell,
# UC Davis

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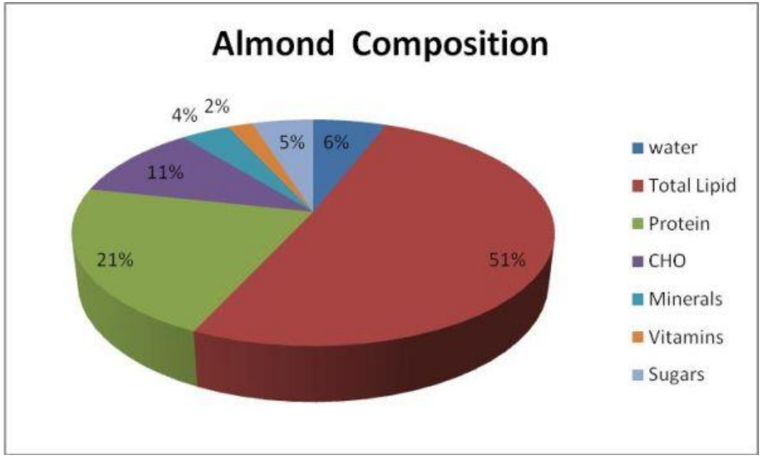
# The Chemistry of Rancidity in Almonds

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

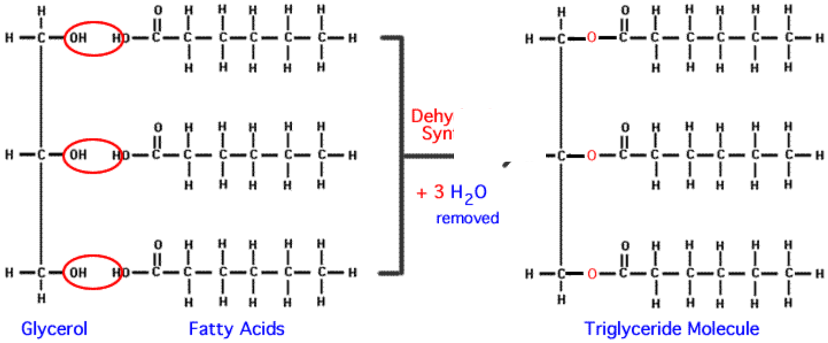
The Almond Conference
Almond Quality Workshop
Dec 9th, 2014
Sacramento CA

# What is Almond Oil?

- Almonds are composed of about 51-60% oil
  - Varies depending upon the cultivar

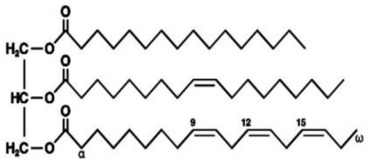



- Almond oil is composed of triglycerides
  - A triglyceride is 3 fatty acid molecules attached to a molecule of glycerol



# Lipid Composition of Almond Oil

- Fatty acids can be saturated (no double bonds) or saturated (double bonds)



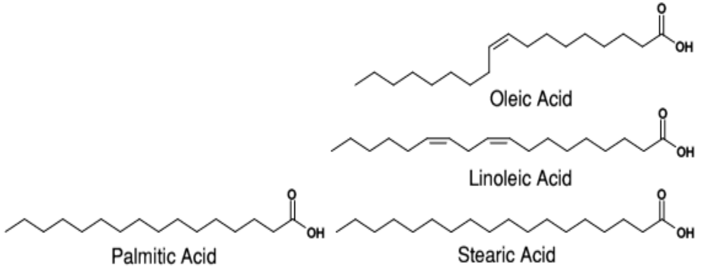

Saturated fat

Monounsaturated fat

Polyunsaturated fat

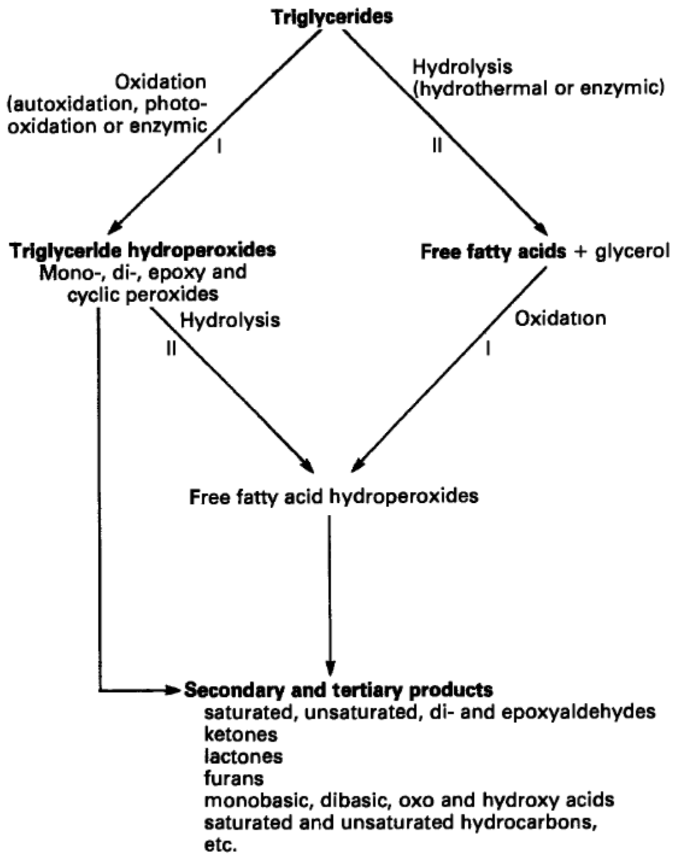
- The primary fatty acids in almonds are:

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



# Rancidity

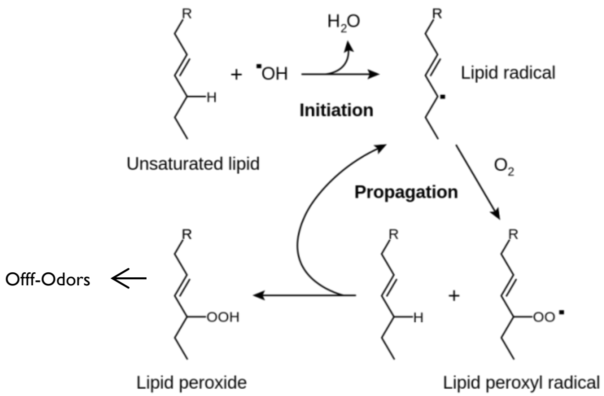
- Rancidity is the unpalatable odor and flavor of deteriorating edible fats and oils in foods
- Rancidity occurs via two chemical reactions:
- Oxidation
  - Oxygen attack of the triglycerides
- Hydrolysis
  - Addition of *water* across triglycerides and release of Fatty acids (FFAs)




**Scheme 1.** Over-all reaction scheme for (I) oxidative and (II) hydrolytic rancidity

*Robards et al., Analyst, 1988 v 113*

# Oxidative Rancidity:
## *Three Phase Process*




1. Initiation Phase
   - Molecular oxygen combines with unsaturated fatty acids to produce hydroperoxides and free radicals
   - Requires an initiator (e.g. heat, light, metals, enzymes, etc.,)
2. Propagation Phase (autoxidation phase)
   - The reactive products of the initiation phase react with additional lipid molecules to form new reactive lipids
3. Termination Phase
   - Lipid radicals react with each other or breakdown to form relatively unreactive compounds including aldehydes and ketones (volatile odors)

# Rancidity in Almonds

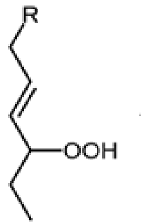
- Rancidity in almonds occurs primarily via the oxidation of oleic [18:1] and linoleic [18:2] acids
  - Initiated by exposure to heat (pasteurization, blanching, roasting, etc.,), or oxygen exposure (e.g. during storage)
- Primary lipid oxidation products include:
  - Lipid peroxides and conjugated dienes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

# Measuring Rancidity

- Although rancidity is one of the most pressing problems confronting processors, there is no completely objective chemical method for determining rancidity
- Industry relies on several analytical methods for routine estimates of oxidation in almonds however, there is no uniform or standard method for detecting oxidative changes
- The biggest challenge:
  - Lipid oxidation is a dynamic process and levels of chemical markers of lipid oxidation change throughout the lipid oxidation process
  - Each method measures something different

# Chemical Measures

*moving analytical targets*




Lipid peroxide

## I. Oxidative Rancidity:

- Peroxide Value (PV)
  - Lipid peroxides are the first product of oxidation and are used as an indicator of the early oxidative changes
  - Measures initial stages of rancidity
  - Almonds PV < 5 meq/Kg is considered the benchmark
- However:
  - PV levels decrease as oxidation progresses as lipid peroxides break down
    - Low levels can be present when there is extensive lipid oxidation

# Peroxide Values in Aged CA Almonds

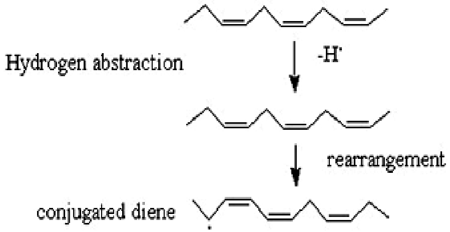
| Monterey (raw) meq/kg of oil | Nonpareil (raw) meq/kg of oil | Fritz (raw) meq/kg of oil | Butte (roasted)* meq/kg of oil |
|---|---|---|---|
| 0.577 ± .192 | 0.788 ± 0.088 | 0.738 ± .171 | 6.715 ± .133 |

- All samples were in refrigerated storage for 24 months before analysis
- *Aged samples were roasted at 190 C for 13 minutes, and analyzed within 48 hours
- Based upon triplicate analysis

*PV < 5 meq/Kg*

# Chemical Measures

*moving analytical targets*




- Conjugated Dienes (CDs)
  - Measures *initial stages* of rancidity
    - When polyunsaturated fatty acids are oxidized, they rearrange to form CDs
    - CDs absorb UV light at 232–234 nm which can be measured
    - The oxidation of linoleic acid is being measured in almonds
  - However:
    - CD levels can decrease as oxidation progresses (decompose)

# Conjugated Diene Levels in Aged CA Almonds

| Monterey (raw) | Nonpareil (raw) | Fritz (raw) |
|---|---|---|
| 0.197 $\pm$ .001 | 0.166 $\pm$ 0.001 | 0.181 $\pm$ .001 |

- All samples were  in refrigerated storage for 24 months before analysis
- Based upon triplicate analysis
- No significant difference between the groups

- No common industry standard exists for CD values in almonds

# Chemical Measures

*moving analytical target*

- Almond Volatiles
  - Measures the later stages of oxidation
    - Lipid peroxides breakdown to form many volatile compounds
    - Generated during roasting for flavor
- Hexanal
  - Most commonly measured secondary product of lipid oxidation
  - No common industry standard for hexanal in almonds
  - A wide range of volatile compounds exist in raw, roasted, and stored almonds

# Chemical Measures
*moving analytical targets*

## II. Hydrolytic Rancidity:

- Free Fatty Acids (FFA):
  - Triglycerides hydrolytically breakdown into FFAs
  - Reported as % by mass of free fatty acids expressed as oleic acid
- For almonds the industry standard is $< 1.5\%$ FFAs
  - Found to correlate with sensory evaluation in butter
  - No studies in almonds

# Free Fatty Acid Levels in Aged CA Almonds

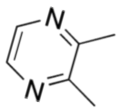
| **Monterey (raw)** % Oleic | **Nonpareil (raw)** % Oleic | **Fritz (raw)** % Oleic | **Butte (roasted)*** % Oleic |
|---|---|---|---|
| 0.084 ± .007 | 1.721 ± 0.078 | 0.054 ± .003 | 0.106 ± .001 |

- All samples were  in refrigerated storage for 24 months before analysis
- Samples were analyzed in triplicate
- *Aged samples were roasted at 190 C for 13 minutes and analyzed within 48 hours

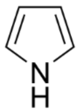
< 1.5% FFAs

# Measuring Volatiles in Almonds

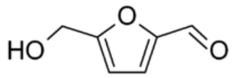
- Limited research available on the composition of volatiles in raw and roasted almonds
  - Takei et al., 1974
    - Solvent extraction
  - L. Vazquez-Araujo, et al., 2008, 2009
    - Simultaneous steam distillation extraction



- Limited information on volatiles changes during storage



- Over the past 3 years we have developed sensitive GC/MS methods for measuring almond volatiles and characterized them in raw, roasted and stored almonds



# Experimental Design

- Measure the impact of roasting and storage on volatile composition
- Early markers of rancidity development
  - *Prunus dulcis* cv. Butte/Padre
  - Dry roasting temperature: 138°C
  - Roasting Time:  28 min, 33 min and 38 mins
- Storage Conditions
  - Temperature: 35°C
  - Humidity:   Ambient and 65% RH
  - Time: Evaluated at 0, 2, 4, 6, 8, 10, 12, 16, 20, 24 weeks
- Analysis:
  - Headspace solid-phase micro-extraction (HS-SPME)
    - *No solvents, heat or artifact generation*
  - GC/MS

