2017 THE ALMOND CONFERENCE

MAXIMIZING SHELF LIFE

Room 314 | December 6 2017

california almonds
Almond Board of California

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The Almond Conference

CEUs – New Process

Certified Crop Advisor (CCA)

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

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

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

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

AGENDA

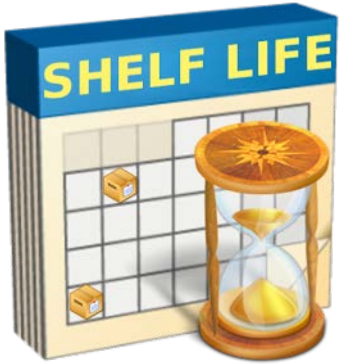
- **Guangwei Huang**, Almond Board of California, moderator
- **Ron Pegg**, University of Georgia
- **Kenneth Marsh**, Kenneth S. Marsh & Associates

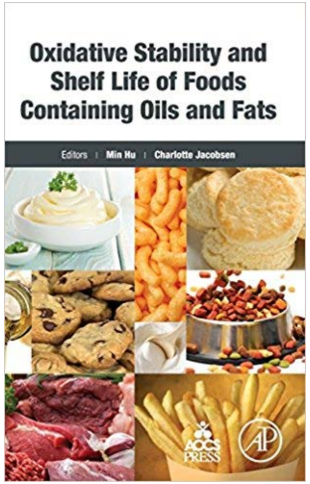
MAXIMIZING SHELF LIFE OF YOUR ALMONDS

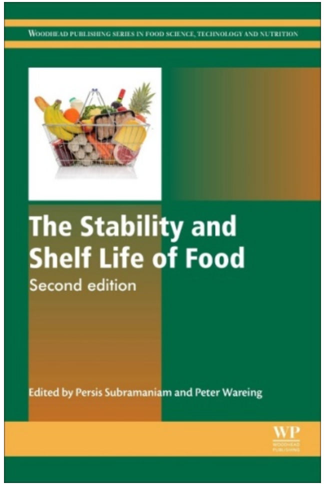
Ronald B. Pegg
Department of Food Science & Technology
December 6, 2017

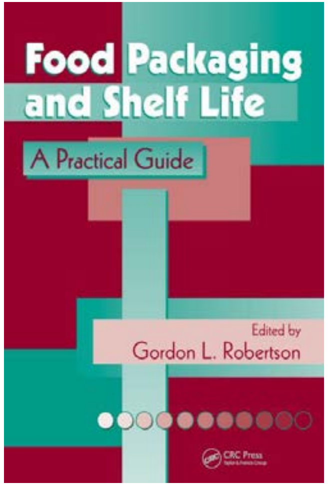
UNIVERSITY OF GEORGIA

What is shelf life (SL)?









SL is a finite length of time (*t*) after production and packaging during which the food product retains a required level of quality under well-defined storage conditions.

Manzocco. 2016. *Crit. Rev. Food Sci. Nutr.* 56:1640-1646.

Basically, there are 2 possibilities for a product to become unacceptable during storage …

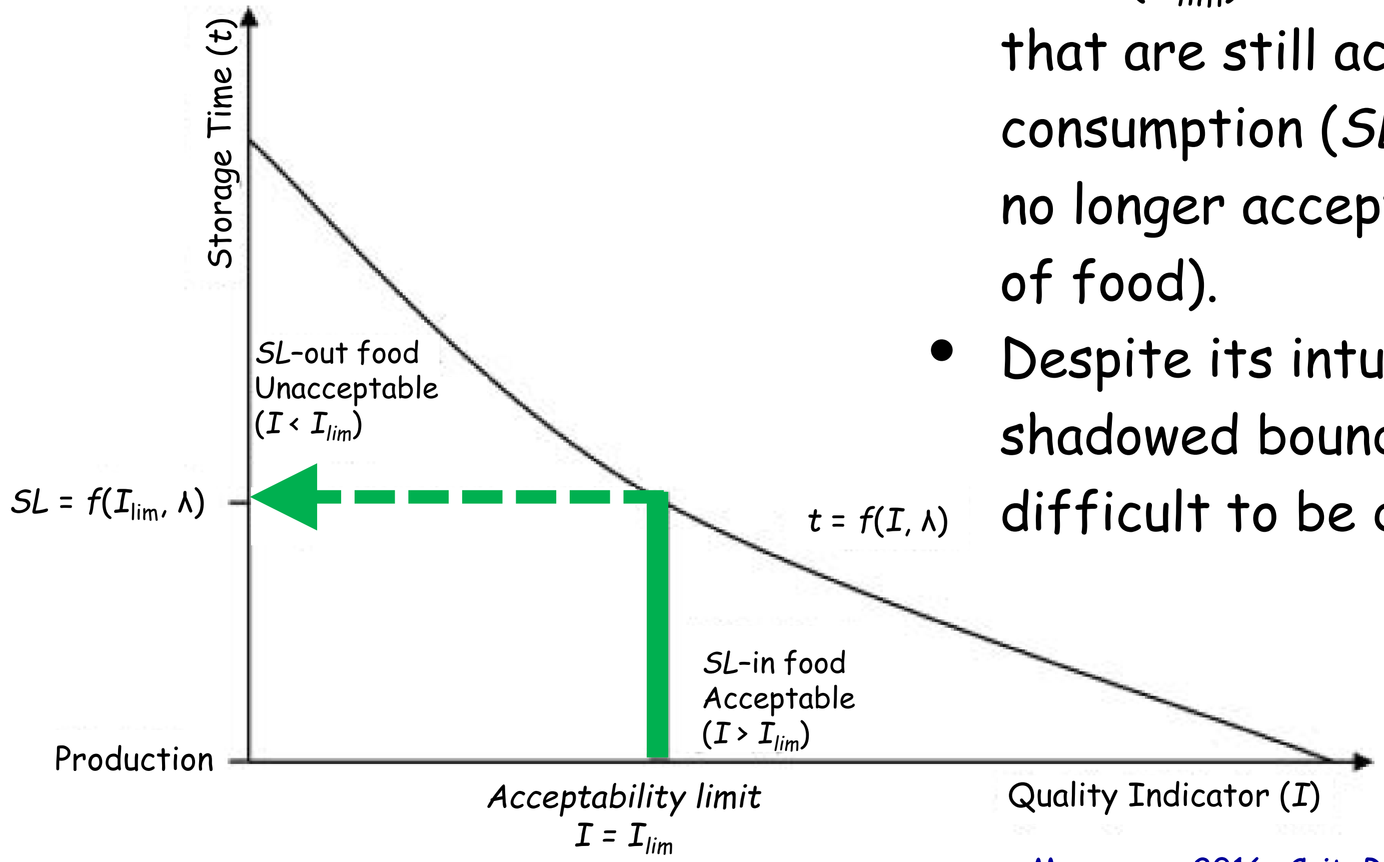
(1) the development of a risk for consumer dissatisfaction due to poor quality appearance, low sensory, and/or nutritional quality of the product (e.g., lipid oxidation);

(2) mainly associated with safety issue potentially leading to a risk for consumer health.