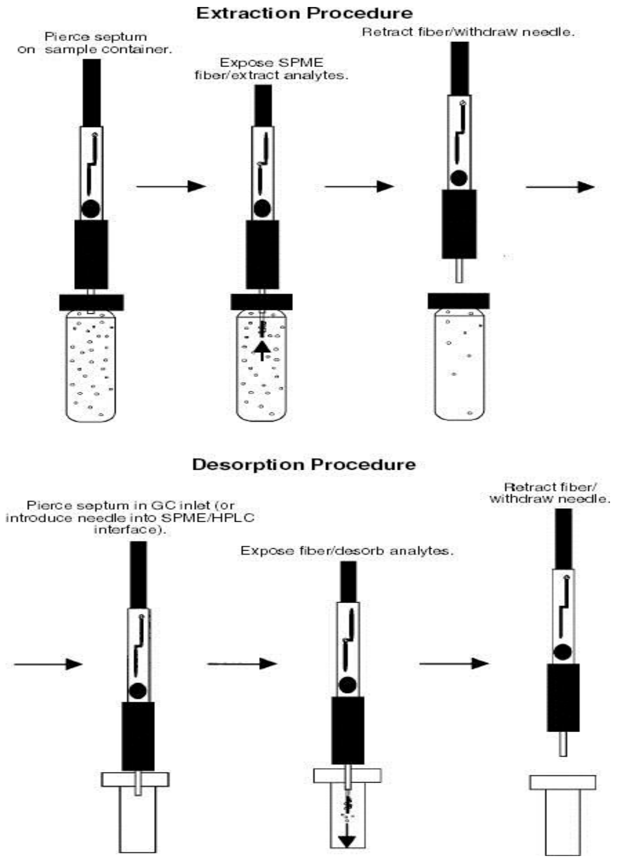
# Sample Preparation

- Preparation: Cold room at 4°C
  - 50 g almonds were homogenized
  - Sifted through a 16 meshes screen for particle size control
  - 5 g was transferred to a 20 mL headspace vial
  - 100 ml internal standard (500 ppb) added and the vial was sealed
  - All samples were prepared in triplicate



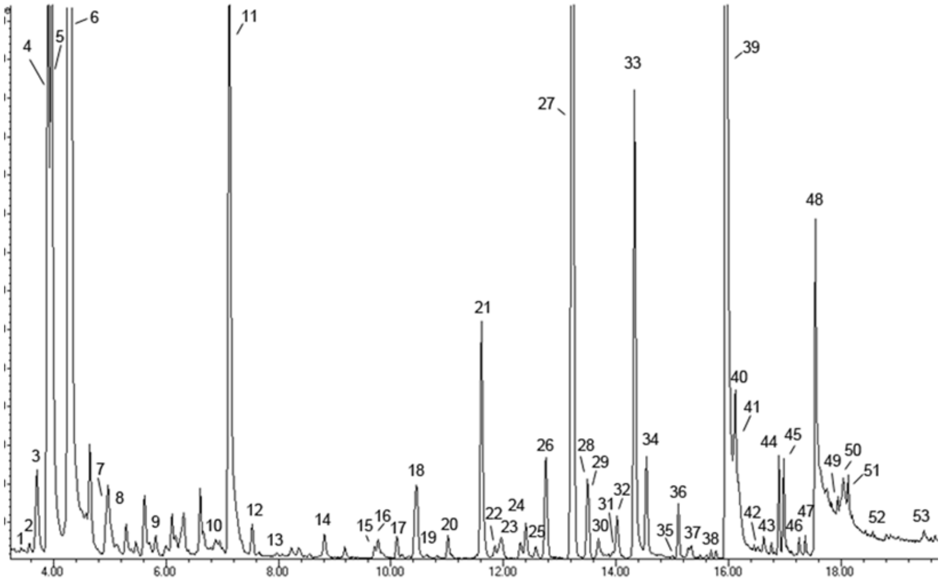

# Headspace solid-phase microextraction (HS-SPME)

- Sample in the vial was equilibrated for 30 minutes
- Exposed to a 1 cm 50/30 μm coated fiber for 30 min at room temp
- Desorption (230°C): 10 min in injection port



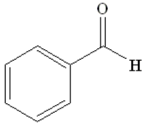
# GC Chromatogram of Almond Volatiles

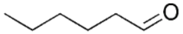
- Peak Identification:
- Comparison of mass spectra and $t_R$ with standards (38) or by comparing MS and Kovats Index with NIST MS database with 80 % cut-off (no standard)

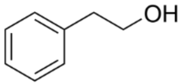


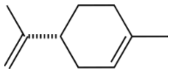

# Volatiles Identified in Raw Almonds

- Identified 41 Compounds:
- 3 carbonyls, 1 pyrazine, 20 alcohols, and 7 additional volatiles



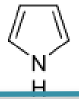



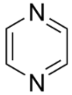



- Benzaldehyde, the breakdown product of amygladin, was the predominant volatile in raw almonds (2,934.6 ± 272.5 ng/g)
  - Almond-like aroma
- Hexanal (422.6 ± 97.9 ng/g); found in other nuts as well
  - Fruity/green (cut grass)
- 2-phenylethanol (6.2 ± 0.6 ng/g); deamination of amino acids in plants
  - Floral
- $\alpha$-Pinene (15.0 ± 0.1 ng/g) and limonene (16.6 ± 0.5 ng/g); terpenes
  - Pine/citrus

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

# Volatiles in Roasted Almonds





- Roasting: an additional 13 volatiles were formed during roasting
  - Most related to flavor: pyrazines, branch-chain aldehydes, alcohols, heterocyclic and sulfur containing compounds
    - Maillard reaction products
    - Some lipid oxidation products
- Storage: an additional 17 new compounds, absent in raw and freshly roasted almonds, but detectable after 10-16 weeks of storage were identified
    - Lipid oxidation products
    - ketones, aldehydes, alcohols, oxiranes and short-chain acids

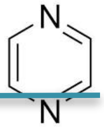
# Changes in Volatile Aldehydes and Keytones

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

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

# Changes in Volatile Pyrazines

## Roasted Nutty Aromas

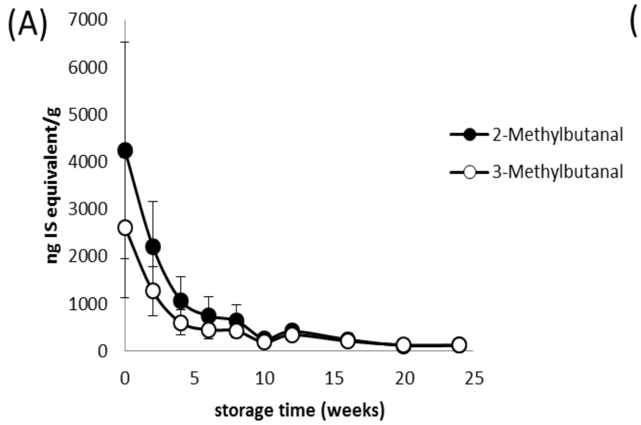


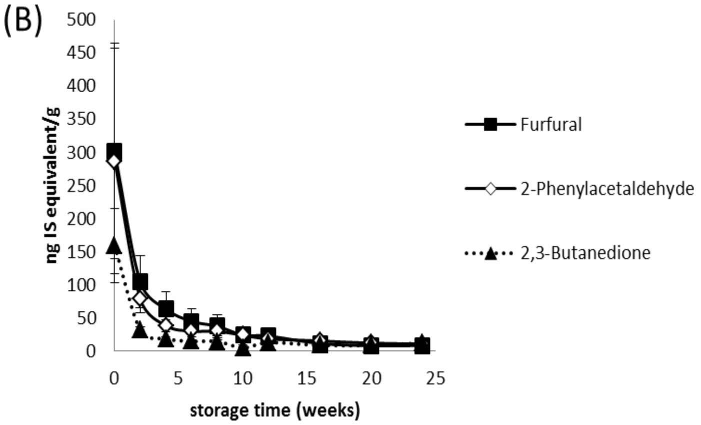

| Compound | raw | roasting time 28 min | 33 min | 38 min | increase[b] (%) |
|---|---|---|---|---|---|
| ***pyrazines*** | | | | | |
| 2-methylpyrazine | ND | $4.1 \pm 0.3^{*}$ | $21.5 \pm 0.6^{***}$ | $26.5 \pm 1.8^{***}$ | New |
| 2,5-dimethylpyrazine | $11.4 \pm 0.5$ | $16.2 \pm 0.6^{***}$ | $53.3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

- Six new pyrazines were identified in roasted almonds
- Chocolate, nutty, meaty, roast flavors
- Generated through the Maillard reaction
- Most have low odor thresholds and increased with the degree of roast

# Decreases in Select Volatiles During Storage

Aldehydes and Keytones



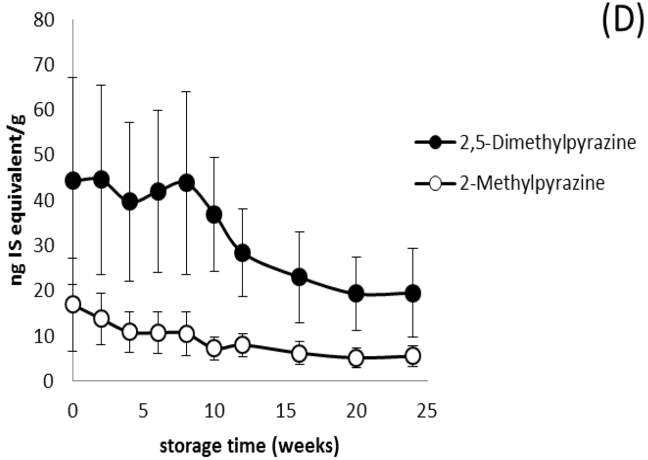




- Levels of aldehydes were significantly higher immediately after roasting
  - These are products generated in response to thermal processing
  - nutty, caramel, chocolate aroma
- Levels decreased significantly (75-88%) over the first 4 weeks of storage
- Some aldehyde levels increase around 20 weeks of storage reflecting lipid oxidation

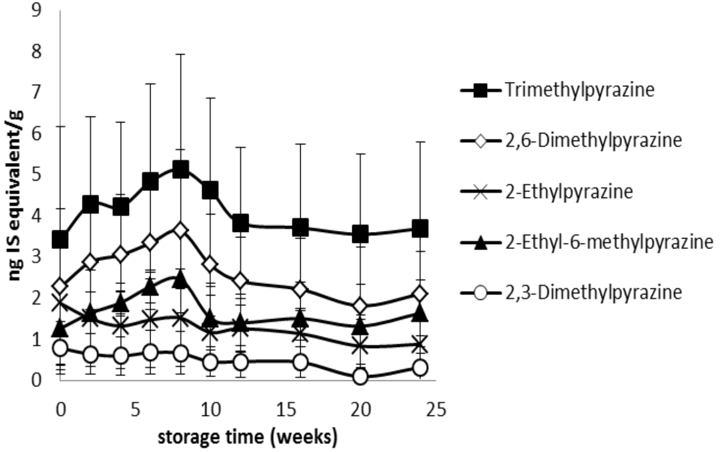
# Decreases in Select Volatiles During Storage

Pyrazines (roasted almond flavor)

(C)



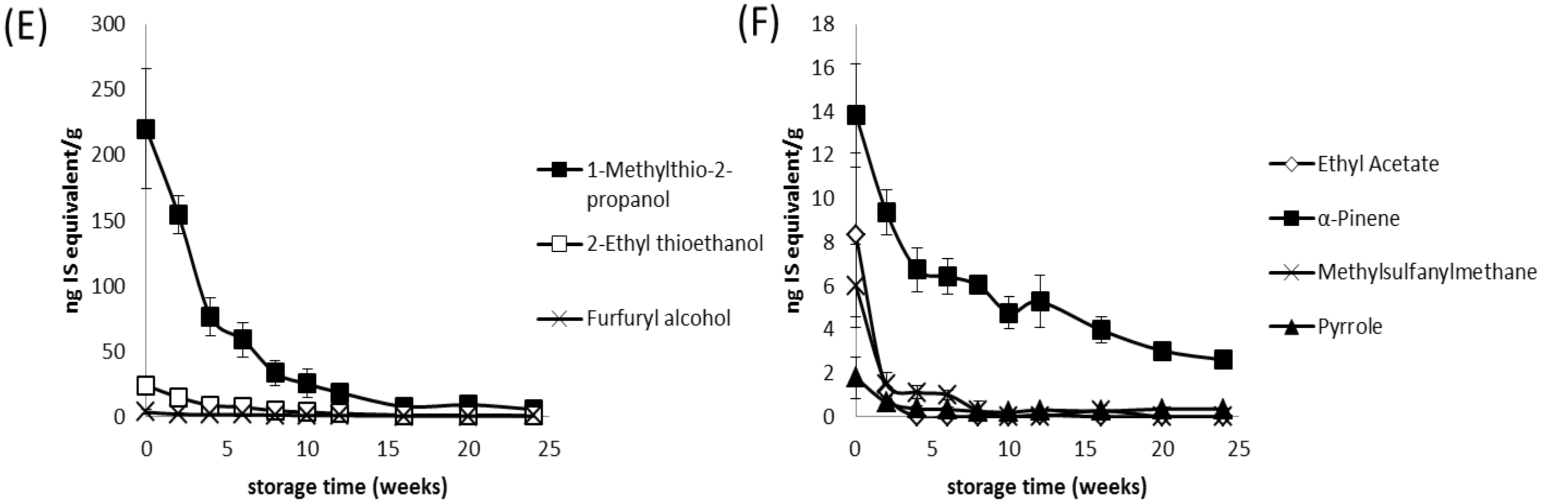

(D)




- The levels of 2,5-dimethylpyrazine and 2-methylpyrazine decreased slowly during 25 weeks storage
- Other pyrazines did not decrease significantly
    - Predominate aromas

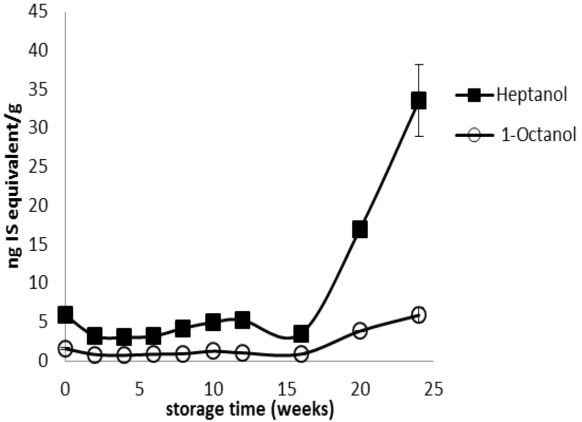
# Decreases in Select Volatiles During Storage

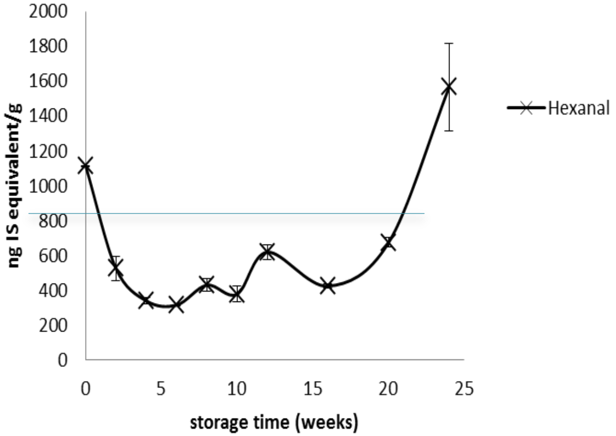
Additional Losses




- Decreases in compounds (4 weeks) relating to roasted almond flavor (1-methylthio-2-propanol) and fresh aroma (a-pinene), ethyl acetate (sweet)

# Increases in Select Volatiles During Storage: Early Markers of Rancidity




- Levels of hexanal decreased initially, and began to increased again ~18 weeks (regardless of roasting temperature). Levels did not increase to above baseline until after 20 weeks
  - Hexenal is a product of the oxidation of linoleic acid
- Linear increases in heptanol and 1-octanol are observed at 16 weeks
- Heptanol has a greater response

# Additional Markers of Early Changes

- Compounds that are initially absent in the roasted almonds but detectable after 16 weeks of storage
- Levels of 2-octanone, 3-octen-2-one, and acetic acid showed large increases as early as 16 weeks

| volatile compounds | light roast (28 min at 138C) | | | dark roast (38 min at 138 C) | | |
|---|---|---|---|---|---|---|
| | 16 wk | 20 wk | 24 wk | 16 wk | 20 wk | 24 wk |
| 2-octanone | 13.4 ± 1.4 | 52.3 ± 2.9 | 33.3 ± 0.1 | 6.4 ± 0.2 | 15.4 ± 0.9 | 34.2 ± 4.0 |
| 2-nonanone | 9.8 ± 1.4 | 47.5 ± 0.9 | 31.2 ± 0.2 | 4.8 ± 0.3 | 16.4 ± 0.4 | 28.6 ± 4.3 |
| 3-octen-2-one | 18.1 ± 1.8 | 41.1 ± 2.0 | 45.4 ± 0.9 | 9.1 ± 0.4 | 19.7 ± 0.6 | 33.6 ± 4.5 |
| 2-decanone | 2.8 ± 0.2 | 13.4 ± 0.2 | 10.3 ± 0.4 | ND[a] | 7.2 ± 1.4 | 7.6 ± 1.3 |
| (E)-2-decenal | 2.9 ± 0.1 | 7.1 ± 1.1 | 10.9 ± 0.9 | 2.4 ± 0.8 | 5.6 ± 0.4 | 6.6 ± 1.4 |
| 2,4-nonadienal | 10.5 ± 0.9 | 14.2 ± 1.2 | 15.4 ± 1.1 | 7.5 ± 0.1 | 10.9 ± 0.5 | 10.4 ± 1.6 |
| 2-undecenal | ND | 2.1 ± 0.7 | 3.4 ± 0.3 | ND | 1.5 ± 0.1 | 1.8 ± 0.3 |
| 1-octen-3-ol | 2.2 ± 0.2 | 7.4 ± 0.4 | 6.9 ± 0.1 | 1.4 ± 0.0 | 4.1 ± 0.0 | 8.9 ± 1.3 |
| nonanol | 0.8 ± 0.1 | 2.2 ± 0.1 | 2.0 ± 0.1 | 0.5 ± 0.1 | 1.1 ± 0.3 | 1.0 ± 0.1 |
| pentyl oxirane | 9.9 ± 0.8 | 55.8 ± 11.1 | 27.8 ± 0.9 | 5.0 ± 0.8 | 9.5 ± 0.4 | 97.5 ± 9.3 |
| hexyl oxirane | 31.0 ± 3.1 | 1.7 ± 0.7 | 42.1 ± 0.2 | 9.7 ± 1.5 | 12.2 ± 0.6 | 2.9 ± 0.3 |
| acetic acid | 35.8 ± 2.7 | 60.8 ± 3.0 | 45.2 ± 2.3 | 43.5 ± 5.4 | 57.9 ± 1.5 | 60.2 ± 16.1 |
| vinyl hexanoate | 1.5 ± 0.2 | 6.8 ± 0.1 | 4.9 ±0.2 | 1.2 ± 0.0 | 4.1 ± 0.4 | 8.1 ± 1.3 |
| pentanoic acid | 0.9 ± 0.1 | 6.1 ± 0.2 | 2.5 ± 0.2 | 0.5 ± 0.1 | 3.3 ± 0.0 | 5.9 ± 1.9 |
| heptanoic acid | 0.6 ± 0.0 | 5.4 ± 2.3 | 4.6 ± 0.4 | 0.5 ± 0.1 | 4.1 ±0.7 | 2.7 ± 0.6 |
| octanoic acid | 0.4 ± 0.1 | 5.2 ± 2.3 | 5.1 ± 0.7 | 0.2 ± 0.0 | 3.6 ±0.7 | 2.0 ± 0.3 |
| nonanoic acid | ND | 1.3 ± 0.8 | 2.5 ± 0.2 | ND | 0.6 ± 0.2 | 0.4 ± 0.0 |

[a]ND stands for not detected.

# Conclusions

- Storage (35°C):
  - Significant decreases in aroma volatiles are observed by 4 weeks of storage
    - independent of the roasting time and storage temperature
  - Oxidation occurs at 16 weeks of storage
  - Oxidation products began dominating the profile by 20 weeks
- Potential markers of *early* oxidative changes:
  - 1-Heptanol (and 1-octanol) as these compound compounds demonstrate robust linear changes in concentration at 16 weeks versus 20 weeks for hexanal
  - Compounds absent from raw and freshly roasted almonds but detectable ~16 weeks of storage ( 2-octanone, 3-octen-2-one, and acetic acid)

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## *Advancing Knowledge a Team Effort*

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- Agilent Technologies
  - Jerry Zweigenbaum, PhD

# Ellie King and Dawn Chapman, National Food Laboratory

,

# Profiling Sensory Differences in Almond Varieties

Dr Dawn Chapman & Dr Ellie King

**The National Food Lab, Livermore CA**

The Almond Conference

# Content

- Capabilities of The NFL
- Methodology – Consensus Rating Evaluation
- Results
- Key Findings

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# 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

# 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 trained for 3+ months before qualification.
- Overseen by experienced panel leaders
  - Advanced degrees (Master’s or Ph.D. in Sensory Science)

# Sensory Evaluation

## Evaluation Methodologies:

- Discrimination testing
- Quantitative descriptive evaluation
- Narrative descriptive analysis
- Consensus rating evaluation

## Applications:

- Product understanding
- Quality assessments
- Sensory specifications
- Panel training /terminology training
- Shelf life studies

# Methodology: Discrimination Testing

**Experimental design:**

- Twenty-thirty trained panelists participated in the study.
- Panelists individually assess each sample.
- Panelists indicate differences or similarities between samples using various types of discrimination tests, such as Triangle Test and Ranking.
- Statistical analyses include Binomial Tests and Friedman's Rank Sum Test.

**Sample presentation:**

- All samples in a test are presented together.
- Samples are identified by random 3-digit numbers.

# Methodology: Quantitative Descriptive Evaluation

**Experimental design:**

- Ten trained panelists participate in the study.
- Panelists participate in Orientation sessions to review samples.
- References are used to illustrate and define the sensory characteristics.
- Panelists individually rate each sample with at least two replications.
- Sensory attributes scored on 15-point scales.
- Statistical analyses include ANOVA and Means Comparisons.

**Sample presentation:**

- Samples are presented monadically (one at a time).
- Samples are identified by random 3-digit numbers.
- Samples are served in a balanced order (i.e., each sample will be seen approximately an equal number of times in each possible position).

# Methodology: Narrative Descriptive Analysis

**Experimental design:**

- Three trained panelists participated in the study.
- Panelists individually assess each sample.
- Panelists verbally indicate the character and intensity of the major sensory characteristics of each samples through group discussion led by a panel leader.
- No statistical analyses are conducted on the narrative data.

**Sample presentation:**

- Samples are presented monadically (one at a time).
- Samples are identified by random 3-digit numbers.

# Methodology: Consensus Rating Evaluation – used to assess almond samples

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**Experimental design:**

- Three trained panelists participated in the study.
- Panelists individually rated each sample.
- Sensory attributes scored on 15-point scales.
- The individual scores were verbally collected by a panel leader and were discussed to reach consensus scores.
- No statistical analyses were conducted on the consensus data.

**Sample presentation:**

- Samples are presented monadically (one at a time).
- Samples are identified by random 3-digit numbers.
- Approximately 10 nuts of each sample provided to each panelist in a white plastic bowl.
- Panelists rate appearance, then aroma, before tasting at least 3 nuts at once and rating texture and flavor attributes.

# Raw Almond Samples

| Almond varieties | Grade | Size |
|---|---|---|
| NPS | Supreme | 25/27 |
| Monterey | SSR | 25/27 |
| Butte | SSR | 34/36 |
| Carmel | SSR | 27/30 |

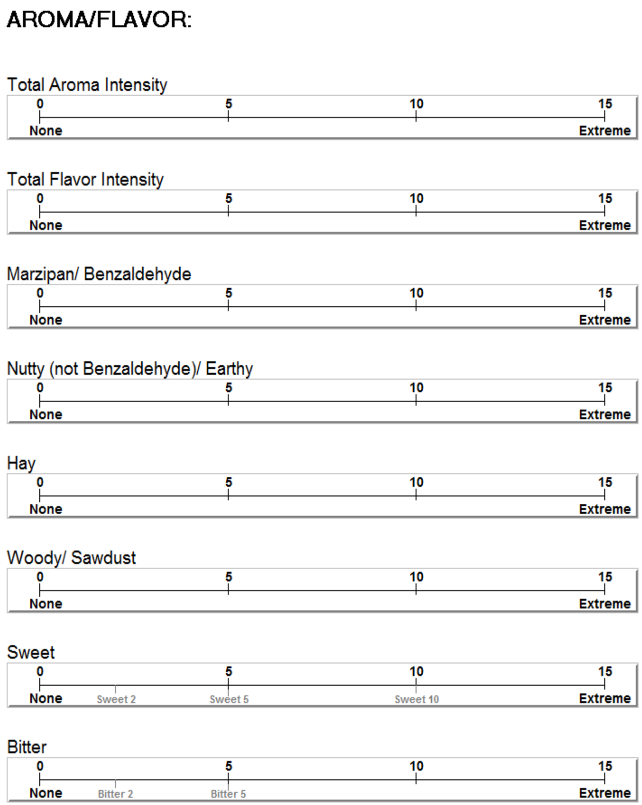
# Sensory Attributes*

**Aroma/Flavor:**

- Overall Aroma Intensity
- Overall Flavor Intensity
- Marzipan/ Benzaldehyde flavor
- Nutty (not benzaldehyde)/ Earthy flavor
- Hay flavor
- Woody/ Sawdust flavor
- Sweet taste
- Bitter taste

**Texture/Mouthfeel:**

- Hardness
- Fracturability/ Brittle
- Deformability/ Spongy
- Chewy
- Crunchy -1st bite
- Moistness
- Cohesiveness of Mass
- Astringency




* Modified from the work conducted by Prof Hildegarde Heymann at UC Davis in 2013.