Shelf Life
Stability Studies

"Best By Date" – Is it Legit?

Λ = parameters such as T, RH, packaging type, # of films & thicknesses, O_2 level …

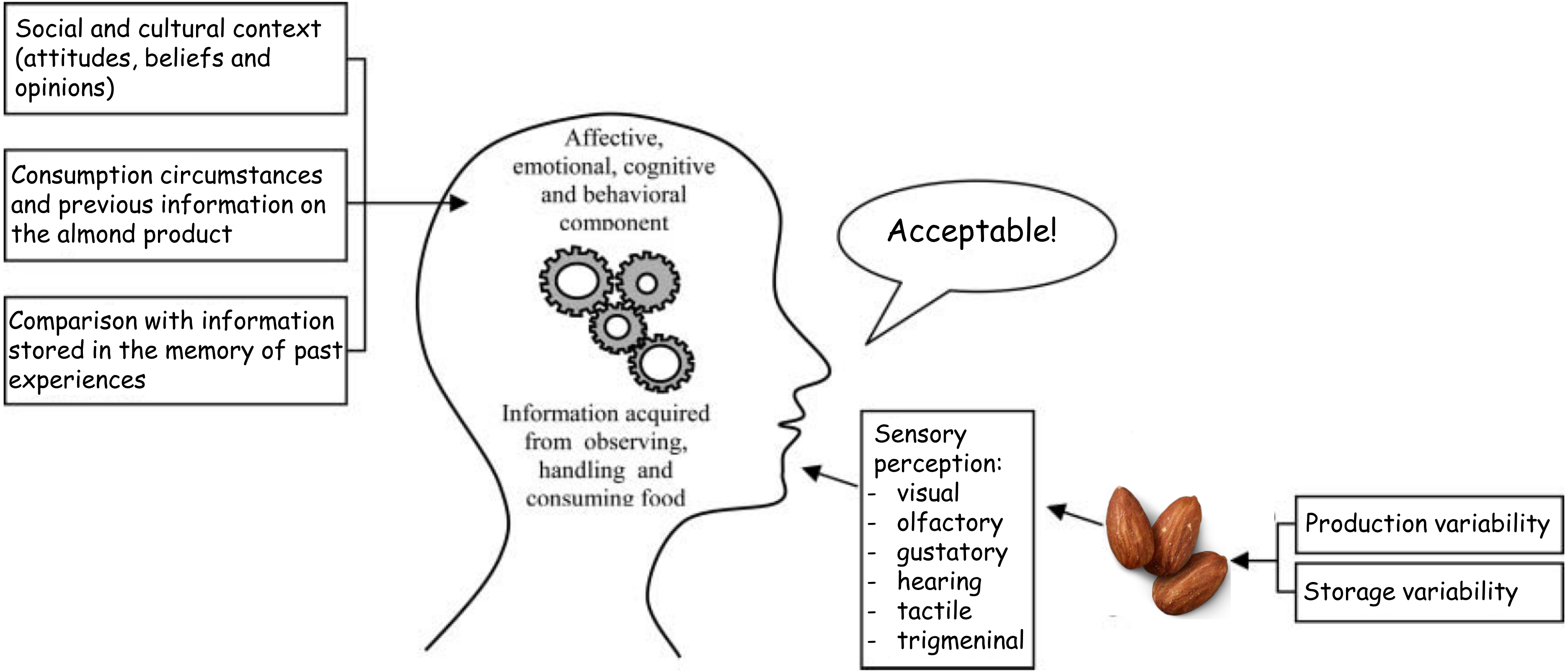


- The concept of an acceptability limit (I_{lim}) discriminates products that are still acceptable for consumption (*SL*-in food) from the no longer acceptable ones (*SL*-out of food).
- Despite its intuitive nature, it is a shadowed boundary that is difficult to be defined.

Manzocco. 2016. *Crit. Rev. Food Sci. Nutr.* 56:1640-1646.

Sensory analysis is one of the most suitable processes for measuring oxidative damage and determining the shelf-life (*SL*) of foods, but it is an expensive and time-consuming methodology.

Lipid oxidation is one of the most common causes of deterioration in the sensory and nutritional quality of nuts.



Variables affecting consumer acceptance or rejection of stored almonds.

Almonds are susceptible to …

- Microbial spoilage … mold

- Oxidation

- Textural degradation

Nuts are protected from light and humidity inside their shells, and they can be conveniently stored for a long time.

The pellicle that covers the nuts is rich in phenolic compounds that confer extra protection against oxidative damage.

For economic reasons, however, a great % of nuts sold in the market are out of their shell and exposed to light, oxygen, and elevated temperatures.

Solutions…

- Microbial spoilage … mold → Reduce moisture content to 4-6%
- Oxidation → Nitrogen flush, vacuum package
- Textural degradation → Protect against too high/too low RH

What is needed to achieve this?

$

Factors that Affect Shelf Life

- Almonds are relatively low-moisture, high-oil-containing nuts with a long shelf life when properly handled.
- Almond quality and shelf life can be influenced by three general factors: the *product characteristics*, the *environment* during distribution and storage, and the *package*.
- These factors interact in many ways to influence almond quality and to impact shelf life.
- Shelf life guidance for almonds must specify the product and the storage conditions.