# Results – Means Table

- Means Table reports the intensity ratings of each sensory attribute for each sample.

**TABLE 1**

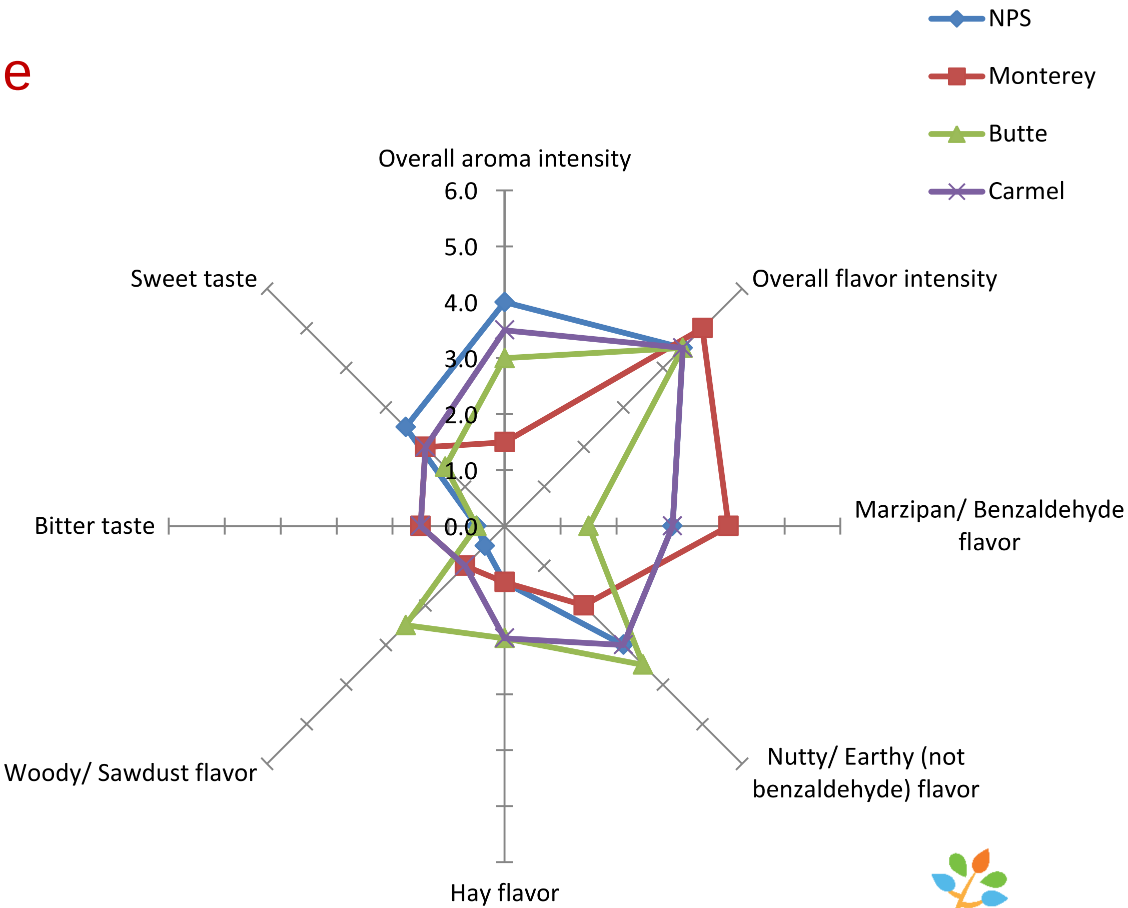
**CONSENSUS RATING EVALUATION OF RAW ALMOND VARIETIES**
**n=3 Panelists**

| | NPS | Monterey | Butte | Carmel |
|---|---|---|---|---|
| **AROMA/FLAVOR:** | | | | |
| Overall Aroma Intensity | 4.00 | 1.50 | 3.00 | 3.50 |
| Overall Flavor Intensity | 4.50 | 5.00 | 4.50 | 4.50 |
| Marzipan/Benzaldehyde | 3.00 | 4.00 | 1.50 | 3.00 |
| Nutty (not Benzaldehyde)/Earthy | 3.00 | 2.00 | 3.50 | 3.00 |
| Hay | 1.00 | 1.00 | 2.00 | 2.00 |
| Woody/Sawdust | 0.50 | 1.00 | 2.50 | 1.00 |
| Sweet | 0.50 | 1.50 | 0.50 | 1.50 |
| Bitter | 2.50 | 2.00 | 1.50 | 2.00 |

| | NPS | Monterey | Butte | Carmel |
|---|---|---|---|---|
| **TEXTURE/MOUTHFEEL:** | | | | |
| Hardness | 4.50 | 5.00 | 6.00 | 3.50 |
| Fracturability/Brittle | 3.00 | 5.00 | 4.50 | 3.00 |
| Deformability/Spongy | 2.00 | 3.00 | 1.00 | 2.50 |
| Chewy | 4.00 | 4.00 | 1.00 | 4.00 |
| Crunchy - 1st bite | 3.00 | 3.50 | 5.00 | 3.50 |
| Moistness | 3.00 | 3.00 | 2.00 | 4.00 |
| Cohesiveness of Mass | 4.50 | 3.50 | 2.50 | 1.50 |
| Astringency | 2.00 | 2.50 | 3.50 | 3.00 |

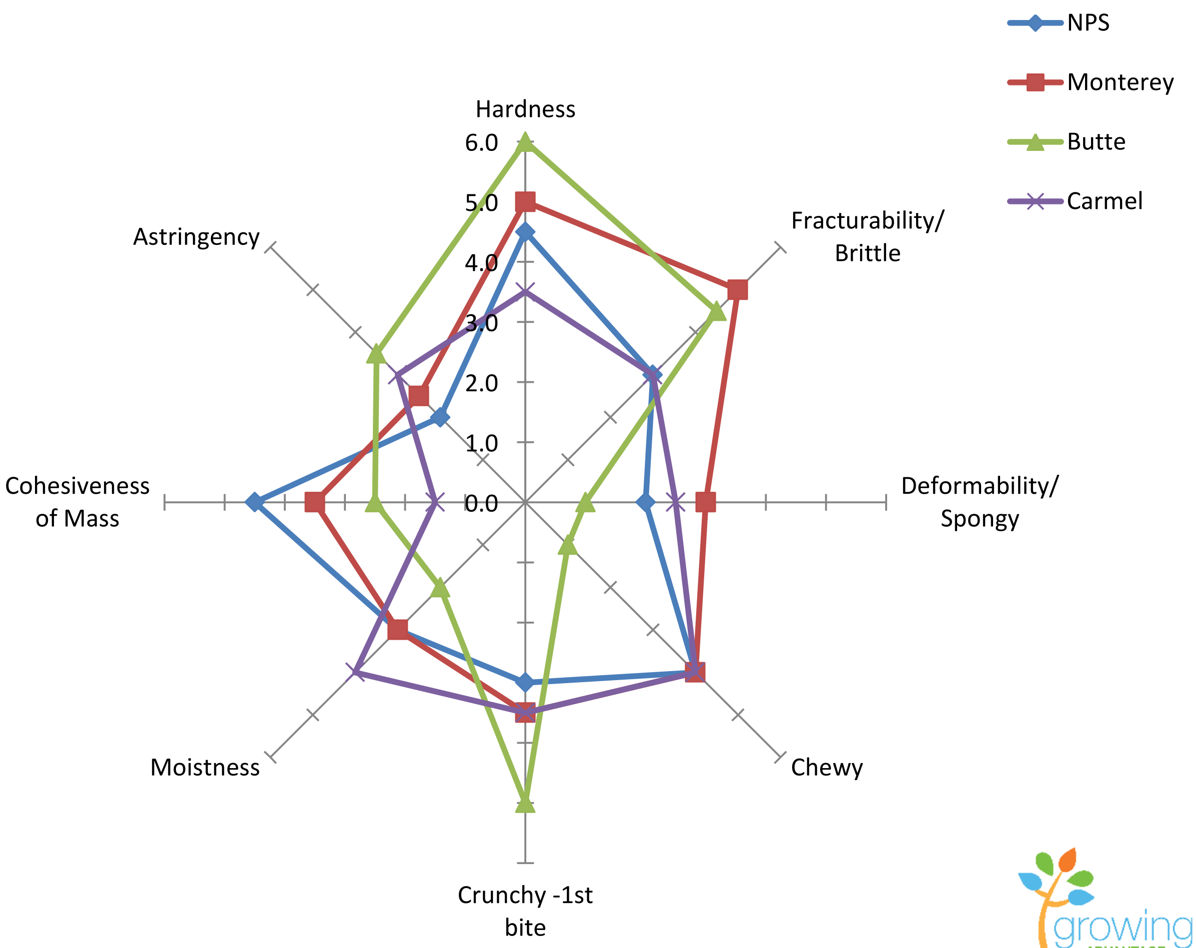
# Results – Aroma/Flavor Profile

- All raw almond varietals have different flavor profiles.
  - NPS has a high Overall Aroma Intensity and Sweet taste.
  - Monterey has a high Overall flavor intensity, with high Marzipan/Benzaldehyde flavors and a slight Bitter taste.
  - Butte is high in Nutty/Earthy, Hay and Woody/Sawdust flavors.
  - Carmel has a similar flavor profile to NPS, but with higher Hay flavors and Bitter taste.



# Results – Texture Profile

- All raw almond varietals have different texture profiles.
  - NPS has an intermediate texture profile with a high Cohesiveness.
  - Monterey is Brittle, Spongy and Chewy.
  - Butte is Hard, Crunchy and Astringent.
  - Carmel is the Softest, Moistest and Crumbliest.



# Key Findings

- The sensory profiling method can be used to quantify intensity differences in sensory attributes among almond samples.
- 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.

# Next Steps – Product Landscape®

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# Next Step

- Another step in analyzing the sensory profile of almonds is to determine Consumer preference.
- The NFL performs **Product Landscape®** analysis – a combination of descriptive sensory and Consumer Testing with multivariate data analyses.

# Product Landscape® In Action

## When to use this tool…

- Understand competitive space/category
  - New to space
  - New product opportunities
- Uncover reasons behind performance issues
- Address competitive pressures
- Strategically target position in crowded space

## What you will learn…

**Product Development Insights**

- Uncover attributes that most strongly impact liking
- Identify specific sensory-driven optimization direction

**Marketing/Consumer Insights**

- Define product opportunity areas/white space
- Determine if product delivers against key benefits
- Identify sensory cues linked to key product benefits

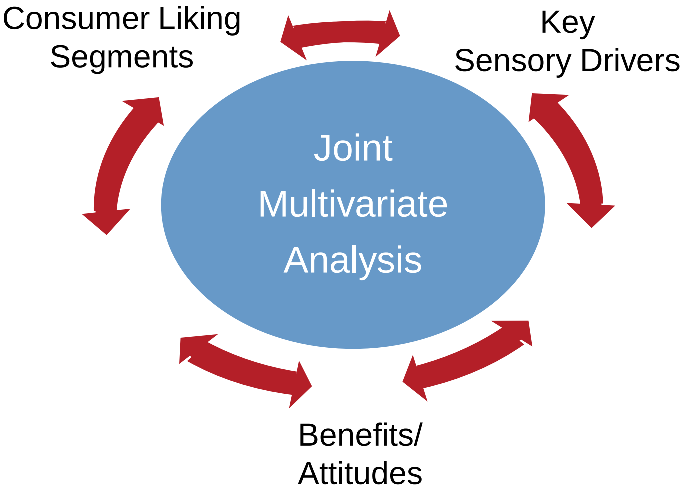
# Product Landscape® Methodology

## INPUT

Thoughtful Sample Selection

- Descriptive Testing
- Consumer Testing
- Consumer Benefits
- Product Analytics

## DATA MINING




## OUTPUT

Identify Segments

*(groups of consumers with different liking patterns)*

- Within each segment…
- Which products are liked?
- Which sensory attributes drive product liking?
- Which sensory attributes are linked to benefit/ attitude cues?