Major Factors Influencing Almond Quality and Shelf Life (ABC 2014)

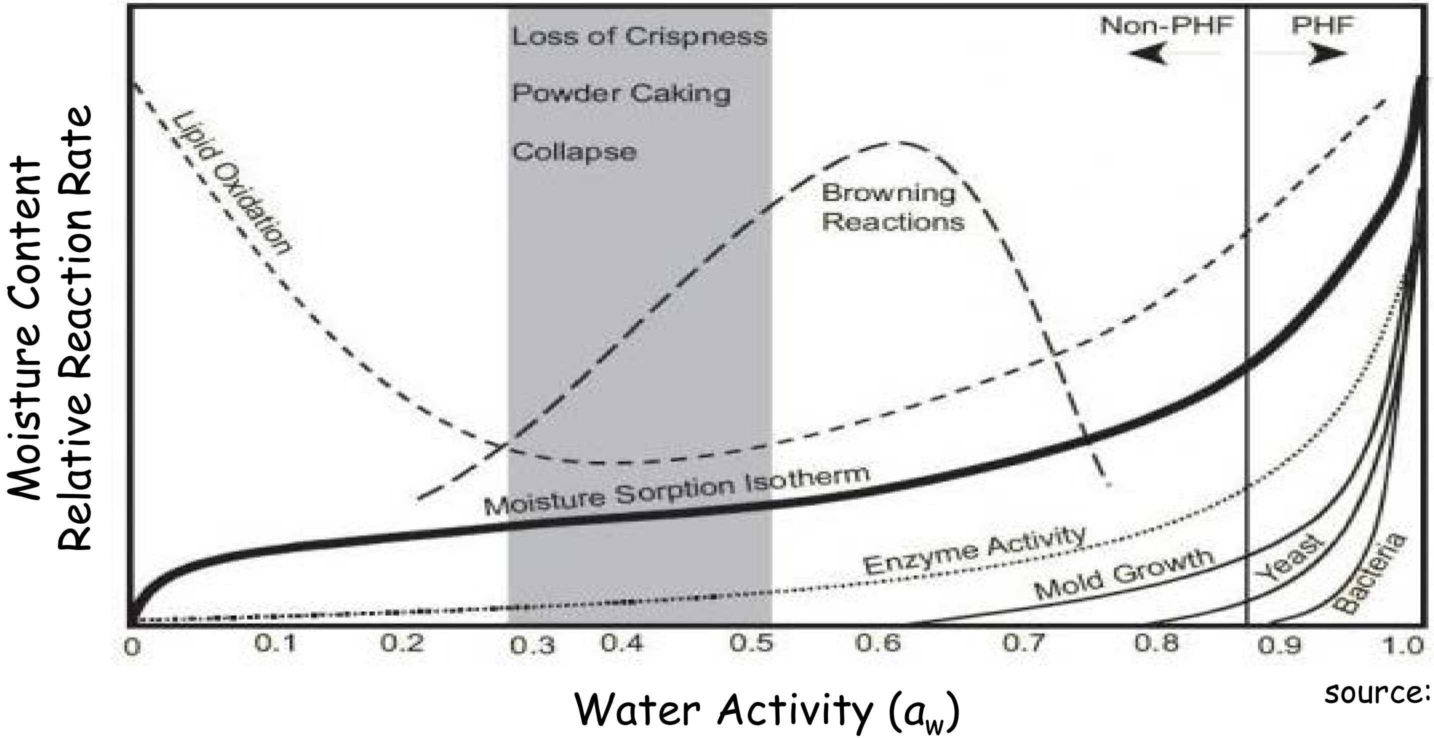
Product characteristics	Environment	Package
Composition; Water activity; Form.	Temperature; Humidity; Oxygen; Processing conditions; Insects, pests, microorganisms.	Physical protection; Moisture barrier; Gas barrier.

ABC Recommendations – Storage Conditions and Handling Practices

- Storage for all almond forms in cool and dry conditions (<50°F/<10°C and <65% relative humidity) is recommended.
- The optimal goal of the recommended storage conditions is to maintain <6% MC, which helps preserve shelf life.
- A cool temperature of <50°F/<10°C is optimal, but a higher temperature that does not stimulate insect activity may work as well to control moisture migration (and also minimize lipid oxidation).
- Almonds are a shelf-stable nut that can have more than two years of shelf life when stored at the recommended conditions.

High Quality → Moisture <6%, a_w 0.25-0.35, Free fatty acids <1.5%, PV <5 meq/kg

Water Activity (a_w) – Stability Diagram

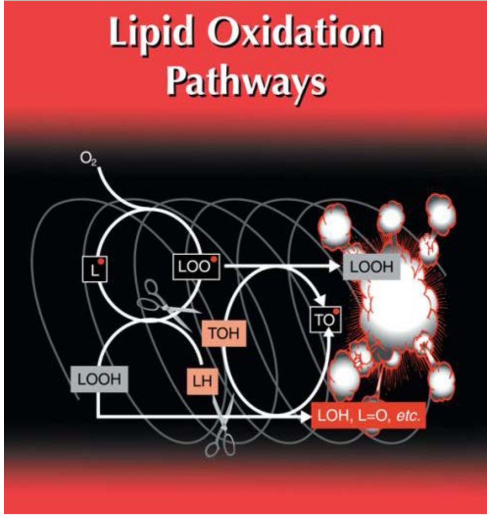


LOx is lowest at a_ws of ~0.2 to 0.4

source: www.aqualab.com

Knowledge of T, RH, and a_w levels can aid in the selection of a package with the correct barrier properties to optimize quality and shelf life.

Lipid Oxidation



- Lipid oxidation (lipox) is a complex series of undesirable reactions that cause the breakdown of fats and oils.

- In almonds, the oxidation reactions lead to a loss of quality as the nuts develop "rancid" flavors and odors.

- During lipox, O_2 reacts spontaneously with the fatty acids in fats to form primary breakdown products (e.g., peroxides, conjugated dienes) and, as oxidation progresses, secondary products (e.g., volatile aldehydes, ketones) are formed that give rise to off-flavors and off-odors.

- Oxidation can be measured by testing for the presence or accumulation of one or more of these primary and secondary products.

Several simple chemical tests based on spectrophotometry or titration can be used to track lipid oxidation in nuts.

- Peroxide value (measure hydroperoxide formation), *1°*
- TBARs (2-thiobarbituric acid reactive substances), *2°*
- *p*AV (*para*-anisidine value), 2°
- Hexanal formation by HS-SPME-GC, 2°
- Tocopherol (vitamin E) analysis

What about the impact of relative humidity (RH)?

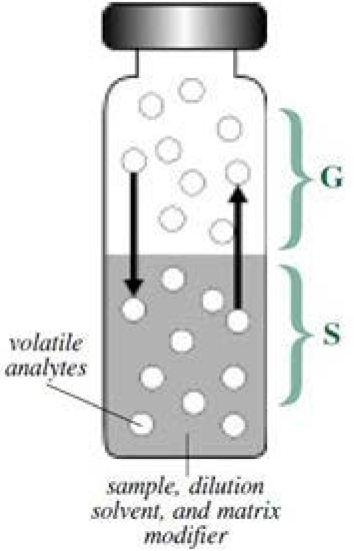
Zajdenwerg (2011. *Eur. Food Res. Technol* 233:109-116) investigated Brazil nut oxidative shelf-life using chemical analysis and sensory evaluation. Accelerated storage at 80°C with no mention of RH.