# Contributors

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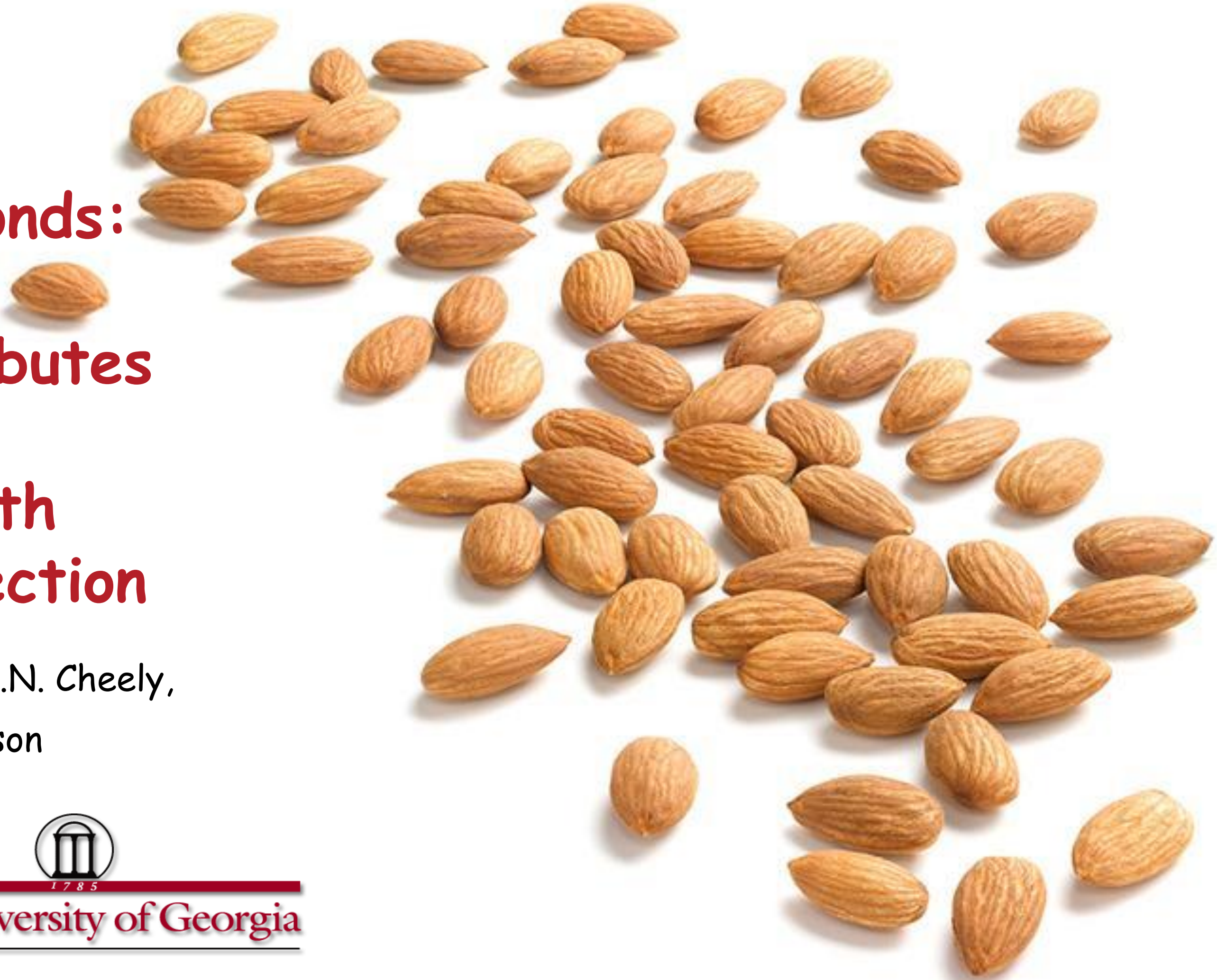
# Shelf-life of nonpareil almonds: Chemical and textural attributes and their association with consumer rejection



R.B. Pegg, D.R. Parrish, A.N. Cheely, W.L. Kerr, and R.B Swanson

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# Objectives

1. To assess roasted and raw almonds stored in different temperature/humidity combinations by chemical, sensory, and textural means over 16 and 24 months, respectively.

2. To establish a lipid oxidation (rancidity) cutoff point linked to consumer acceptability.

3. To determine if packaging strategies (*i.e.*, choice of bags, $N_2$ flushing, environmental control) impact the shelf-life.

4. To determine the relationship between chemical indices and sensory evaluation of almonds under different storage conditions.

5. To identify and quantify oxidation volatiles over time, and to determine which volatiles and their levels trigger lack of product acceptability.

# Importance of this Research

- Almonds are currently the largest specialty crop export in the U.S. ($2.8 billion in 2011).
- Sales of products containing almonds grew $236 million from 2008 to 2011.
- Almonds are ~50% oil by weight.
- Oleic (68%) and linoleic acids (28%) dominate.
- Almond storage is necessary!
- During storage, "off-flavors" develop as a consequence of unsaturated fatty acid oxidation.
- Rancidity is chiefly why almonds are rejected by consumers.

# Experimental Design

# Sample Handling & Packaging

Table: Packaging of Nonpareil Raw and Roasted Almonds

| | Raw | Roasted |
|---|---|---|
| Unlined Carton {UC} (600 ± 5 g) | X | |
| Polypropylene Bag {PP} (300 ± 5 g) [a] | X | X |
| High Barrier Bag {HBB} [b,c] | | X |

[a] Bags were flushed with food-grade $N_2$ and sealed, providing a “pillow-pack” design. The headspace was analyzed in multiple samples, and the initial $O_2$ level was < 0.5%.

# Loading Plan

It was hypothesized that (1) almonds stored at a higher temperature (T) and relative humidity (RH) will degrade most rapidly; and (2) roasted almonds will deteriorate quicker than raw samples. Samples were loaded in the order of their expected deterioration.

| | Product | Raw | | Roasted | |
|---|---|---|---|---|---|
| Load Day | Packaging | UC | PP Bag | PP Bag | HBB |
| Day X [a] | Storage Conditions | -40 °C | | | |
| Day G [g] | | 4 °C | | 4 °C | |
| Day F [f] | | 15 °C, RH = 50% | | | 15 °C |
| Day E [e] | | 15 °C, RH = 65% | | | |
| Day D [d] | | 25 °C, RH = 50% | | | 25 °C |
| Day C [c] | | 25 °C, RH = 65% | | | |
| Day B [b] | | 35 °C, RH = 50% | | | 35 °C |
| Day A [a] | | 35 °C, RH = 65% | | | |

[a] November 26, 2012, [b] November 28, 2012, [c] November 30, 2012, [d] December 2, 2012, [e] December 4, 2012, [f] December 16, 2012, [g] December 18, 2012.


TEMPERATURE
HUMIDITY

# Sampling Plan

Samples stored under each T/RH condition were removed at 2 month intervals from the environmental chambers for assessment.

# Breakdown of Sampling Plan

| Day 1 | Day 2 | Day 3 (if sample "triggers" sensory) | Day 4 | Day 5 |
|---|---|---|---|---|
| Expeller-pressed Oil | Peroxide Value[a,d] | Roasted Trained Panel ($n$ = 6 x 2)[e] | Roasted Screening Panel ($n$ = 35)[f] | Roasted Confirmatory Panel ($n$ = ~120)[g] |
| Particle Size Reduction | Free Fatty Acids[a] | Raw Consumer Screening Panel ($n$ = 34-40)[g] | Raw Confirmatory Panel ($n$ = ~120)[g] | |
| Headspace Analysis[b] | Conjugated Dienes[a] | | | |
| Moisture Analysis[b] | TBARS[a] | | | |
| Water Activity[b] | | | | |
| Texture Analysis[c] | | | | |

[a]Evaluated with oil; [b]Evaluated with ground sample; [c]Evaluated with whole almonds; [d]Peroxide value  2 meq active $O_2$/kg oil; [e]Trained panel only for Roasted Samples, [f]Screening panel only necessary if roasted samples are deemed unacceptable to the trained panel, but not conclusively [g]Confirmatory panel for "triggered" raw samples and roasted samples that are deemed unacceptable to the screening panel.

# Expeller-pressed Oil

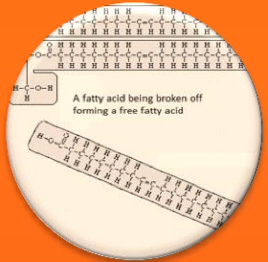
- Oil is recovered with a Carver press and transferred to 20-mL amber vials, which are then $N_2$ flushed and stored at 4 °C until the next day.

# Sample Preparation

Ground almond test samples are evaluated by headspace analysis (GC-SPME-FID and GC-SPME-MS), water activity ($a_w$), and moisture content.

Whole almonds are evaluated using a texture analyzer.

# Methods for Chemical Testing




**Free Fatty Acid Value:**

Free fatty acids are said to be free when they are no longer esterified to glycerol.

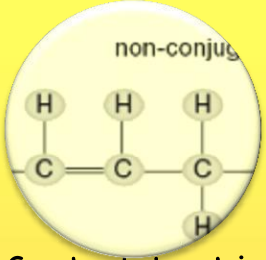
Free fatty acids accelerate oxidation.

Expressed in percent as oleic acid.


**Moisture Content and Water Activity:**

Moisture accelerates oxidation.

Free water in a system (*i.e.*, $a_w$) is a better measure of $H_2O$ effects on oxidation.



**Spectrophotometric Determination of Conjugated Dienoic Acids:**

CDs are more prone to form free-radical species that lead to ROOH formation.

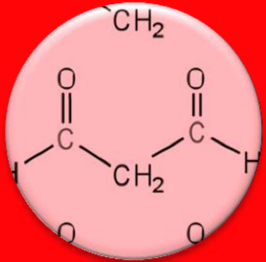
Measured using a spectrophotometer at $a_{233nm}$ and reported as absorptivity


**Peroxide Value:**

ROOHs are the main initial (primary) products of autoxidation.

PV is based on the ability to liberate $I_2$ from KI.

Expressed in terms of milliequivalents of active $O_2$ per kg fat.



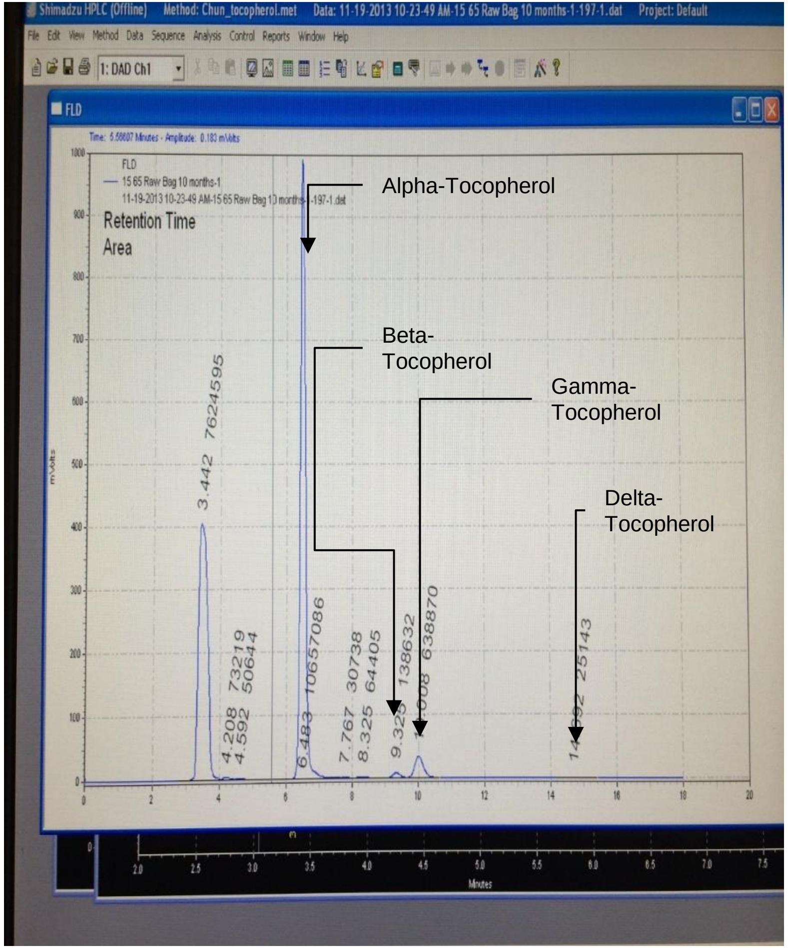
**2-Thiobarbituric Acid Value Direct Method:**

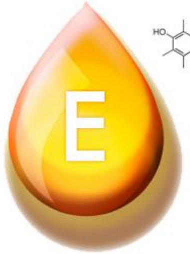
Oxidative products (reported as MDA eq.) produce a color reaction with 2-TBA that is measured at 530 nm.