- Consumers rejected nuts after 12 days
- PV = 18.8 meq. active O_2/kg oil
- *p*AV = 7.68
- Hexanal = 49 µmol/100 g oil

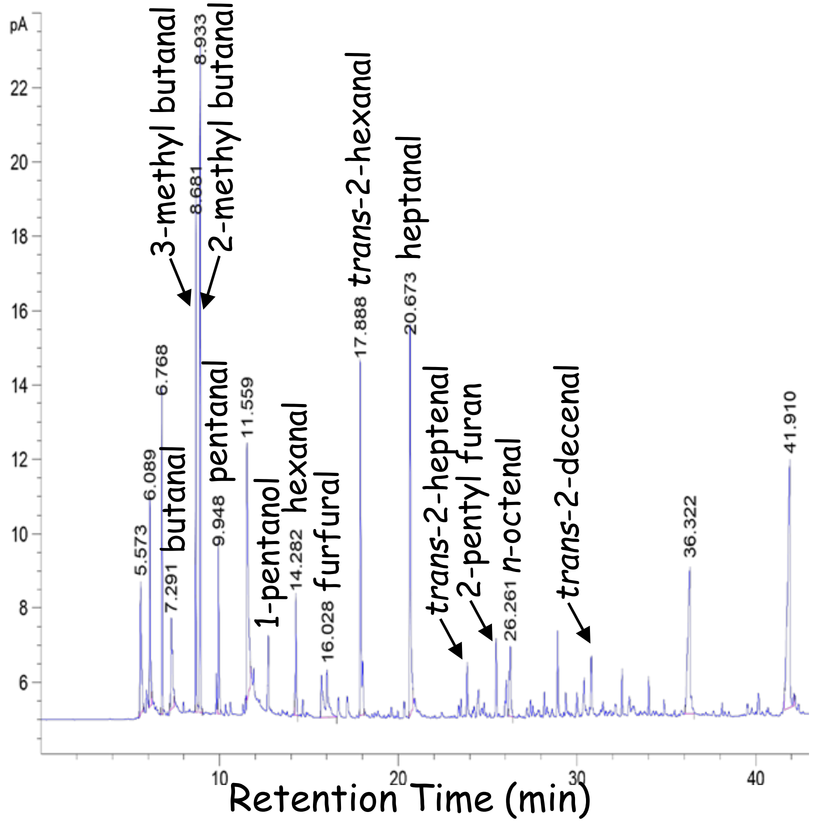
Volatiles Reaching our Nose

- Hexanal is an important secondary product of lipox of linoleic acid.
- It is a volatile aldehyde with a "fatty, green, grassy" note.
- It forms as almonds oxidize during storage; it can be measured and used as an indicator of oxidative rancidity.
- Other volatile compounds exist in raw, roasted, and stored almonds.
- Emerging research is showing that selected volatiles other than hexanal might be sensitive markers of early oxidation in almonds.

Headspace – Solid Phase Microextraction – Gas Chromatography – Mass Spectrometry Analysis



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

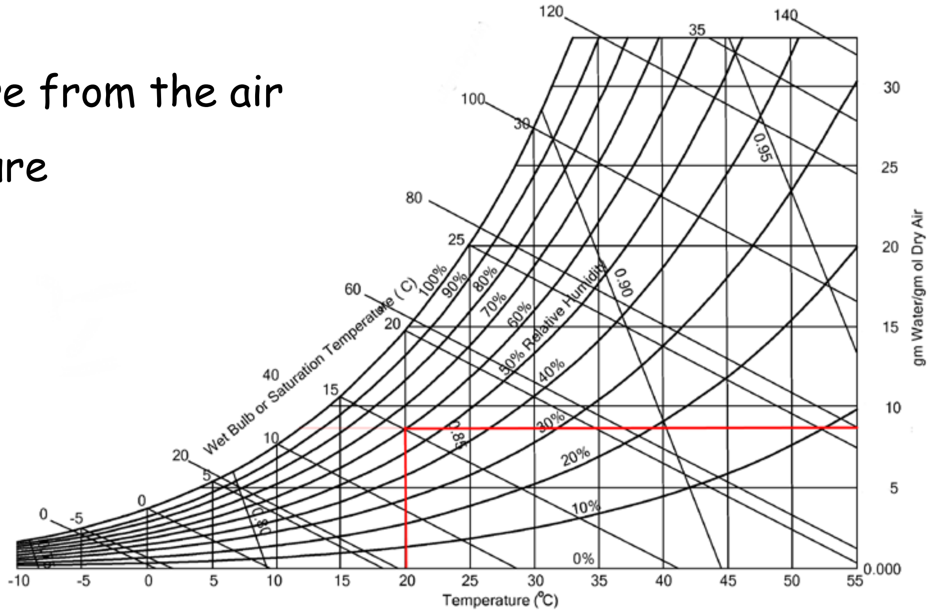


Moisture Migration

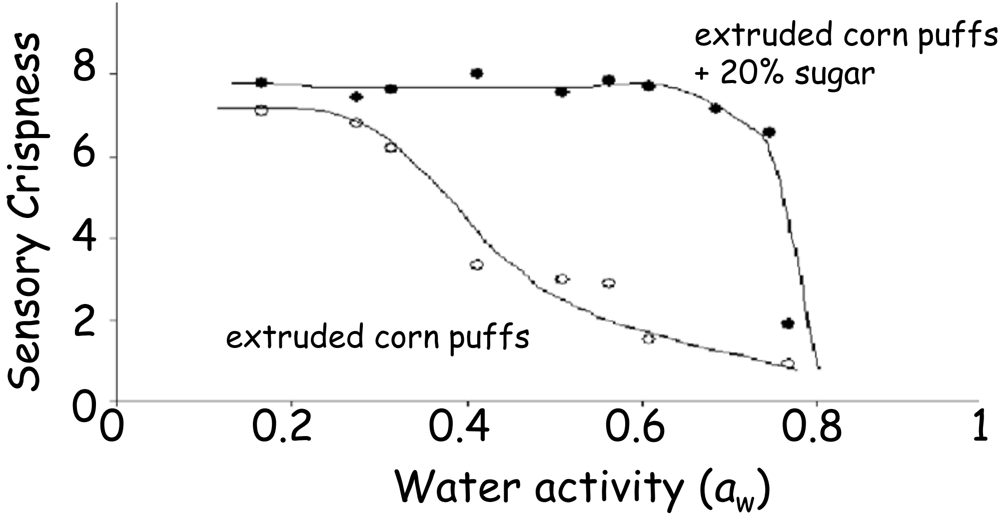
- The difference between the relative humidity (RH) of the surrounding environment and water activity (a_w) of the food determines whether a food gains or loses moisture during storage
  - RH > a_w, then food will absorb moisture from the air
  - RH < a_w, then the food will lose moisture
  - At equilibrium,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

a_w is the vapor pressure of water above a sample (P) divided by that of pure water at the same T (P_o)