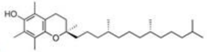
Used to measure secondary oxidation products of autoxidation.

# Vitamin E Analysis

- Beginning on month 8, the tocopherol profile of almond lipids were determined.
- α-Tocopherol quenches radical oxygen species, so tracking vitamin E over time could help determine the overall oxidation mechanism.





# Method for Texture & Sound Analysis

- Texture analysis was performed using a Texture Technologies TA-XT2i texture analyzer.
- The fracturability of  whole almonds was evaluated using the texture analyzer with a compression disk.
- The audio was recorded during texture analysis and will be analyzed to provide a more complete fracturability profile.

# Consumer Sensory Testing

Screening (*n* = 35-40) and confirmatory (*n* = ~120) panels

9-Point hedonic scale

- Odor
- Flavor
- Texture
- Overall acceptability

Rejection question

Response to …

*"if you had purchased this product, would you eat it?"*

Product Code Number: ____________ Panelist Number: ____________

## Almond Sensory Scorecard

You will evaluate XX samples today, each presented in a closed container. Please check the box (□) that best reflects your opinion of this sample

Before tasting, evaluate the odor of the product. Hold the cup close to your nose and gently lift the lid as you take three short sniffs.

**Odor**

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Extremely Dislike … Extremely Like

Eat the almonds and evaluate texture, flavor and overall acceptability by marking the box (□) that best reflects how much you like this product

**Texture**

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Extremely Dislike … Extremely Like

**Flavor**

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Extremely Dislike … Extremely Like

**Overall Acceptability**

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Extremely Dislike … Extremely Like

Please drink water and eat some crackers and/or carrot to cleanse you mouth

**Turn-over and complete the back**

# Descriptive Plan Roasted Almond Sample Training

| Timeline for training panels[a] | |
|---|---|
| Prescreening Session[b] | Description |
| 1 | 12 participants were prescreened resulting in 8 panelists to be trained |
| Training Sessions (*n* = 6-8)[cd] | |
| 1 | Introduction to descriptive panel and scaling concepts |
| 2 | Texture- Hardness, crunchiness |
| 3 | Texture- Hardness, crunchiness |
| 4 | Flavor attributes- learning universal intensity and sweetness scales |
| 5 | Universal intensity scale, sweetness, and introducing fat oxidation- rancid (odor) |
| 6 | Cardboard, rancid, painty (odor and flavor) |
| 7 | Cardboard, rancid, painty (odor and flavor) |
| 8 | Relating previously discussed attributes to nuts |
| 9 | Relating previously discussed attributes to almonds |
| 10 | Overall almond intensity; establishing method and protocol for individual assessment |
| 11 | Running mock panels and troubleshooting; finalizing methods for individual assessment |
| Calibration/Refinement Testing (*n*=6)[ef] | |
| 3 sessions | Groups of 2-3; mock panels with short reviews of topics previously discussed |

[a]Constant reviewing throughout each session of previously discussed subject; [b]Contact hours = 9 h; [c]Final panel has 6 participants— Two panelists were released due to scheduling conflicts; [d]Contact hours = 28 h; [e]Calibration panels were continued until means ± SD were within acceptable range; [f]Contact hours = 24 h.

# Descriptive Panel

## Odor and Flavor Attribute Intensity Evaluation

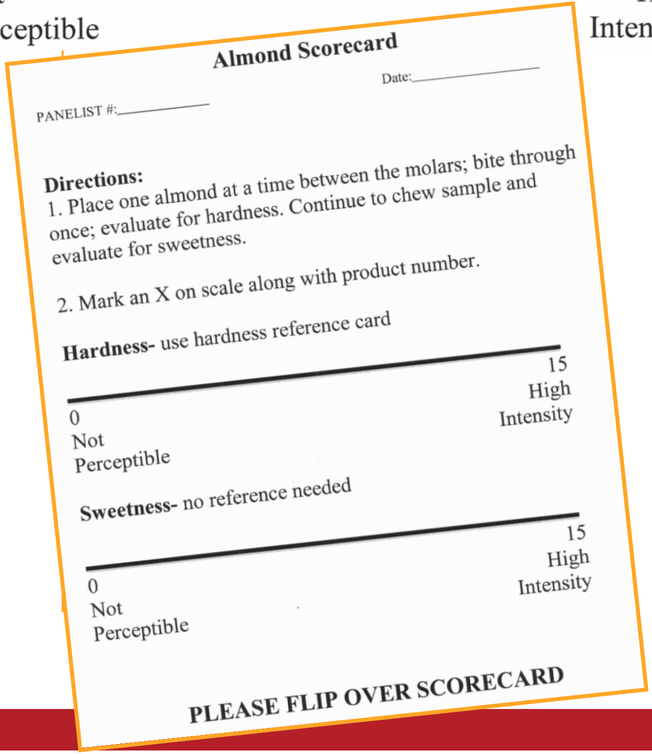




**Universal Intensity Reference**

| Soda in premium cracker | Grape in Kool-aid | Orange in Minute Maid OJ | Grape in Welch's grape juice | Cinnamon in Big Red gum |
|---|---|---|---|---|
| 2 | 4 | 7 | 10 | 12 |

0 Not Perceptible — 15 High Intensity



**Almond Scorecard**

PANELIST #:__________ Date:__________

**Directions:**

1. Place one almond at a time between the molars; bite through once; evaluate for hardness. Continue to chew sample and evaluate for sweetness.

2. Mark an X on scale along with product number.

**Hardness-** use hardness reference card

0 Not Perceptible — 15 High Intensity

**Sweetness-** no reference needed

0 Not Perceptible — 15 High Intensity

**PLEASE FLIP OVER SCORECARD**

# Descriptive Panel

## Texture Attribute Intensity Evaluation

### Crunchiness





### Hardness





**Crunchiness Reference**

| Corn muffin | Graham crackers | Ginger snaps | Life Savers |
|---|---|---|---|
| 1 | 4.2 | 8 | 15 |

0 Not Perceptible — 15 High Intensity

**Hardness Reference**

| Cream Cheese | Green Olive | Peanut | Life Savers |
|---|---|---|---|
| 1 | 6 | 9.5 | 15 |

0 Not Perceptible — 15 High Intensity

**Directions:**

1. Place one almond at a time between the molars; bite through once; evaluate for hardness. Continue to chew sample and evaluate for sweetness.

2. Mark an X on scale along with product number.

**Hardness**- use hardness reference card

0 Not Perceptible — 15 High Intensity

**Sweetness**- no reference needed

0 Not Perceptible — 15 High Intensity

**PLEASE FLIP OVER SCORECARD**

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# Findings as of 18 mo

- In order to fail, samples must have a rejection rate ≥ 25%.
- At 18 mo, 13 samples have failed, and roasted is no longer being tested.

| Raw | Roasted |
|---|---|
| 2 mo → UC → 35 °C/65% RH | 12 mo → PP → 35 °C/65% RH |
| 6 mo → UC → 35 °C/50% RH | 14 mo → PP → 35 °C/50% RH |
| 6 mo → UC → 4 °C {RH > 90%} | 16 mo → PP → 25 °C/65% RH |
| 6 mo → PP → 35 °C/65% RH | 16 mo → HBB → 35 °C |
| 12 mo → PP → 35 °C/50% RH | |
| 12 mo → UC → 25 °C/65% RH | |
| 16 mo → UC → 25 °C/50% RH | |
| 16 mo → UC → 15 °C/65% RH | |
| 16 mo → PP → 25 °C/65% RH | |

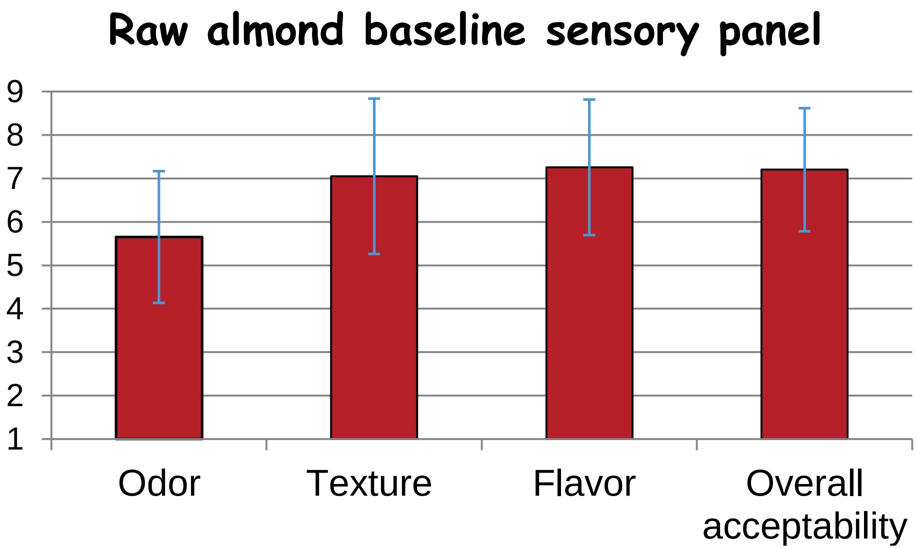
# Findings as of 22 mo

- In order to fail, samples must have a rejection rate ≥ 25%.
- At 22 mo, 4 samples have yet to fail.

| Raw | Overall Acceptability (n=38) |
|---|---|
| Baseline | 6.0% |
| PP → 25 °C/50% RH | 10.5% |
| PP → 15 °C/65% RH | 15.8% |
| PP → 15 °C/50% RH | 13.2% |
| PP → 4 °C {RH > 90%} | 7.9% |

**Rejection Question:**
If you had purchased this product, would you eat it?

# Baseline Consumer Data: Sensory Raw Almonds (*n* = 118)




**Rejection Question:**
If you had purchased this product, would you eat it?

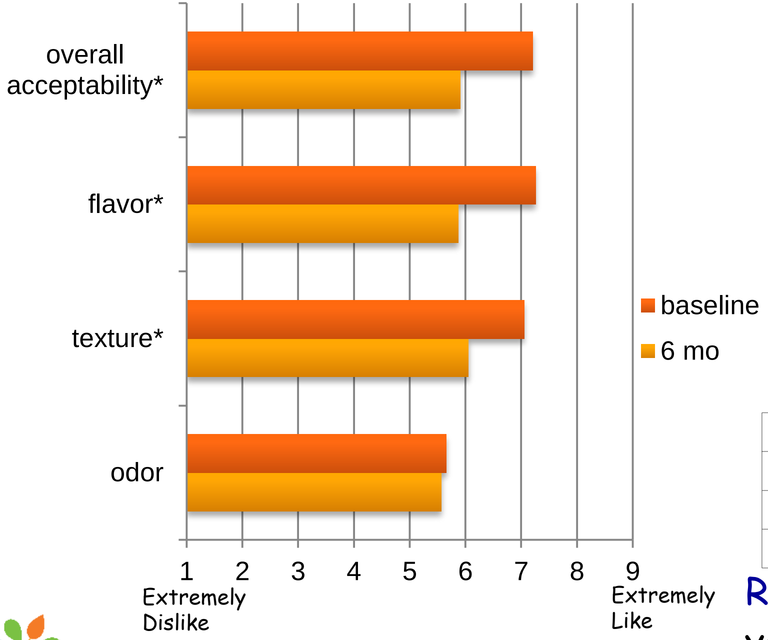
5.98% - No

**Panel profile for raw baseline (*n* = 118) of 118 participants:**
**78.4% were female and 75.9% were aged between 18 to 27 years.**

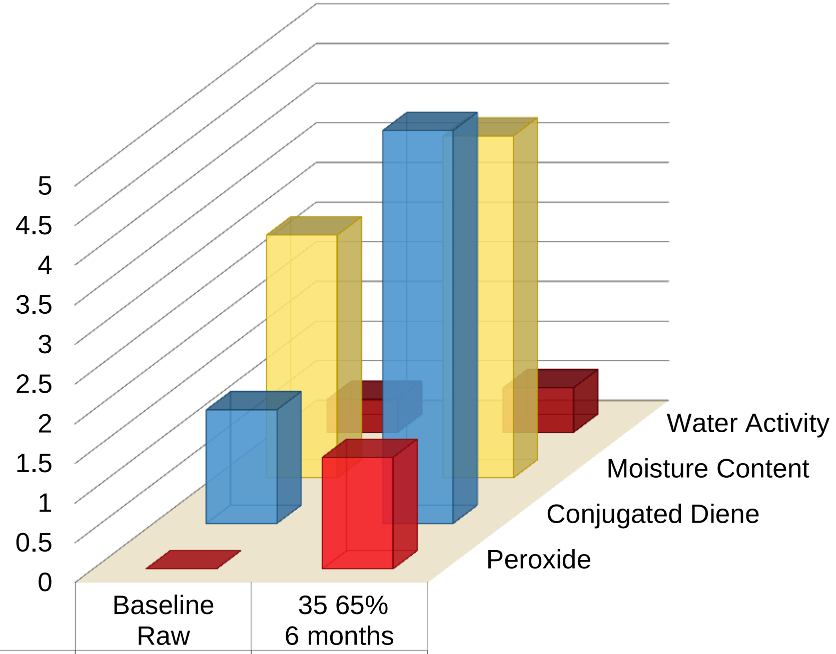
| | Daily | Several times a week | Several times a month | Once a month | Several times a year | Never |
|---|---|---|---|---|---|---|
| **Consumption** | Frequency (%) | | | | | |
| **Nuts** | 19.0 | 35.3 | 28.4 | 10.3 | 6.0 | 0.9 |
| **Almonds** | 6.9 | 25.0 | 32.8 | 12.1 | 19.8 | 3.4 |

# 6 mo - Results for Rejected Raw Almond Sample in a PP Bag @ 35 °C/65% RH

## Consumer sensory evaluation: Baseline vs. rejected sample




## Chemical analyses: baseline vs. rejected sample

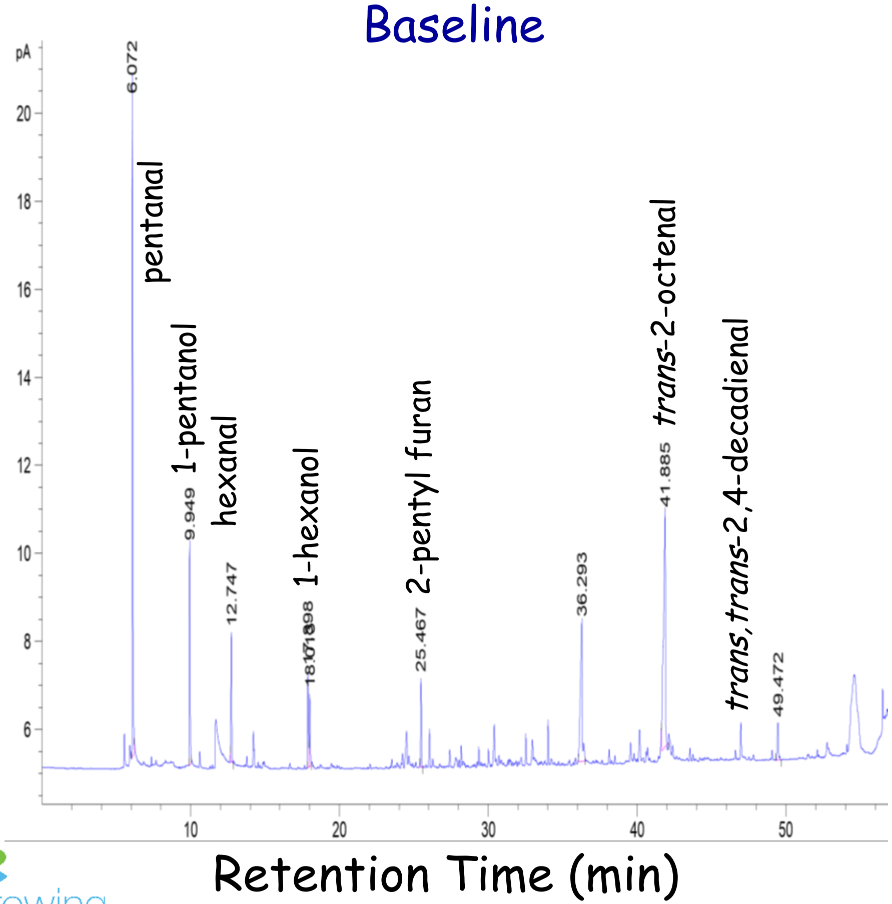


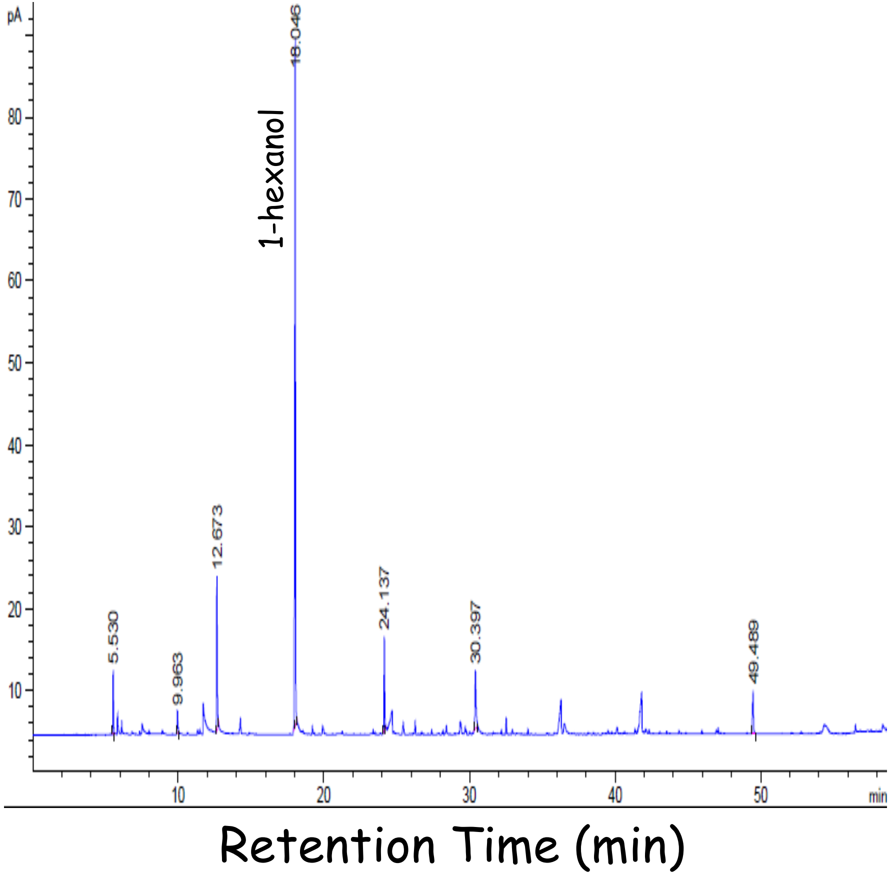

| | Baseline Raw | 35 65% 6 months |
|---|---|---|
| Peroxide | 0 | 1.405 |
| Conjugated Diene | 1.43 | 4.95 |
| Moisture Content | 3.06 | 4.31 |
| Water Activity | 0.414 | 0.561 |

Rejection Question: If you had purchased this product, would you eat it?

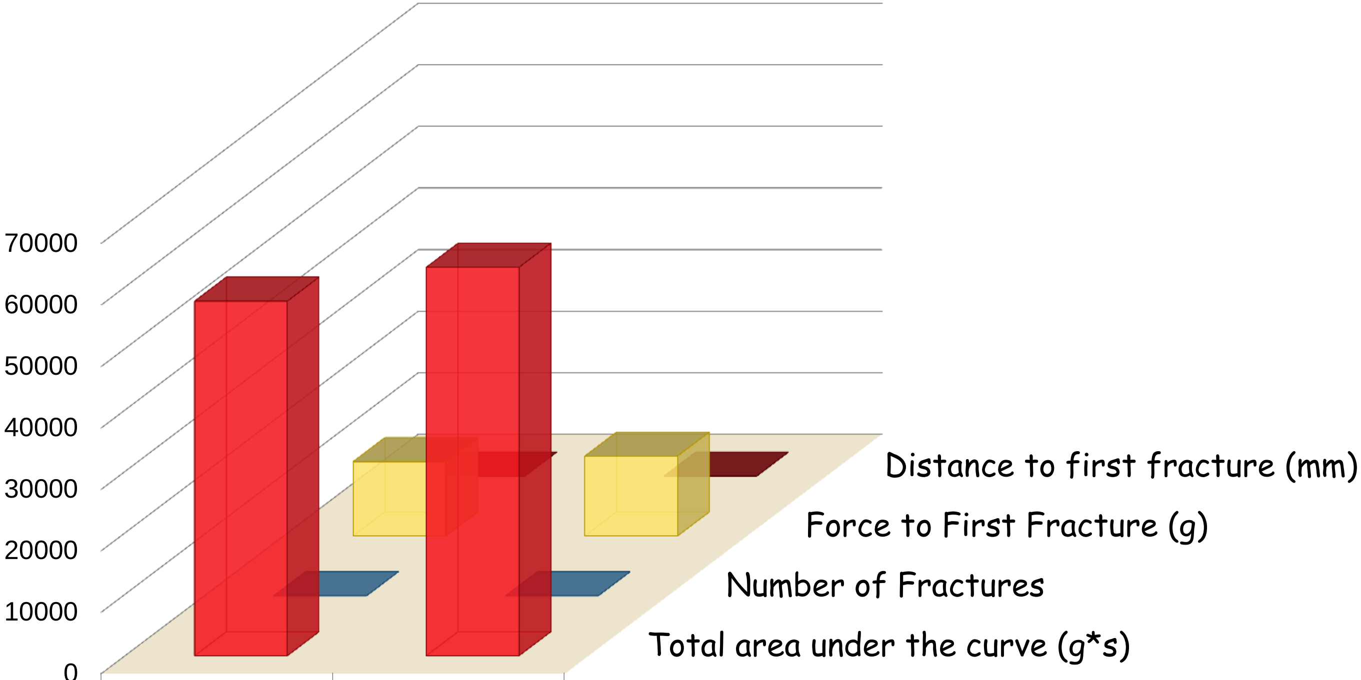
5.98% 'No' at baseline; 27.2% 'No' at 6 months.

# 6 mo - Results for Rejected Raw Almond Sample in a PP Bag @ 35 °C/65% RH



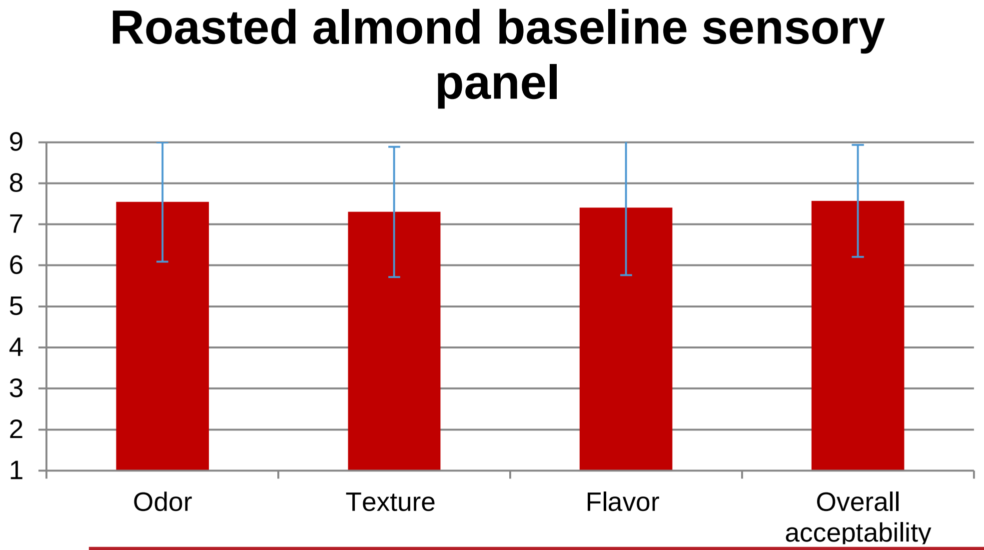



# 6 mo-Texture Results for Rejected Raw Sample in a PP Bag @ 35 °C/65% RH




| | 35 65 6 months | Baseline Raw |
|---|---|---|
| Total area under the curve (g*s) | 57700 | 63200 |
| Number of Fractures | 6.3 | 5.91 |
| Force to First Fracture (g) | 12100 | 13000 |
| Distance to first fracture (mm) | 1.24 | 1.19 |

# Baseline Data: Sensory Roasted Almonds (n=119)




**Rejection Question:**
If you had purchased this product, would you eat it?

4.00% - No

**Panel Profile for roasted almond baseline (n= 119) of 119 participants 77.3% were female and 74.8% were aged between 18-27 years.**

| | Daily | Several times a week | Several times a month | Once a month | Several times a year | Never |
|---|---|---|---|---|---|---|
| **Consumption** | Frequency (%) | | | | | |
| **Nuts** | 17.6 | 32.8 | 34.5 | 8.4 | 8.4 | 5.9 |
| **Almonds** | 5.0 | 22.7 | 38.7 | 15.1 | 16.8 | 1.7 |