$a_w = P/P_o$



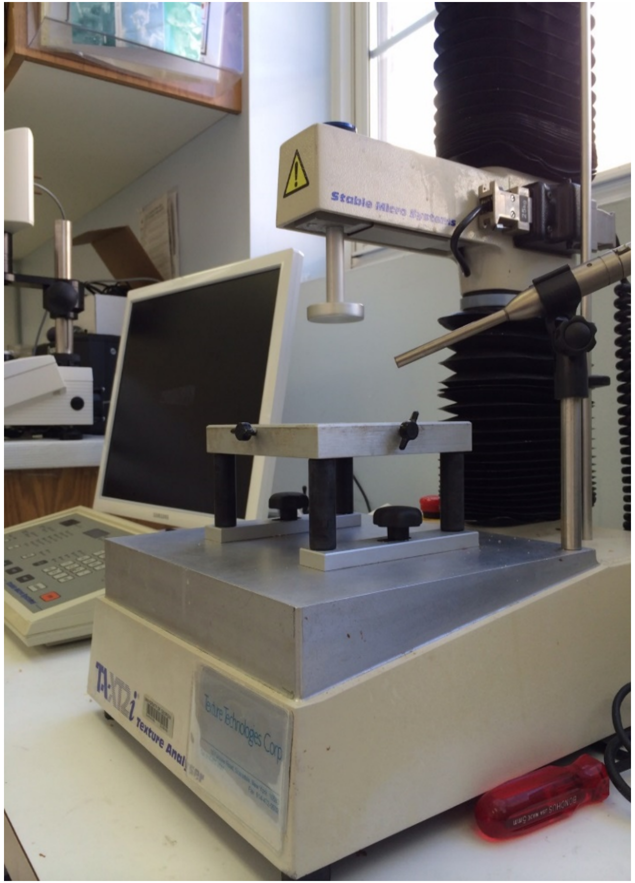
Crispness scores drop when a critical moisture (a_w) is reached



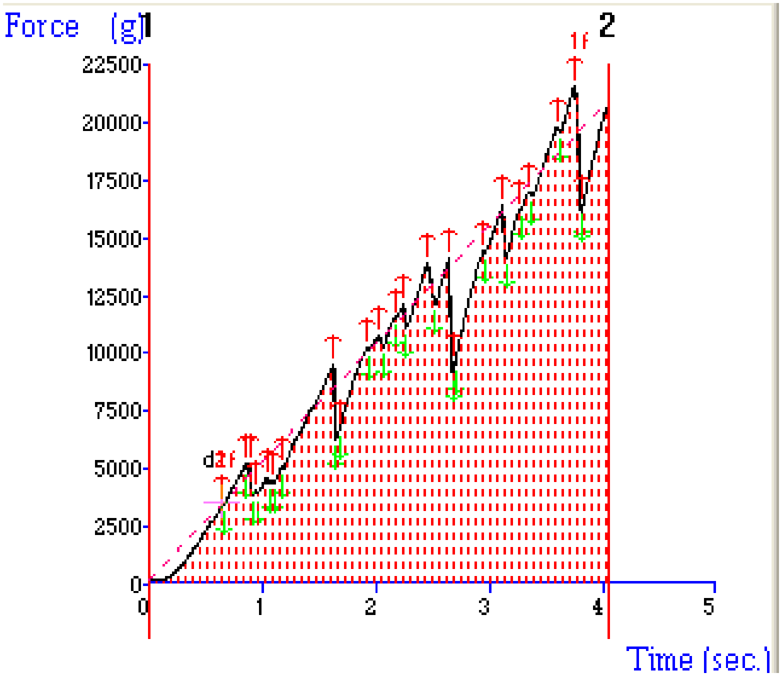
G. Roudaut. (2007). Ch 8 in *Water Activity in Foods*. Blackwell Publishing.

Method for Texture & Sound Analysis

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



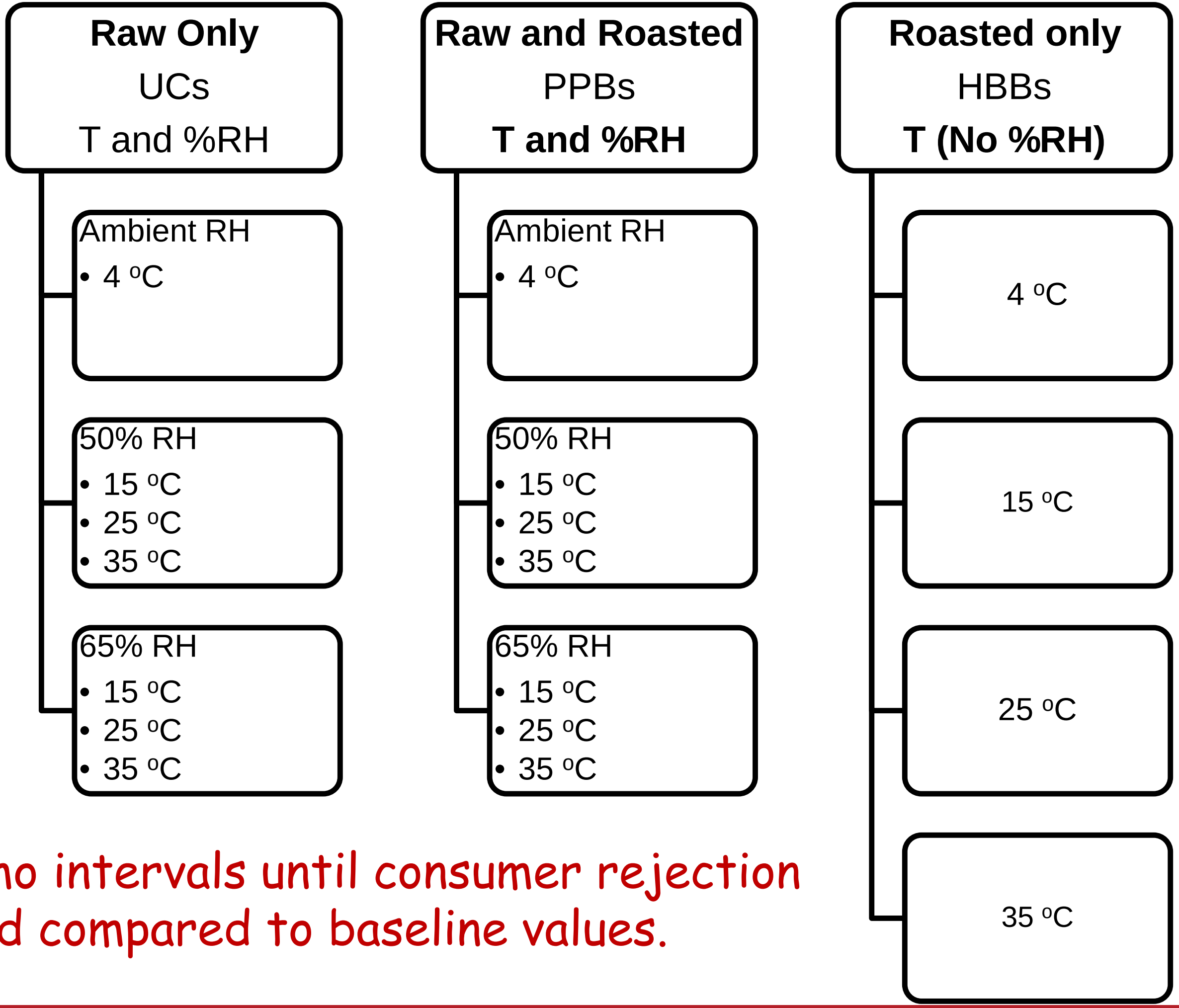
Description of textural factors extracted from the force/displacement curves



Parameter	Textural association
Number of force peaks (FP)	Crispness Brittleness
Average gradient (AG)	Chewiness
Average drop-off (AD)	Crispness Brittleness

Study Design

The effects of environmental storage conditions on roasted and raw almond quality characteristics were investigated with an incomplete factorial design (n = 25) over 16-mo and 24-mo, respectively.



Samples were analyzed at 2-mo intervals until consumer rejection or conclusion of the study, and compared to baseline values.

Rejection timeline for raw and roasted almond samples

Rejection timeline (mo) for all samples

A (Raw PPB)				35/65			35/50		25/65	15/65
B (Raw UC)		35/65		35/50 4/90			25/65 15/65		25/50 15/50	
Mo	**0**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**>> 24**
C (Roast PPB)							35/65	35/50	25/65	
D (Roast HBB)									35	

Samples that were not rejected

Sample	Rejection Rate
A 25/50	22.5%
A 15/50	10.0%
A $4/90^{+}$	12.7%
C 25/50	18.6%
C 15/65	20.6%
C 15/50	8.9%
C 4/90	9.8%
D 25	2.9%
D 15	7.9%
D 4	5.9%

Shelf-life:
HBB >> PPB > UC
At 35 °C, roasted > raw

Summary

<u>Chemical</u>

- ↑ values → ↓ overall acceptability and ↑ rejection rate
- Univariate analysis revealed …
  - Overall acceptability: a_w > FFAs > PVs
  - Rejection rate: FFAs > PVs

<u>Textural</u>

- ↑ FPs, ADs → ↑ overall acceptability and ↓ rejection rate
- ↑ AGs → ↓ overall acceptability and ↑ rejection rate
- Univariate analysis revealed …
  - FPs > ADs

Overall Study Conclusions

- For both raw and roasted almonds, an interaction of chemical and textural parameters predicted shelf life.
- Both temperature and humidity are important to regulate during storage …
  - Almonds stored at higher Ts degraded more rapidly than counterparts at lower Ts.
  - Almonds stored at higher %RH degraded more rapidly than counterparts at lower %RH
- Using univariate analysis, a_w and MC were determined to be the better predictors of overall acceptability and rejection rate.

Acknowledgments

Almond Board of California

Guangwei Huang

Karen Lapsley

Managing Moisture to Maximize Shelf Life of Almonds

Kenneth S. Marsh, PhD, CPP, CFS

Kenneth S. Marsh & Associates, Ltd.

www.drkenmarsh.com

42nd Almond Annual Conference

Sacramento Convention Center

December 6, 2017

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Shelf Life

- Time after production that a food product remains acceptable

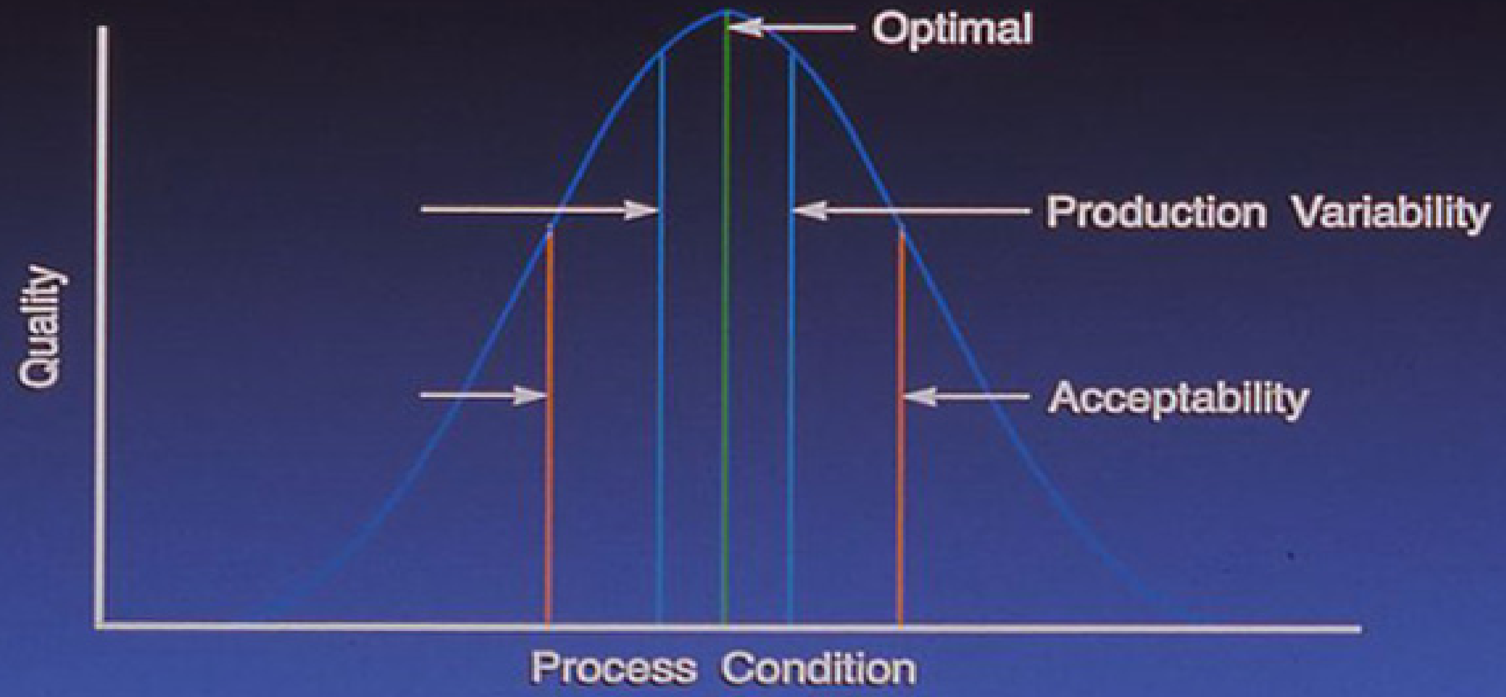
- Factors effecting shelf life:
  - Product
  - Processing
  - Packaging
  - Storage environment
  - Company standards