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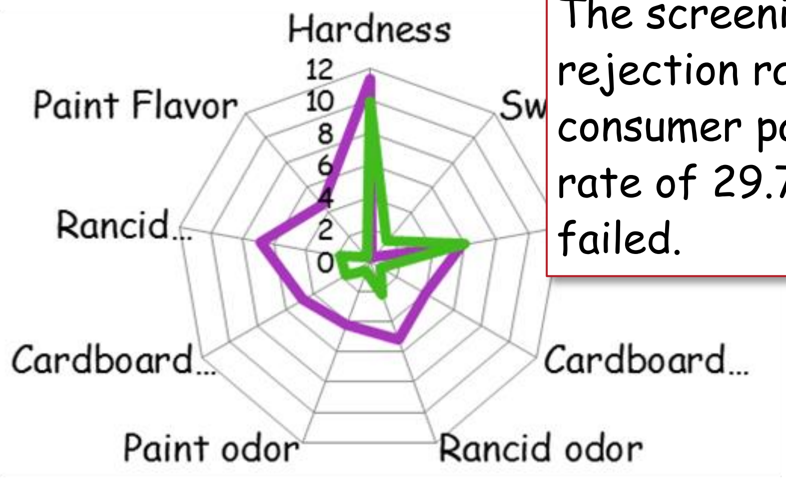
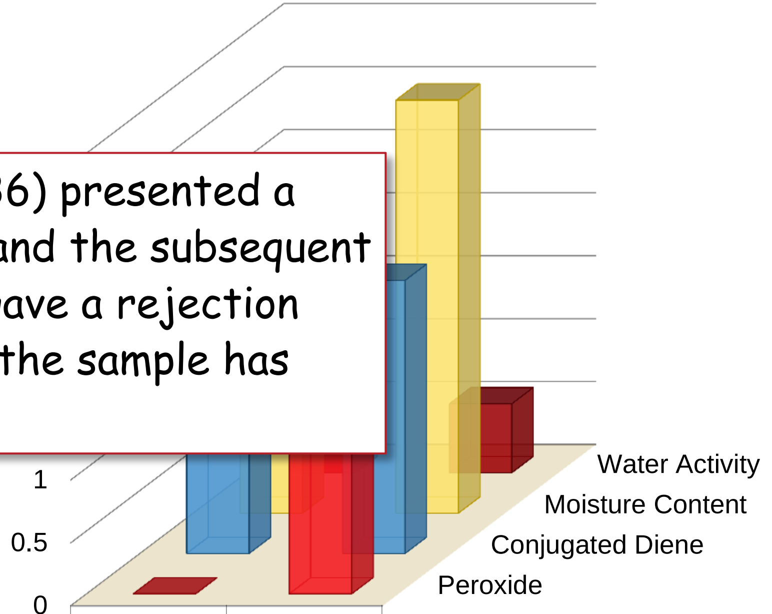
# 12 mo - Results for Roasted Almond Sample in a PP Bag @ 35 °C/65% RH

## Descriptive sensory evaluation: Baseline vs. 12 mo




The screening panel ($n$ = 36) presented a rejection rate of 25.0%, and the subsequent consumer panel ($n$ = 101) gave a rejection rate of 29.7%, indicating the sample has failed.




| | Baseline Roasted | 35 65% 12 mo |
|---|---|---|
| Peroxide | 0 | 1.89 |
| Conjugated Diene | 1.85 | 2.17 |
| Moisture Content | 0.893 | 3.28 |
| Water Activity | 0.141 | 0.548 |

Attribute means on truncated 15-point lines (* = $p < 0.05$)

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| Analysis type | Effect on Consumer Acceptability |
|---|---|
| ↑ PV | ↑ Rancid odor/flavor |
| ↑ Moisture | Δ Texture Characteristics |
| ↑ $a_w$ | Δ Texture Characteristics |
| ↓ # of Fractures | Δ Texture Characteristics |

# Roasted Almonds
# PE bag 35°C/65% RH

| Non-sensory data | |
|---|---|
| PV (meq. $O_2$/kg oil) | 1.49±0.18 |
| Moisture (%) | 2.87±0.07 |
| $a_w$ | 0.46±0.003 |
| # of Fractures | 10.2±4.78 |

**8 mo**

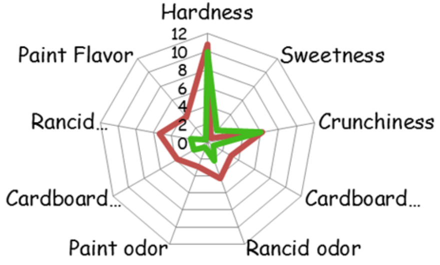
| Non-sensory data | |
|---|---|
| PV (meq. $O_2$/kg oil) | 1.84±0.022 |
| Moisture (%) | 3.80±0.31 |
| $a_w$ | 0.53±0.006 |
| # of Fractures | 5.3±3.53 |

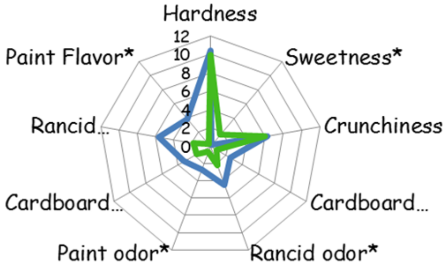
**10 mo**

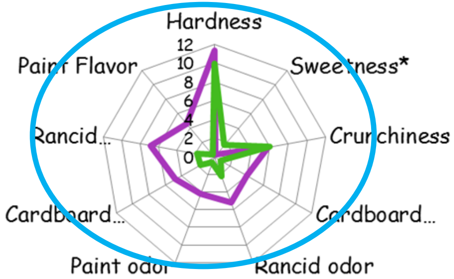
| Non-sensory data | |
|---|---|
| PV (meq. $O_2$/kg oil) | 1.89±0.048 |
| Moisture (%) | 3.28±0.09 |
| $a_w$ | 0.55±0.004 |
| # of Fractures | 4.1±1.45 |

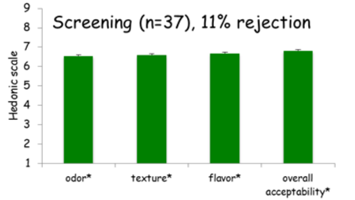
**12 mo**

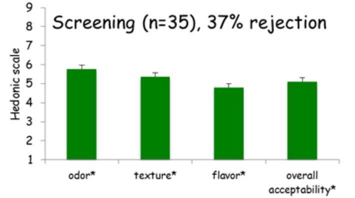
## Descriptive (n=6)

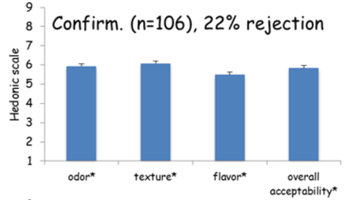


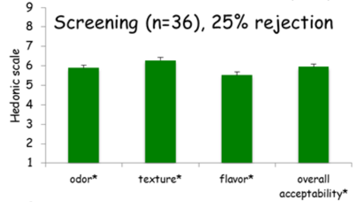



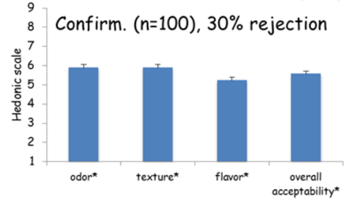



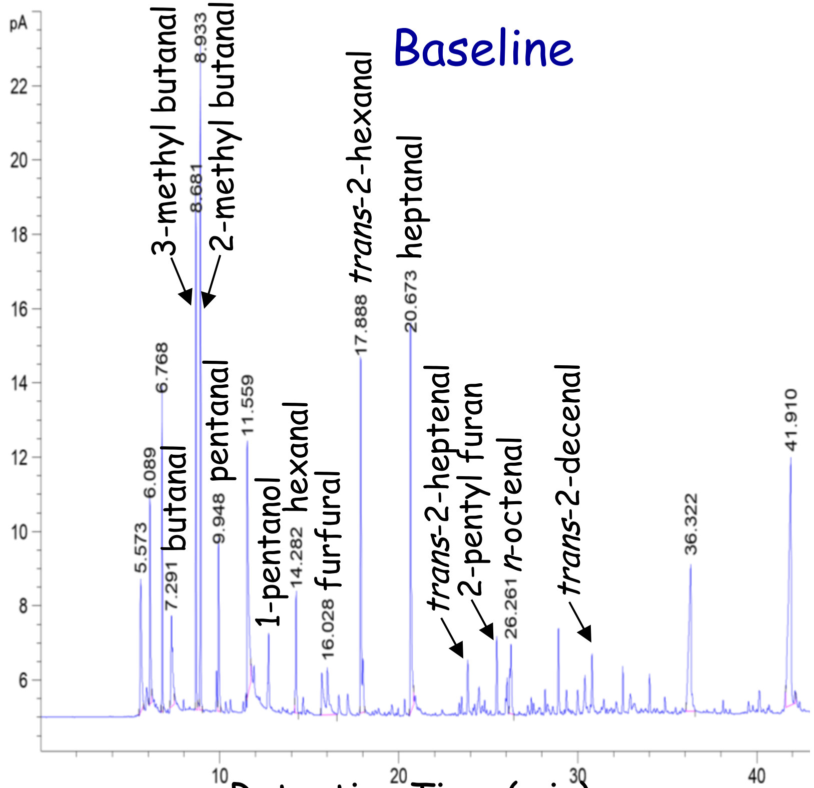



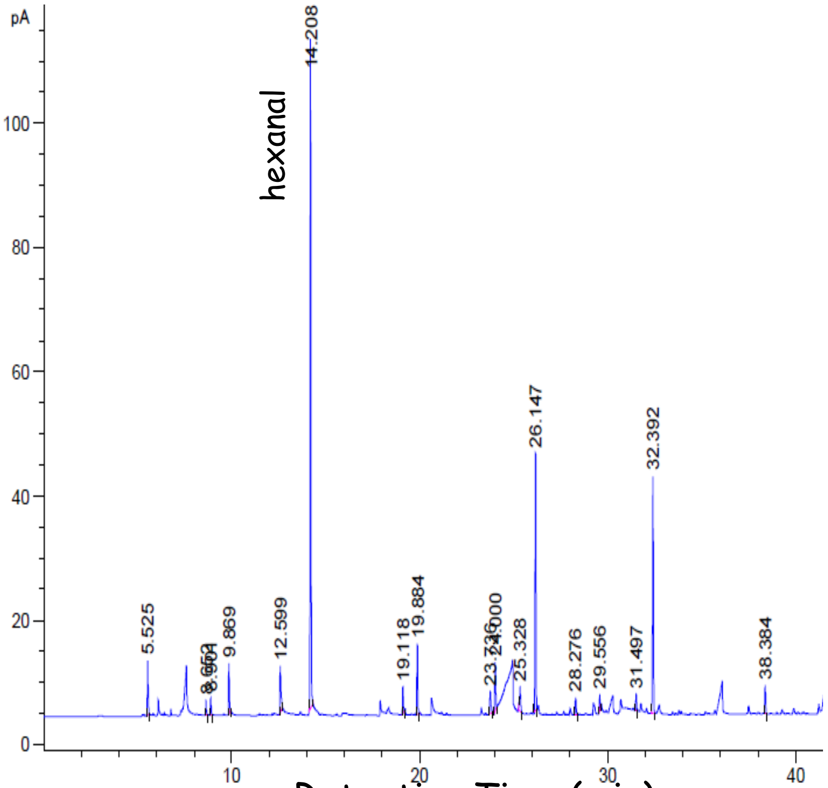



# 12 mo - Results for Roasted Almond Sample in a PP Bag @ 35 °C/65% RH



# Findings to Date

- Almonds stored at **higher Ts** are degrading more rapidly than counterparts at lower Ts.
- Almonds stored in the **unlined cartons (UC) at higher RHs** are absorbing more $H_2O$; this is negatively impacting textural properties and rancidity.
- For almond samples in unlined cartons, desirable flavor volatiles **decrease** with time giving rise to overtone carbonyl compounds; these are related to rancidity.
- The **texture** has proven to be extremely important to the rejection of samples.
  - The texture of raw almonds (**which showed no signs of oxidation**) stored in unlined cartons at 4 °C and without RH control was more like that of an undercooked bean rather than a crunchy almond.
- The early onset of lipid oxidation compounds impacting odor and flavor in almonds does not translate to consumer rejection.

**$N_2$-flushed PP bags provide adequate storage for raw and roasted almonds up to 22 mo and 16 mo, respectively, at 25 °C/50% RH or below.**

# Acknowledgments

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Questions?

growing

ADVANTAGE

The Almond Conference