Some Comments

- Safety is mandatory; quality is optional
- Definition of acceptability is important
- Multiple degradation - pick most critical
- Packaging contains, protects, presents
- Distribution plays an important role

- Modeling lets you “try” alternatives

QUALITY PROFILE



Almond Package Examples from China Market

Local Packages and Dates

Claimed Best by Quality Remaining (months) for Some Commercial Almond Products

Package – from "Best by:" and "Sell by" dates	Ambient
Almonds in PETE tub	6
Almonds-All Natural - in pouch (suggest fridge)	9
Trail Mix - clear stand-up pouch	9
100 Calorie Almonds – pouch-in-box	12
Wasabi-Soy Almonds - foil stand-up pouch	14
Whole Natural - in can	19

Shelf Life Modeling

- Product parameters: initial moisture, critical moisture, moisture isotherm that defines moisture impact.
- Packaging parameters: WVTR, thickness, area, net weight
- Environmental parameters: Temperature, relative humidity

Assumed in 12 oz. package of OPP25/ink/adh/EVOH50 – WVTR 0.258

Shelf Life Model

$$\text{Shelf Life} = \frac{\text{Ln}\ ((Me-Mi)/(Me-Mc))}{(WVTR*((A/100/Ws)*(Po/b))}$$

Me, Mi, Mc = equilibrium, initial, critical moistures

WVTR = Water Vapor Transmission Rate

Ws = Weight solids

A = Area of package

Po = Saturated vapor pressure

b= slope isotherm

Estimation of Shelf Life Potential Based on Moisture Adsorption

- Estimation assumption – Shelf life is defined by moisture content:
  - Initial moisture: 5.0%
  - End moisture: 6.0%

12 oz. package

OPP25/ink/adh/EVOH50 – WVTR 0.258

Same size flexible pouch

Note: Almonds are both moisture and oxygen sensitive. Shelf life is determined by that parameter that makes the product unacceptable first, and can be packaging dependent. If you use an excellent moisture barrier, rancidity can be the critical factor.

Oxidation is complex, based on history and harder to model.

Obtaining Equilibrium Moisture and Slope from Moisture Adsorption Isotherms

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TRADE & REGULATORY AFFAIRS

INTERNATIONAL TRADE
TECHNICAL INFO KIT
ALMOND QUALITY
- Almond Quality Overview
- California Almond Characterization
- Moisture Migration and Management
- Effects of Processing
- Lipid Oxidation and Oil Migration
- Shelf Stability and Shelf Life

MOISTURE MIGRATION AND MANAGEMENT

USDA Standards Almonds In-Shell

USDA Standards Shelled Almonds

Relative Humidity and Moisture

Almonds can pick up or lose moisture depending on their initial moisture content and the relative humidity (rH) of the surrounding environment — called moisture migration. Unwanted moisture migration in almonds may affect texture, microbial stability and the rate of various reactions that impact shelf life. When almonds pick up moisture (adsorption), they may lose some of their crunch, mold may start to grow, and lipid oxidation increases. Moisture loss (desorption) may lead to some desirable changes, such as more crunch, but at very low moisture lipid, oxidation also increases.

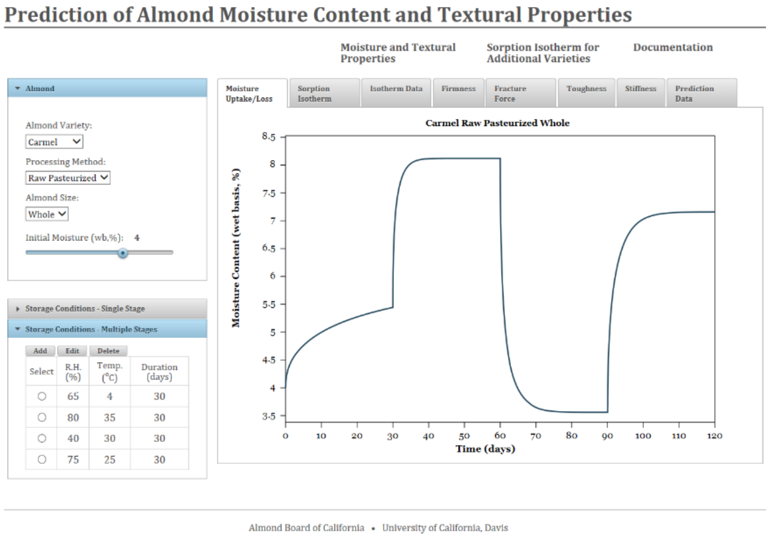
Moisture migration occurs until equilibrium within the system is reached; almonds in high-humidity environments will generally pick up moisture, especially at ambient and higher temperatures. Stopping moisture migration requires either a moisture-barrier package and/or reducing the humidity of the environment.

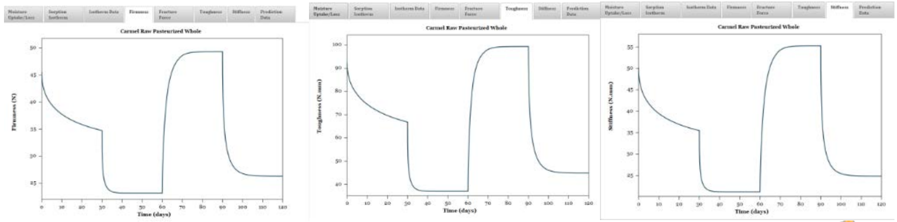
The effects of environmental rH on almond moisture levels are expressed by water sorption isotherms. As shown from almond isotherms, at a range from 20 to 65% rH, almonds will retain moisture levels from 3.0 to 6.0; at these levels, almonds are less prone to biological or chemical reactions. More ideal moisture levels for almonds are 3.0 to 5.0%, which can be achieved at environmental conditions of 20 to 55% rH. During storage, managing environmental humidity is a key to preserving almond quality. It is critical to maintain a steady environmental rH so the moisture levels in almonds will not fluctuate over storage.

Studies at the University of California, Davis, indicate that different varieties or sizes of whole almond kernels and pasteurized or unpasteurized almonds interact similarly with environmental rH, but roasted and blanched almonds interact differently.

Relative humidity fluctuation will affect almond moisture changes, which will impact texture quality. This online moisture and texture model demonstrates the effects of environmental rH on almond moisture content and the impact on texture properties.

To use the online moisture and texture model, click the image below.





http://www.almonds.com/processors/choosing-and-using-almonds/almond-quality/moisture-migration-management

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WVTR of Packaging Materials Used by Almond Stakeholders

Package	g/100in^2/day
1.25 mil NA940 – LLDPE	0.88
OPP25/ink/adh/EVOH50	0.258
48gaPET/DL/48gaVMPET/DL/320gaLLDPE	0.18
Nylon (MVTR from spec sheet)	0.077
PP/ink/adh/MPET/adh/PE	0.05
76gaOPP/DL/48gaVMPET/DL/160gaLLDPE	0.05
Foil	<0.001
48gaPET/12#PE/.000285Foil/12#PE/150gaLLDPE	0.0006

Time to attain 6% moisture for Monterey Raw Unpasteurized at (25˚C/65%RH)

Package	Shelf Life-days
No Packaging Film	3
1.25 mil NA940 – LLDPE	88
OPP25/ink/adh/EVOH50	94
48gaPET/DL/48gaVMPET/DL/320gaLLDPE	134
Nylon (MVTR from spec sheet)	314
PP/ink/adh/MPET/adh/PE	484
76gaOPP/DL/48gaVMPET/DL/160gaLLDPE	484
Foil	years
48gaPET/12#PE/.000285Foil/12#PE/150gaLLDPE	years

Effects of Relative Humidity and Temperature to attain 6% (months)

Product	10°C/65%	15°C/50%	15°C/65%	25°C/65%
Monterey-Raw pasteurized	23.2	stable	12.6	28.0
Monterey-Raw unpasteurized, no package	3 days	stable	3 days	3 days
Monterey-Raw unpasteurized	14.7	stable	13.3	9.9
Monterey-Raw blanched	37.9	stable	68.9	stable
Nonpareil-Raw pasteurized	stable	stable	stable	stable
Nonpareil-Raw unpasteurized	30.7	stable	29.0	stable
Carmel-Raw pasteurized	stable	stable	stable	stable
Carmel-Blanched	stable	stable	stable	stable

Assumed in 12 oz. package of OPP25/ink/adh/EVOH50 – WVTR 0.258

Attaining 6% moisture under accelerated conditions (months)

Product	10°C/75%	15°C/75%	25°C/75%
Monterey-Raw pasteurized	7.8	6.5	4.8
Monterey-Raw unpasteurized	5.8	4.8	3.1
Monterey-Raw blanched	10.2	8.2	7.2
Nonpareil-Raw pasteurized	9.2	7.5	5.1
Nonpareil-Raw unpasteurized	8.9	7.2	4.8
Carmel-Raw pasteurized	12.3	8.9	6.1
Carmel-Blanched	18.8	11.6	8.9

Assumed in 12 oz. package of OPP25/ink/adh/EVOH50 – WVTR 0.258

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Other Shelf Life Impact Factors

- Larger size – area goes up as square, volume as cube → longer shelf life   Note: Bulk packaging does not fit model. It's longer!
- Better barrier usually increases shelf life
- Faster distribution reduces requirement

- Oxidation is a function of history/product handling in addition to barrier and package size.

Model Capabilities

- Shelf life v. Barrier or Barrier v. Shelf life
- Area/net wt. or Volume v. Shelf life
- Initial or Critical moisture v. Shelf life
- Moisture level v. Storage time
- Shelf life v. Temperature
- Available Shelf life in real world conditions

Impact of Initial and End Moisture Levels, and Relative Humidity (Monterey Raw Unpasteurized)

Temp	R.H.	Mi	Mc	Slope	WVTR	Oz.	days
25	65%	**3.5%**	6.0%	.0942	.88	12	379
25	65%	**4.0%**	6.0%	.0942	.88	12	334
25	65%	**4.5%**	6.0%	.0942	.88	12	283
25	65%	**5.0%**	6.0%	.0942	.88	12	218
25	65%	**5.5%**	6.0%	.0942	.88	12	133
25	65%	5.0%	**5.5%**	.0942	.88	12	85
25	65%	5.0%	**6.5%**	.0942	.88	12	556
25	65%	5.0%	**7.0%**	.0942	.88	12	years
25	65%	5.0%	6.0%	.0942	.88	**24**	310
25	65%	5.0%	6.0%	.0942	**.44**	12	437
25	**70%**	5.0%	6.0%	.0942	.88	12	150
25	**75%**	5.0%	6.0%	.0942	.88	12	116
25	65%	5.0%	6.0%	**.1880**	.88	12	188

Shelf Life Verify

- Shipping tests
- Storage tests
- Accelerated tests
  - Temperature
  - Permeability

- Models can improve choices for testing

"Proposal" System

- Products Released On Properties Obviously Selected for Additional Life
- Record temperature/RH in real time
- Use information to calculate available shelf life remaining
- Ship on the basis of shortest available shelf life
- For normal shipments - this defaults to FIFO
- For abused shipments, it would add profits

Contact Information

Kenneth S. Marsh, Ph.D., CPP, CFS

Kenneth S. Marsh & Associates, Ltd.
Consultants on Packaging, Protection, Shelf Life & International trade
&
Woodstock Institute for Science in Service to Humanity (WISSH for Global Food Security)

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130 Cane Creek Harbor Road
Seneca, SC 29672 USA

Thank you!

What's Next

Almond Stage Presentation at 3:00 p.m.

- How Important is the Quality of Data from In-Field Sensors in Making Accurate Navel Orangeworm Treatment Decisions in Almonds?, presented by Semios

Almond Stage Presentation at 3:30 p.m.

- Navigate Your Utility Bill, presented by Coldwell Solar

3:00 p.m. – 5:00 p.m. Coffee Break is sponsored by Actagro

2017 THE ALMOND CONFERENCE

ALMOND ALLIANCE OF CALRNIA – GENERAL MEETING

Room 314 | December 6 2017

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